ผลของความเข้มข้นของซิลิกาและการดัดแปรสภาพพื้นผิวของหมึกผงต่อการก่อประจุ การถ่ายโอนภาพ และคุณภาพภาพพิมพ์ของหมึกผง

นางสาวนพรัตน์ แก้วอ่อน

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EFFECTS OF SILICA CONCENTRATION AND TONER SURFACE MODIFICATION ON TONER CHARGING, TRANSFERRING AND PRINT QUALITY

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สมบัติไทรโบอิเล็กทริกของสารสร้างภาพชนิดสององค์ประกอบเป็นปัจจัยสำคัญในการควบคุมคุณภาพงานพิมพ์ระบบอิเล็กทรอโฟโตกราฟี สารเติมแต่งผิวหน้า ได้แก่ ละอองซิลิกา มีหน้าที่ปรับปรุงความสามารถในการไหลและความเสถียรของประจุ วิทยานิพนธ์นี้ศึกษาผลของความเข้มข้นของซิลิกา(ร้อยละ 0–1 โดยน้ำหนักหมึกผง) และแรงที่ใช้ผสมซิลิกา (0.5-4 เท่า) บนผิวหมึกผงชนิดพอลิเอสเทอร์ ความเข้มข้นของหมึกผง และกลไกการก่อประจุด้วยวิธีการหมุนในแนวนอน การหมุนในแนวตั้ง และการเขย่าด้วยมือ ประเมินคุณภาพงานพิมพ์ที่ค่าความดำพื้นตาย ความดำพื้นหลัง การบวมของเม็ดสกรีน และความคมชัดของขอบตัวอักษร จากผลการวิจัยพบว่าเมื่อความเข้มข้นของซิลิกาเพิ่มขึ้น ความสามารถในการไหลและค่าประจุต่อมวลของหมึกผงเพิ่มขึ้น ความดำพื้นตายสูงขึ้น ความดำพื้นหลังต่ำ ความคมชัดของขอบตัวอักษรดีขึ้น แต่การบวมของเม็ดสกรีนมากขึ้นเช่นกัน ในขณะที่หมึกผงซึ่งไม่มีซิลิกามีความสามารถในการไหลต่ำมาก ค่าประจุต่อมวลต่ำและไม่สม่ำเสมอ ความดำพื้นตายต่ำความดำพื้นหลังค่อนข้างสูง และเกิดการแหว่งของขอบตัวอักษร นอกจากนี้ซิลิกาซึ่งเกาะบนผิวหมึกผงด้วยแรงผสมที่ต่างกัน ให้ค่าประจุต่อมวลสัมพันธ์กับแรงผสมระหว่างหมึกผงและตัวพา พบว่าค่าประจุต่อมวลของหมึกผงแต่ละชนิดต่างกันอย่างชัดเจนเมื่อแรงผสมสูงขึ้น (1200-1400 รอบต่อนาที) ทั้งนี้เพราะว่าแรงผสมทำให้สภาพการยึดติดและพื้นที่ผิวของซิลิกาบนผิวหมึกผงเปลี่ยนแปลงไป อย่างไรก็ตามความสามารถในการไหลของหมึกผงแต่ละชนิดไม่แตกต่างกัน และคุณภาพงานพิมพ์แตกต่างกันน้อยมาก นอกจากนี้ เมื่อความเข้มข้นของหมึกผงเพิ่มขึ้น ทำให้ค่าประจุต่อมวลลดลง และวิธีการก่อประจุแต่ละชนิดให้ผลที่แตกต่างกัน พบว่าการเขย่าด้วยมือให้ค่าประจุต่อมวลสูงและอิ่มตัวในเวลาอันสั้น ในขณะที่การก่อประจุด้วยวิธีการหมุนทั้งในแนวตั้งและแนวนอนให้ค่าประจุต่อมวลต่ำกว่าเนื่องจากผลจากการกระทบกับผนังของภาชนะบรรจุ

ภาควิชา <u>วิทยาศาสตร์ทางภาพถ่ายและเทคโนโลยีทางการพิมพ์</u>	ลายมือชื่อนิสิต...
สาขาวิชา <u>เทคโนโลยีทางภาพ</u>	ลายมือชื่ออาจารย์ที่ปรึกษา....................................
ปีการศึกษา <u>2543</u>	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม…………………..

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KEY WORDS: TRIBOELECTRIC CHARGE / ELECTROPHOTOGRAPHIC SYSTEM / SURFACE ADDITIVE / FUMED SILICA / FLOW ABILITY

NOPARAT KAEW-ON : EFFECTS OF SILICA CONCENTRATION AND TONER SURFACE MODIFICATION ON TONER CHARGING, TRANSFERRING AND PRINT QUALITY. THESIS ADVISOR : PROF. DR. SUDA KIATKAMJORNWONG, Ph.D., THESIS CO-ADVISOR : PROF. DR. YASUSHI HOSHINO, Ph.D., 149 pp. 974-13-0432-3.

Triboelectric property of a two-component developer is an important factor that controls print quality in an electrophotographic system. A surface additive, fumed silica, is added to improve the flow ability and charge stability of the toner in the developer. This thesis investigated the charging properties of the polyester toner, which contains various concentrations of silica from 0 to 1 wt %, and the charges was produced by number of times for attachment forces of the silica particles from 0.5 to 4 times. Other important factors, toner concentration and charging mechanism comprising the vertical rotating, horizontal rotating and hand shaking, were also studied. The print qualities were focused on the solid density, background density, dot gain percentage, and edge sharpness of the characters. When the silica concentration increased, the q/m values and flow ability increased. They produced lower background density, higher solid density and dot gain percentage. The toner without silica gave the lower and inconsistency of q/m values resulting in poor image edge sharpness. The q/m values of the toners containing various silica attachment forces were related with the rubbing forces between the toner and carrier particles in developing step. They were inevitably different at the high rubbing force (1200-1400 rpm) that changed the adherence state and surface area of the silica on the toner surface. However, these silica attachment forces did not impose a significant impact on the flow ability and print quality. When the toner concentration increased, the q/m values decreased. Various charging mechanisms gave different q/m values. Hand shaking charging produced the highest q/m values, which reached a saturation within a short time, whereas both horizontal and vertical rotating charging gave lower q/m values because of the impaction effect on the glass wall of the vessel.

Department Imaging and Printing Technology	Student's signature......................................
Field of study Imaging Technology	Advisor's signature ....
Academic year 2543	Co-advisor's signature ....

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Noparat Kaew-on

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CHAPTER 1

INTRODUCTION

1.1 Scientific Rationale

Electrophotography technology is applied for printers and copiers that are very widely used for both high and medium quality of printers. The evolutional machines and materials for this system were continually developed. Concerning the electrophotographic materials, the triboelectric properties of two-component developer are important in practical machines, because toner charge is an important parameter that controls the developed toner mass. By this reason, the toner characterizations that depend on toner charge are a very important factor for the developer design in commercial copiers and printers. Many factors that affects the toner triboeletric properties such as mixing force, toner concentration, toner composition and shape or sizes of the toner are mostly studied. The size of toner particles was recently reduced in order to improve print quality, which comprised high solid density, high resolution, and better tone reproduction. As the size of the toner particles is reduced, the toner flow ability decreases and toner agglomeration occurs. Fumed silica and other metallic oxide can be used to modify the physical properties of the toner by improving the toner flow and breaking the agglomerated particles down. Besides these, the triboelectricity of the toner is influenced by types of core material and surface modification, their concentration, and adherence of fumed silica particles on the toner surface.

This research investigates the effects of silica concentration and toner surface modification, including various forces for the silica particle attachment on the tribocharging property and the print quality.

1.2 Objectives of the research work

The objectives of this research are as follows:

1.2.1 To elucidate effects of silica concentration and toner surface modification on the toner charging.

1.2.2 To elucidate effects of silica concentration and toner surface modification on the printing quality.

1.3 Scope of the research work

This research involves measurement and characterization of the toner, including various silica concentrations and silica attachment forces, on the steel carrier (TSV-200). The triboelectric values and the charging times were determined with various toner concentrations, charging mechanisms that included a hand shaking, simple shaking in the vertical direction and rotating in the horizontal direction. Furthermore, the toner flow ability was also measured by a powder tester. The principal size and size distribution of the toner were studied using scanning electron microscopy (SEM) and electrical single particle aerodynamic relaxation time (E-SPART) technique.

The printouts, which were produced from a test form on the plain paper, were printed by an OKI 400 micro line CL printer in order to elucidate the print quality. The quality of the printout papers was measured for solid density, background density and dot gain percentage with a reflection densitometer. The halftone dot structure, the sharpness of the lines and the characters were determined by an image analyzer.

The attainable results can lead to improvements of toner manufacturing for electrophotographic printing.

1.4 Content of the research work

This thesis consists of 5 chapters including introduction, theoretical background and literature review, experimental, results and discussion, and conclusion and suggestions. Chapter 2 displays a brief of electrophotography history, the electrophotographic process, the toner component and characterization, the carrier materials, types of development, toner charge measurement methods and the short literature review of some previous reports. In chapter 3, the details about the materials, apparatus and procedure of this research are explained. Chapter 4 presents the results and discussion of the dependency of q/m ratio on the silica concentration, the toner concentration, the charging mechanism, the silica attachment force. Moreover, the flow ability, and the toner charge are measured by E-SPART, and the print evaluation is also explained.

CHAPTER 2

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Theoretical background

2.1.1 History of Electrophotography

The active history of electrophotography began with the inventions of Chester Carlson in 1938. He used sulfur as a photoactive material to make images. In 1959, Haloid Corporation (now is Xerox) introduced a 914 automatic copier, which used selenium metal as the photoreceptor and this is regarded as the first commercial negative dry toner, styrene-methacrylate copolymers. During the 1970s, IBM and Kodak developed and introduced copiers based on organic photoactive materials and positive charging toners. During the 1980s, Japanese manufacturers, such as Canon and Minolta, produced low speed copiers based on selenium and cadmium sulfide photoreceptors using negative toners. They also introduced dry toner copiers using a single-component development, eliminating the use of carrier beads. Since the 1980s, many combinations of single- and two-component developments, and positive and negative toners have been used in the industry.[1]

2.1.2 The Electrophotographic Process

The electrophotographic process is based on six basic steps in reproducing a document: charging, exposure, development, transfer, fusing and cleaning. This process is schematically shown in Figure 2-1, and described in following items (a-f).

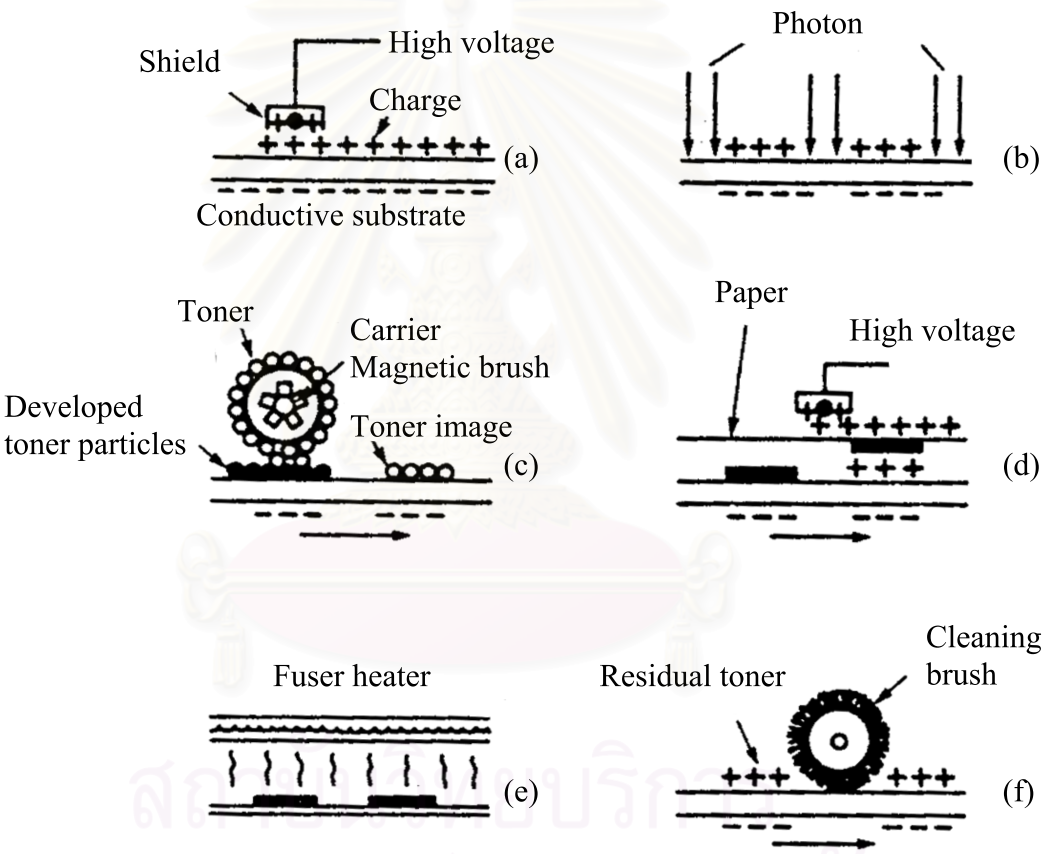


Figure 2-1 Schematic diagram of the electrophotographic process

a) In the charging step, the photoreceptor is covered with ions of the appropriate polarity through the use of a wire or grid bias to high voltage.

b) In the exposure step, an optical system forms an image of the document on the photoreceptor. When the document is white, there is sufficient light to cause the photoreceptor to conduct charge and neutralize the image, but the dark lines of the text leave the charge undistributed when imaged on the photoreceptor. This step forms a latent image of charges, duplicating the original document.

c) In the development step, a toner of the opposite sign from the latent image is typically brought into contact with this image.

d) In the transfer step, a piece of paper is brought onto the photoreceptor, and the backside of the paper is charged with ions opposite in polarity from the toner. This attaches the great majority of the toner particles to the paper. The paper is then removed from the photoreceptor and passed through the fuser.

e) In the fusing step, the toner is melted onto the surface of the paper.

f) In the cleaning step, the small amount of toner remaining on the photoreceptor, after being transferred, is be removed by an eletrostatic brush or a conformable rubber blade.

2.1.3 Toner components

Dry electrophotographic toners consist mainly of a colorant in a binder resin. Besides these essential ingredients, a particular toner design may contain charge control additives, surface additives, magnetic additives and other additives such as wax.

2.1.3.1 Resin

The role of resin in a toner is to bind the pigment to the paper or transparent material to form a permanent image. The selection of the polymer depends on the fusing or melting properties and the fusing method, which can be subdivided as follows.

a) Cold pressure method

The materials for this method are typically lower molecular weight polypropylenes, polyethylenes, ethylene-vinyl acetate copolymers, and mixture of these materials. These cold pressure fix materials have the advantage of requiring low power in operation and no standby power.

b) Continuous radiant source

Using a quartz lamp or heated coil to melt the toner into the paper fibers. The viscosity of the toner usually reaches quite low melt viscosities in flowing into the paper. The polymers such as polyesters and epoxies, which have a molecular weight ranging from 5,000 to 50,000 and glass transition temperature from 50 to 60° C, are often used.

c) Flash fusing

The toner is melted into the paper by a very short, high intensity flash of light lasting less than 5 ms. Styrene copolymers, epoxies, and polycarbonates have used this fusing technique for fixation of toner images.

d) Roll fuser

The paper with the unfused toner passes through a nip formed by a heated roll and a backup roll forced against the heated roll at fairly high pressures.

The polymers used are styrene copolymers such as styrene acrylates, methacrylates, and butadienes, which have molecular weights ranging 30,000 to 100,000 and glass transition temperatures ranging from 50 to 65°C

2.1.3.2 Colorants

The most common colorant for electrophotographic toners is carbon black. Important properties of carbon blacks for applications are their dispersibility in the polymer resin and their tendency to charge either positively or negatively. Carbon black is usually used in toners at 5 to 15% loading. Besides carbon black, there are other materials that can be used to make black toners, for instance, magnetite is used to control magnetic properties of toner, and nigrosine is used as charge control agent as well as black pigment. For full color electrophotography, the organic pigments are usually used, such as, copper phthalocyanines are used for cyans and blues, azo pigments for yellows, and quinacridones or rhodamines for magentas and reds.

2.1.3.3 Charge control additives

Charge control additives, CCA, are added to the toner when the pigment blended into the polymer does not give an adequate charge level or rate of charging. For positive images, the quaternary ammonium salts are usually used in color toners because they are colorless. The other is nigrosine, which is black and used in black toners. For negative applications, acidified carbon blacks, fumed silicas and metal complexes are used.

2.1.3.4 Surface additives

Surface additives, such as fumed silicas are added to the toner surface to improve flow properties, transfer efficiency of the toner from the photoreceptor to paper by decreasing the adhesion of the toner to the photoreceptor, and improving the charge stability of the toner and carrier mixture. The fumed silicas also decrease the toner agglomeration.

2.1.3.5 Other additives

These additives are used in a specific application, such as silicone oil, which is used as a release agent for the fuser roll.

2.1.4 Toner Characterization

2.1.4.1 Rheology

The rheological characteristic of a toner especially affects fixing behavior. There are three significant temperatures necessary to characterize the toner-fixing behavior.

a) The minimum fixing temperature is an adequate temperature at which the image is fixed to the paper.

b) The hot offset temperature is higher than the minimum fixing temperature at which the toner is so fluid that it simply splits apart when the paper leaves the fuser roll, leaving traces of the image on the fuser roll to undesirably contaminate the next sheet.

c) The blocking temperature is the temperature at which significant sintering occurs.

Besides these, a commonly measured characteristic of a polymer is its glass transition temperature, *Tg,* where the polymer changes from a hard glass to a rubbery state. This is measured in a differential scanning colorimeter, which looks for the change in heat capacity at the transition. For adequate blocking, toners generally should have a *Tg* value above 50˚ C.

2.1.4.2 Colorimetrics

For the black toner, the primary consideration is to be able to generate high optical densities. For highlight color toners, there should be able to develop an optical density of the color with the tinting strength or chroma of color and pleasing hue. For process color developers, the goal is to generate as wide a color spectrum as possible, which depends on the detailed spectral absorption of the various pigments.

2.1.4.3 Particle Size

Toner particle sizes are generally in the range of about 10 to 20 μm in diameter. The particle sizes larger than these usually produce ragged lines and dots. The smaller particle sizes than this range improve color reproduction and noise reduction. However, the smaller particle sizes require longer times in manufacturing, hence are more expensive to produce. Also smaller sizes tend to produce more dirt at a given charge-to-mass ratio and to cause more rapid developer degradation.

2.1.4.4 Charging

The charge on the toner is controlled by the selection of its carrier chemical nature and through the mixing condition. When the toner and the carrier are rubbed together, the triboelectric series which depends on a work function of them are generated. The one lower on the work function series becomes the electron acceptor or negative charge, and the one higher on the work function series becomes the electron donor or positive charge. There are two quantities of the toner charge measurement as shown in Section 2.1.7. For the toner particle size 10 μm, the useful range of charge-to-mass ratios is from 10 to 30 μC/g. Toner particles with a higher charge are difficult to strip from the carrier and also deposit little mass for a given amount of charge image density. The q/m values below 10 μC/g generally lead to both a dirty in the machine and background density on the copy.

2.1.5 Current carrier powders

2.1.5.1 Definition and function of carrier

Carrier is a general term in electrophotographic imaging or printing that applies when a two-component developer is used. Its most important function is to impart a static charge to the toner particles and carry the toner to the electrostatically charged images on the photoreceptor drum in the copier.[3]

2.1.5.2 Types of carrier

a) Steel (Spherical)

The developer with teflon-coated spherical steel carrier, was quite insulating; consequently, the solid area reproduction was poor, and background and machine dirt have been the source of problem.

b) Iron (Irregular)

Most of the iron particles are oxidized to control the resistivity and partially coated to control the electrostatic charging. For irregular powder, the high points are oxidized and poorly coated, to supply the required resistivity, while the valleys are better coated to supply the charging effect required.

c) Soft Ferrites (Spherical)

The resistivity of ferrite is lower than the insulating sand or glass and higher than the iron or steel. Ferrites with semiconducting properties have resistivities in the range desired, 10^{6}-10^{12} Ω cm, because they are transition metal oxides and magnetic ceramic materials, which in some applications can be used without partial coating for toner charging. The size range is variable, from 10-120 μm for the spherical ferrites, which are raising some interest in the industry. The spherical powder is formed by the spray drying step. The saturation magnetic moments are 20-75 electromagnetic units per gram. Too high a moment will result in a stiff brush, scratch the image, nonuniformities in the solids and ragged edges on the line copy.

d) Hard Ferrites (Spherical)

The commercial use of the hard or permanent magnet type of ferrite is a very recent development. In 1998, Eastman Kodak used hard ferrites for full color copiers, and gave highlights at higher speeds.

2.1.6 Two-component and single-component developments

There are two methods of charging the dry toner, which bring about the charge pattern on the photoreceptor to develop the latent image, single- and two-component developments.[4]

2.1.6.1 The two-component developer

This developer consists of the toner particles and the carrier beads, which provides two functions for the toner, charge generation and toner transportation through the developer housing. First, the rubbing of the carrier against the toner generates the desired magnitude and sign of charge on the toner. Second, the toner particles attach to the carrier bead by the electrostatic force and then can be moved to contact the latent image on the photoreceptor. Figure 2-2 shows the developer housing of two-component developer. The two-component development can be subdivided as two types, cascade development and magnetic brush development.[5]

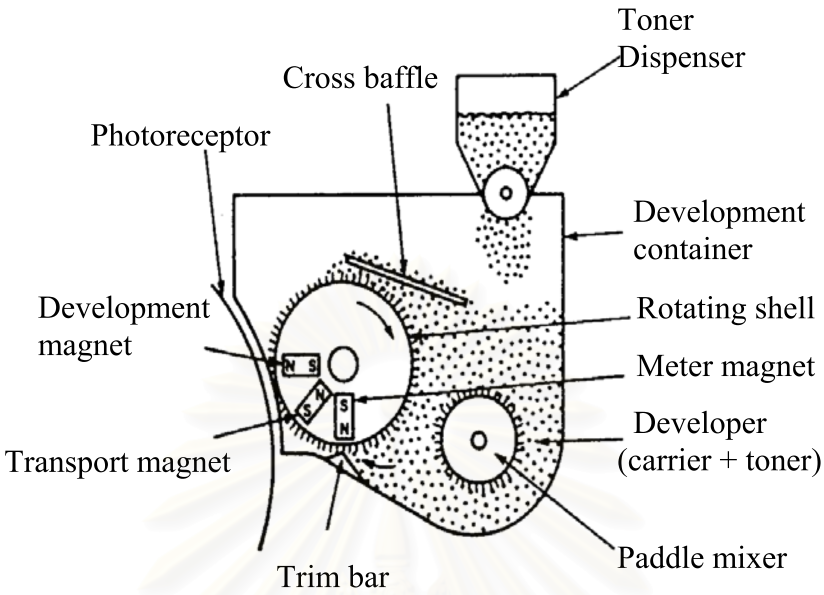


Figure 2-2 Structure of a typical two-component development housing

a) Cascade development

The toner of this system has a approximate diameter 10 μm particle size. They are mixed with a much larger carrier material such as glass or sand (diameter ~200-500 μm) in order to control the toner charge and transportation. In addition to control, the carrier attracts and holds the toner particles by a triboelectric interaction, which produces an electrostatic charge on the toner particles. Development of the latent image occurs as the developer flows or cascades over the surface of the dielectric material (photoreceptor) as shown in Figure 2-3. The electrostatic attraction of the latent image and the impact forces cause the toner particles to separate from the carrier and deposit on the latent image regions.

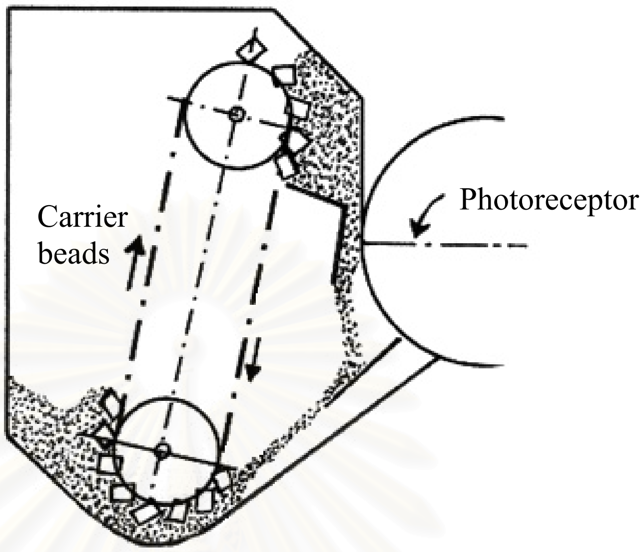


Figure 2-3 Schematic diagram of a cascade development system

b) Magnetic brush development

A magnetic brush development system is shown schematically in Figure 2-4. The toner particle size of this system is similar to that of the cascade developer. The carrier is a magnetic particle such as iron or ferrite in the size range of 50 to 200 μm. The friction between the toners and the carriers due to the magnetic field, causes the carrier particles to align as bristles of a brush. These magnetic carriers bring the toner particles into contact with the latent image on the photoreceptor.

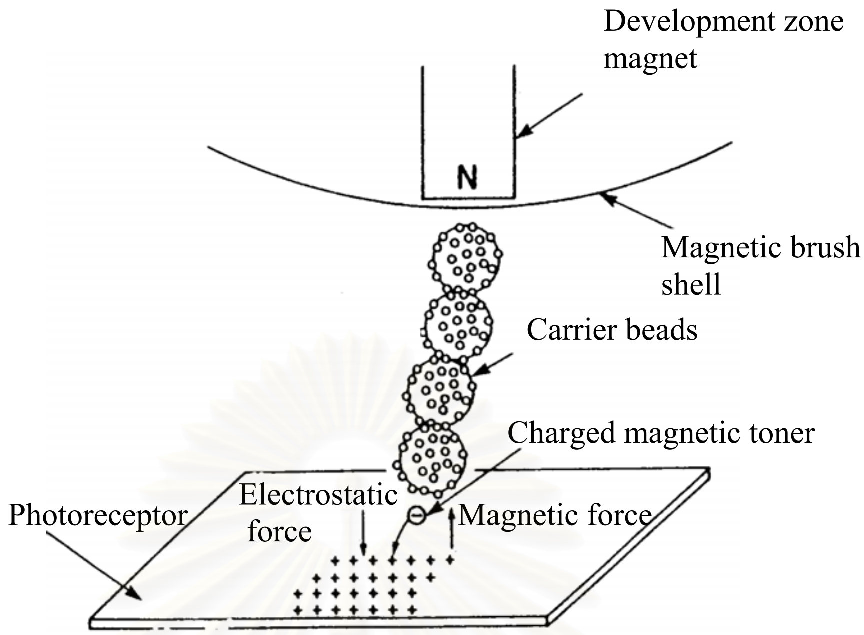


Figure 2-4 Schematic diagram of a magnetic brush development system

2.1.6.2 Single-component development

Single-component developer separates the carrier and charging functions so that only charged toner is delivered to the latent image. So, problems of carrier aging, carrier charging of the dielectric receptor and the need to control the ratio of toner to carrier are eliminated completely. The volume of developer housing, and cost can be reduced. There are two types of this toner, magnetic toner and non-magnetic toner. A typical single-component developer housing is shown in Figure 2-5.

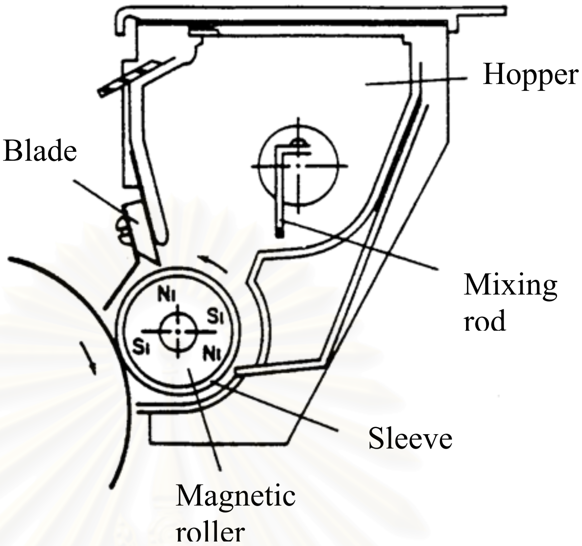


Figure 2-5 Single-component development unit

2.1.7 The charge measurement

The charge exchange between particles in a powder is measured using a q/m measurement method such as the blow off method and the E-SPART analyzer as described below:

2.1.7.1 Blow off method

This is a typical method for the two-component developer simply, by placing the developer in a Faraday cage (Figure 2-6) with a mesh screen on both ends. The mesh screen size ranges between the diameter of the toner and the carrier. An air blows the toner particles out of the cage. The changes of the charge and mass are measured.[6]

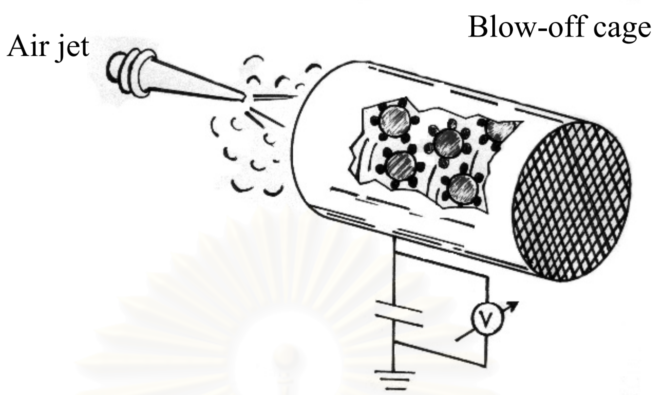


Figure 2-6 Apparatus of a blow off measurement

2.1.7.2 E-SPART analyzer

The Electrical Single Particle Aerodynamic Relaxation Time (E-SPART) is used for a real-time simultaneous measurement of aerodynamic size and electrostatic charge distribution of particles on each single particle. It simultaneously measures size in the range from submicron to 100 μm and the charge distribution from zero to saturation levels.[7]

Its operating principle depends upon the phenomenon that when an airborne particle is subjected to an oscillatory external force, such as acoustic excitation driving field, the particles vibrate at the same frequency as the acoustic field but with a phase lag due to particle inertia. The larger the particle the greater the phase lag, which can therefore be related to particle size. To determine this phase lag, the analyzer uses a differential laser Doppler velocimeter (LDV) to measure the velocities of individual particles subjected to a combination of an acoustic and a DC electric field. Simultaneously a charged particle will have its vertical position shifted by the electric field by an amount related to the charge. The maximum count rate varies from 10 to 2000 particles per second depending upon particle size, which typically, can range from 0.3 μm to 75 μm.

The particles are sampled in a laminar flow field through the LDV sensing volume. As each particle passes through the sensing volume it experiences the acoustic excitation and the superimposed DC electric field in a direction perpendicular to the direction of the laminar air flow. The schematic diagram of the E-SPART is shown in Figure 2-7

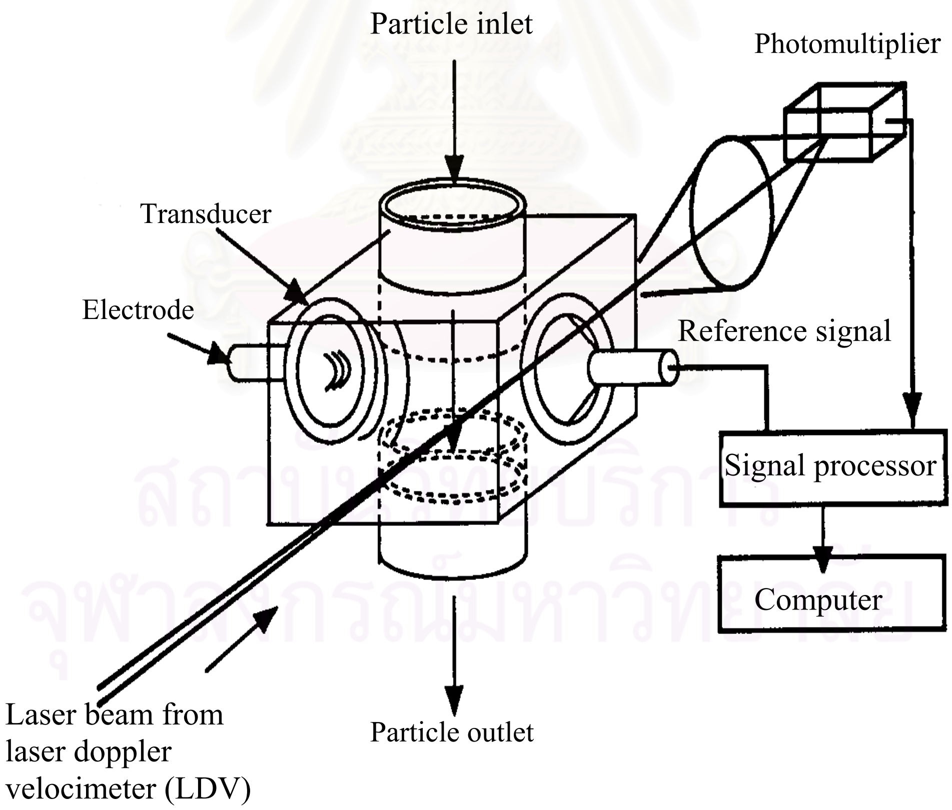


Figure 2-7 Schematic diagram of the E-SPART analyzer.

2.2 Literature reviews

Kutsuwada and Nakamura [8] applied Millikan's Oil Drop apparatus to measure the radius and electric charge quantity on a single particle. The amount of charge and the radius of one toner particle in air can be determined by this apparatus. The experimental results were reported that the electric charge quantity of toner is nearly proportional to the third power of its radius, especially for the spherical toner particle. In different types of tribocharging, the electric charge quantity of toners were different for each charging mechanism, but showed a similar tendency of radius dependence of electric charge for toner particles.

Anderson [9] presented an electronic model of triboelectrification of two-component electrophotographic developer, which predicted the relationship between toner charge-to-mass ratio, toner concentration, toner particle size and carrier particle size. The charging of toner occurred by exchanging of electrons between acceptor and donor sites on the surface of carrier and toner, as shown in the following equations.

Acceptor site $$A + e^- \longleftrightarrow A^- \qquad (2\text{-}1)$$

Donor site $$D \longleftrightarrow D^+ + e^- \qquad (2\text{-}2)$$

$$A + D \longleftrightarrow A^+ + D^- \qquad (2\text{-}3)$$

Law et al.[10] presented a mechanism of charge-exchange in xerographic toner powders. This exchange was discussed in terms of a dual mechanism. Firstly, the major charging mechanism, which is a contact charging process between the fresh toner and the carrier beads. Secondly, the minor charging mechanism is an ion-exchange process between charged and uncharged toners. The charge-exchange rate is monitored by “an admixed time”, a time required for the uncharged and charged toners to become equilibrated chargewise after mixing together.

Kishimoto and Takahashi[11] presented the effect of toner concentration on toner charging characteristic, which was dominated by the relative difference of charging site numbers between toners and carriers. When the maximum number of triboelectric charging site of carrier (Nc) is much more than the maximum number of triboelectric charging site of toner (Nt), the amount of the charge is only governed by number of toner effective charging sites. On the other hand, when Nc < Nt, the amount of the charge is merely governed by number of carrier effective charging sites. When Nc = Nt, the amount of the charge depends on the number of toner effective charging sites (lower toner concentration) and the number of carrier effective charging sites (higher toner concentration).

Noshiro et al.[12] described the tribocharging behavior in two kinds of toners which had the same composition but different shapes (spherical and irregular). Ferrite carrier and toner were mixed together. The tribocharging behavior of the toner was measured by the blow-off method. The experimental results were that the time constant for charging of irregular toner was smaller than that for spherical toner but the maximum charge to mass ratio, $(q/m)_{max}$ of the irregular toner was larger than the spherical toner. However, the maximum charge density on the spherical toner surface and the irregular toner surface were approximately equal.

Kamiyama et al.[13] presented a comparison of properties of the polymerized toner and conventional melt mixed toner. For the two-component type toner, the powder fluidity was enhanced by the spherical shape of the polymerized toner particles. The image quality with this toner was also enhanced in the reproduction of fine lines and small dots. For the mono-component polymerized toner, the powder fluidity was not improved over the conventional melt mixed toner. However the spherical particles of the toner may introduce a smooth and efficient agitation on the magnetic brush, so the toner particles form various uniform triboelectric charges. Accordingly, the developed toner image has a smoother profile with less background fog.

Gady et al.[14] described the effects of silica concentration on the toner transferring and image quality. The toner surface was covered by hydrophobic silica, which concentration was varied between 0 and 2% weight of the toner. It was found that the transfer efficiency increased with an increasing silica particle concentration on the toner surface, while the resolution and dot structure was degraded. These results agreed with the decrease of the toner adhesion to the photoconductor, as measured by an ultracentrifuger. They suggested that the adhesion and cohesion of toner could be governed by van der Waals interaction. However, electrostatic forces became significant when silica concentration increased.

Law and Tarnawskyj[15] described the effects of surface area and surface modification of fumed silica on the charging and humidity sensitivity in toners. The toner used is styrene-butadiene toner (90:10). The silica additive was used at very low concentration (0.5% weight of toner surface). The result showed that the hydrophobic silicas gave more negative charge than that of the hydrophilic silicas; but the admix time of hydrophilic silicas was shorter than that of the hydrophobic silicas and the charge level was primarily governed by the surface area. The q/m increased as the surface area increased. The effect of RH (relative humidity) on the toner charging was also examined. The toner charging was sensitive to RH when silicas were added in toners. Additionally, the tribo-value and admix time decreased as RH increased.

Veregin et al.[16] studied the role of water in the triboelectric charging of silica as toner surface additives. The silica was treated with alkylchlorosilane. The surface water content of silica was determined by infrared spectroscopy. The charging of hydrophobic silica was controlled by the water distribution. At RH values below 20%, the charge increased with increasing water content, which showed that water was necessary for charging. At RH values above 20%, the adsorption of water on the silica occurred at a lower rate than that at RH values below 20 %. The charge decreased linearly with an increasing water content, and it was controlled by the amount of adsorbed water. They explained that the charging behavior of toner additives was related to relative humidity by two mechanisms. First, the water acted to block a charging site by covering the silica charging sites in order to prevent their charge exchange with the carrier. In addition, the water on the silica itself did not exchange charge with the carrier or the adsorbed water on the toner transfers to the carrier. In the other case, no charge exchange occurred between toner and carrier sites because both toner and carrier had the same amount of water. Second, the silica surface was conducted by water. More surface conductivity was due to a contiguous network of water on the silica. In this report, the presence of the hydrophobic chains disrupted the conductive water paths on the surface of the silica, at least at low water content.

Saelow et al.[17] studied the dependence of toner charge on mixing force. They divided the mixing force between toner and carrier into three regions: elastic, plastic and destructive. In the low mixing force region, contact between toner and carrier was proposed by elastic force. It means that after contact, the shape of toner and carrier did not change. The contact area increased when mixing force increased. So, toner charge increased. Over the force of elastic, the toner charge saturated and then decreased as the force increased. The decrease of toner charge was claimed to be a result of SiO_2 plunging into the toner and/or carrier contamination by CCA.

Lee et al.[18] described a correlation of the toner triboelectric charge dependence with the silica content on the toner surface. The toner and silica samples are positively and negatively charged by tribocharging, respectively. It was found that an integrated toner tribocharging was strongly affected by silica charging site. In increasing silica content, the contact probability between toner charging site and carrier charging site was decreased, whereas the contact probability between silica charging site and carrier charging site was increased. They had considered that the integrated toner tribocharge could be combined with toner tribocharge itself and silica tribocharge itself as shown in Equation (2-4):

$$q_i = |q_t^+| - |q_s^- n| \tag{2-4}$$

where q_i is an integrated toner tribocharge, q_t^+ is a toner tribocharge itself by a number of charging site on the toner surface, q_s^- is a silica tribocharge itself of one silica particle and n is a number of silica particles.

For the case of lower silica content, n is very small. The charged site of toner was greater than the charged site of silica. Then the integrated toner tribocharge was mainly controlled by toner charged site as shown in Equation (2-5):

$$q_i = q_t^+ \tag{2-5}$$

For the case of middle silica content, the fumed silica coverage was increased. Therefore, the integrated toner tribocharge affected both toner charged site and silica charged site as shown in Equation (2-4):

In the case of higher silica content, n is very large. The fumed silica coverage was near 100%. Then the integrated toner tribocharge is mainly controlled by silica charged site as shown in Equation (2-6):

$$q_i = q_s^- n \qquad (2\text{-}6)$$

Iimura et al.[19] studied the effects of toner treatment by fumed silica on toner adhesion force. Toner samples with various silica concentrations were prepared and the surface coverage by silica was then evaluated by image analysis of electron micrographs. The adhesion force between a toner surface and a photoconductor drum was measured by a centrifugal method. It was found that the non-electrostatic force decreased with the increasing surface coverage, and became saturated at a certain coverage. A relationship between non-electrostatic adhesion force and the surface coverage could be explained as the change of Van der Waals force. Electrostatic adhesion force increased in proportion to the square of toner charge-to-mass ratio, and the slope decreased exponentially with an increase in the surface coverage. The change of the electrostatic adhesion force by the additive was related to the difference of a charge distribution on the toner surface.

Poomtien et al.[20] studied a charging behavior of three types of CCA of various concentrations. The presence of CCA helped increase the effectiveness of the charging sites on the toner, so that the proper increment in CCA amounts increases the q/m values. The charging properties influenced the quality of the printed images. The toners without CCA had the lowest print density. The higher the CCA amount, the higher the print density, but the background densities of the toners without CCA were higher than the toners with CCA. Three types of charging mechanism were also studied. The q/m values of a hand shaking charging are higher than the rotating charging mechanism. Because, the hand shaking charging for both the toners and carrier particles moved up and down along the length of the sample holder, the charging sites of one carrier particle were higher than the rotating charging mechanism. For the printing charging mechanism, the toner particles were charged by rubbing together with a development roller. The toners stayed still while the development roller was moving. The smooth surface of the roller, considered as a tribocharge medium, could better transfer charges to the toner. This mechanism can also be considered as an elastic charging, which results in the highest q/m values.

Netpradit et al.[21] investigated the dependence of the toner charge-to-mass ratio (q/m) in the two-component developer on the toner concentration (T/C), the carrier size, and the toner size in order to acquire the relationship of the print qualities, in terms of print density and the background density. It was found that the q/m values that decreased with increasing T/C were much affected by the larger carrier and the smaller toner. The latitude of T/C is wider when the carrier size is smaller or the toner size is larger. Besides that, a low T/C resulted in higher toner charge, which also produced a lower print density. On the other hand, a high T/C value induced a very low toner charge and the very high background density.

Murota et al.[22] divided a type of fumed metallic oxides that are used as toner additive into 5 groups. Group 1 is dimethyldichlorosilane treated fumed silica. The additives in this group are negatively charged and appropriate for the analog-Se drum system. Group 2 is dimethylpolysiloxane treated fumed silica and group 3 is hexamethyldisilane treated fumed silica. Both are negatively charged and supported for the digital-OPC drum or analog-a-Si drum systems. Dimethylpolysiloxane is used for improvement of the toner cleaning, while hexamethyldisilane treated fumed silica is used for the high speed copying machine because of better free flow effect. Group 4 is a combination of aminosilane and hexamethyldisilane or dimethylpolysiloxane treated fumed silica, are positively charged and less hydrophobicity than other group due to a hydrophobicity of amino group. These metallic oxides are used for the analogue-OPC drum. Group 5 is alkylsilane treated fumed silica or fumed titania exhibiting weekly negative charges, which is used for color copying system.

CHAPTER 3

EXPERIMENTAL

3.1 Materials

3.1.1 Toner (Polyester toner; made by a crushing method): eight types were used:

3.1.1.1 Toner without silica attachment:

CT-01

3.1.1.2 Toner with silica attachment:

Various silica attachment forces:

CT-01a

CT-01b

CT-01c

CT-01d

Various silica coverage percentages:

CT-01b-1

CT-01b-2

CT-01b-3

3.1.2 Carrier: one type was used: TSV 200 (steel carrier)

3.2 Apparatus

3.2.1 Rolling type of toner charger: MS 1 Minishaker, IKA - WORK, Inc., Wilmington, USA

3.3.2 Rotator, MD 6325-24 from ORIENTAL MOTOR Co.,Ltd. Tokyo, Japan

3.2.3 Blow-off measurement unit (home made) comprising two important units:

3.2.3.1 A vacuum cleaner: VC-K50K 500, TOSHIBA, Chiba, Japan

3.2.3.2 Electrometer R8240 Digital Electrometer, Advantest Corporation, Tokyo, Japan

3.2.5 Electronic balance: AEX - 120 G Analytical balance, SHIMADSU Corporation, Gyoda, Japan

3.2.6 Powder characteristic tester: Model: PT-E from Hosokawa Micron Corporation, Osaka, Japan

3.2.7 Densitometer: RD 915, Macbeth Corporation, Newburge, USA

3.2.8 Scanning Electron Microscope : JSM 6400, JEO, Tokyo, Japan

3.2.9 Image analyzer : LUZEX F, PM 10-AD, Olympus, Nireco Corporation, Tokyo, Japan

3.2.10 E-SPART analyzer : EST-1, Hosokawa micron Corporation, Osaka, Japan

3.2.11 Printer for testing toner: 6ex, Oki Electronics (Singapore) Pte. Limited, Shenton Way, Singapore

3.3 Procedure

3.3.1 Developer preparation

The developers (toners and carrier), prepared by Tomoegawa Paper Co., Ltd. in Japan, are different in component and concentration (wt %). They are shown in Table 3-1.

Table 3-1: Developers with different compositions and contents.

Developers			Toner attachment with silica	
Name	Carrier	Toner	toner weight (%)	Force for attachment (times)
A	TSV-200	CT-01	0	-
B	TSV-200	CT-01a	1	½
C	TSV-200	CT-01b	1	1
D	TSV-200	CT-01c	1	2
E	TSV-200	CT-01d	1	4
F	TSV-200	CT-01b-1	0.5	1
G	TSV-200	CT-01b-2	0.25	1
H	TSV-200	CT-01b-3	0.125	1

3.3.2 Measurement of toner charging properties

3.3.2.1 Toner charge dependence on silica attachment

a. The developers namely B, C, D and E were prepared by mixing the carrier (TSV-200) 9.5 grams and toner (namely CT-01a, CT-01b, CT-01c and CT-01d, respectively) 0.5 grams in a rotating roller (a glass cell, 24 mm diameter). A rolling glass cell for the developer was rotated at rotating speeds of 800, 1000, 1200 and 1400 rpm, respectively, to generate the toner charges. The rotating roller was stopped after 15, 30, 60, 90,120, 240, 360 and 720 seconds of mixing in order to measure the charge-to-mass ratio (q/m) by a blow off measurement unit that was connected to an electrometer and a vacuum cleaner.

b. The developer was poured carefully into a cage of the blow off measurement unit, which had a metal mesh size of 25 micrometers on the bottom, to make a uniform layer of mixture. The cage with the mixture was weighed by an analytical balance. After that, the toner was blown off through the mesh screen for 15 seconds.

c. The q value was read from the electrometer. The cage with the mixture was weighed again to determine the weight of the toner only. Then, the toner charge-to-mass ratio (q/m) was calculated.

3.3.2.2 Toner charge dependence on silica concentration

The developers in Table 3-2 were experimented using the same method, as mentioned in Section 3.3.2.1. The charge-to-mass ratio (q/m) was then calculated.

Table 3-2: Developers with different compositions

Developer				Silica concentration (wt % by toner weight)	Rotating speed (rpm)
Name	Carrier (g)	Toners			
		name	(g)		
A	9.5	CT-01	0.5	0	800
C	9.5	CT-01b	0.5	1	800
F	9.5	CT-01b-1	0.5	0.5	800
G	9.5	CT-01b-2	0.5	0.25	800
H	9.5	CT-01b-3	0.5	0.125	800

3.3.2.3 Toner charge dependence on toner concentration

The developers namely A, C and F were prepared by mixing the carrier and toner namely CT-01, CT-01b and CT-01b-1, respectively. They are shown in Table 3-3. The toner charge measurement was carried out as mentioned in Section 3.3.2.1. Then the charge-to-mass ratio (q/m) was calculated.

Table 3-3: Developers for toner charge dependence on toner concentration.

Developer			Toner concentration (wt %)	Rotating speed (rpm)
Name	Toner	Carrier		
A	CT-01	TSV-200	1, 3, 5, 7, 10	800
C	CT-01b	TSV-200	1, 3, 5, 7, 10	800
F	CT-01b-1	TSV-200	1, 3, 5, 7, 10	800

3.3.2.4 Toner charge dependence on charging mechanism.

The developer C, which was prepared with various toner concentrations (3, 5 and 7 wt %) was put inside the glass bottle for charge measurement. Their charge was generated by different charging methods.

3.3.2.4.1 By rotating charging (vertical direction).

The glass bottle of developer was rotated vertically by a rotator (IKA-MS1 mini shaker). The rotating speed was 800 rpm. The rotator was stopped after 15, 30, 60, 90, 120, 240, 360 and 720 seconds of mixing in order to measure the q/m by blow-off method as mentioned in Section 3.3.2.1.

3.3.2.4.2 By rotating charging (horizontal direction).

The glass bottle of developer was rotated horizontally by a rotator (Rotator model MD625B-3). The rotating speed was 75 rpm. The rotator was stopped after 15, 30, 60, 90, 120, 240, 360 and 720 seconds of mixing in order to measure the q/m by blow-off method as mentioned in Section 3.3.2.1.

3.3.2.4.3 By hand shaking

The developer in the glass bottle was mixed together by hand shaking. The speed of shaking was controlled consistently and stopped at 15, 30, 60, 90, 120, 240, 360 and 720 seconds, respectively in order to measure the q/m by blow-off method as mentioned in Section 3.3.2.1.

3.3.3 Measurement of charge properties by the E-SPART analyzer

The toners, CT-01, CT-01b-3, CT-01b-2 and CT-01b-1, were selected to measure their charges by the E-SPART analyzer. First, the toner (0.5 grams) and TSV-200 carrier (9.5 grams) were mixed together by hand shaking. Then, the toner charge was measured by the E-SPART analyzer.

3.3.4 Measurement of toner flow ability

The toner flow ability was measured by a powder characteristic tester: (Hosokawa Micron, PT-E). The toner (20 grams) was shaken for 10 times before being conditioned at 50°C and 40% RH for 24 hours. After that, it was poured in a cell, which has different sizes of three layer meshes, 350, 250 and 150 μm in to diameter. The cell was vibrated and the toner was passed through the meshes from the larger to the smaller size in 30 seconds, at 25°C and 30% RH. After that the remaining toner was measured by an electronic balance.

3.3.5 Printing experiment

The toner sample was poured into a developing unit of the OKI 400 micro line CL printer. The plain paper sheets were printed with a test form, which was produced by the eighth Illustrator program. The test form consisted of “A to Z” characters, different percentages of the round halftone dots of 20, 40, 60, 80 and 100 and a resolution target. The printouts were measured for solid density, background density and dot gain percentage. The density and dot gain percentage were evaluated by a reflection densitometer (Macbeth, RD915). The solid density was measured by a reflection densitometer, which was calibrated with the black and white tiles; and the background density was measured by a null density mode of the reflection densitometer, which was calibrated to be zero on the paper surface used for the printing experiment. The dot structure, the “a, E, f, g, 2 and 5 characters and the lines (0.25 and 0.5 points) were observed by an image analyzer (LUZEX F, PM 10-AD).

3.3.6 Morphology of toners and carrier

All toners and the carrier were analyzed for the morphology in terms of particle shape, size and surface texture by SEM technique.

For the coverage of the toners on the carrier surface, the CT-01b toner was mixed with the TSV-200 carrier to the total weight of 1, 3, 5, 7 and 10 wt %, and was rotated with a speed 800 rpm for 360 seconds. These developers were observed for the toner coverage on the carrier surface by SEM.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Morphology of the toner and the carrier particles

The scanning electron micrographs of all the toners as shown in Figure 4-1, reveal that all toners have irregular shapes. Figure 4-2 displays the SEM photographs of the toner surface, which were covered by the various silica concentrations (wt %), the higher the concentration, the greater the coverage. Figure 4-3 shows the coverage of silica on the toner surface by number of times applying forces for silica attachment.

The SEM photographs of TSV-200 carrier shown in Figure 4-4 indicate irregular shape with cracks and holes on its rough surface.

4.2 Dependence of toner charge on silica concentration

The toner charge-to-mass ratio (q/m) was dependent on the concentration of the silica added onto the toner surface. The developers were prepared by mixing the TSV-200 carrier and the toners containing various silica concentrations from 0 to 1 wt %, at 5 wt % toner concentration. They are rotated at the rotating speeds of 600, 800, 1,000, and 1,200 rpm.

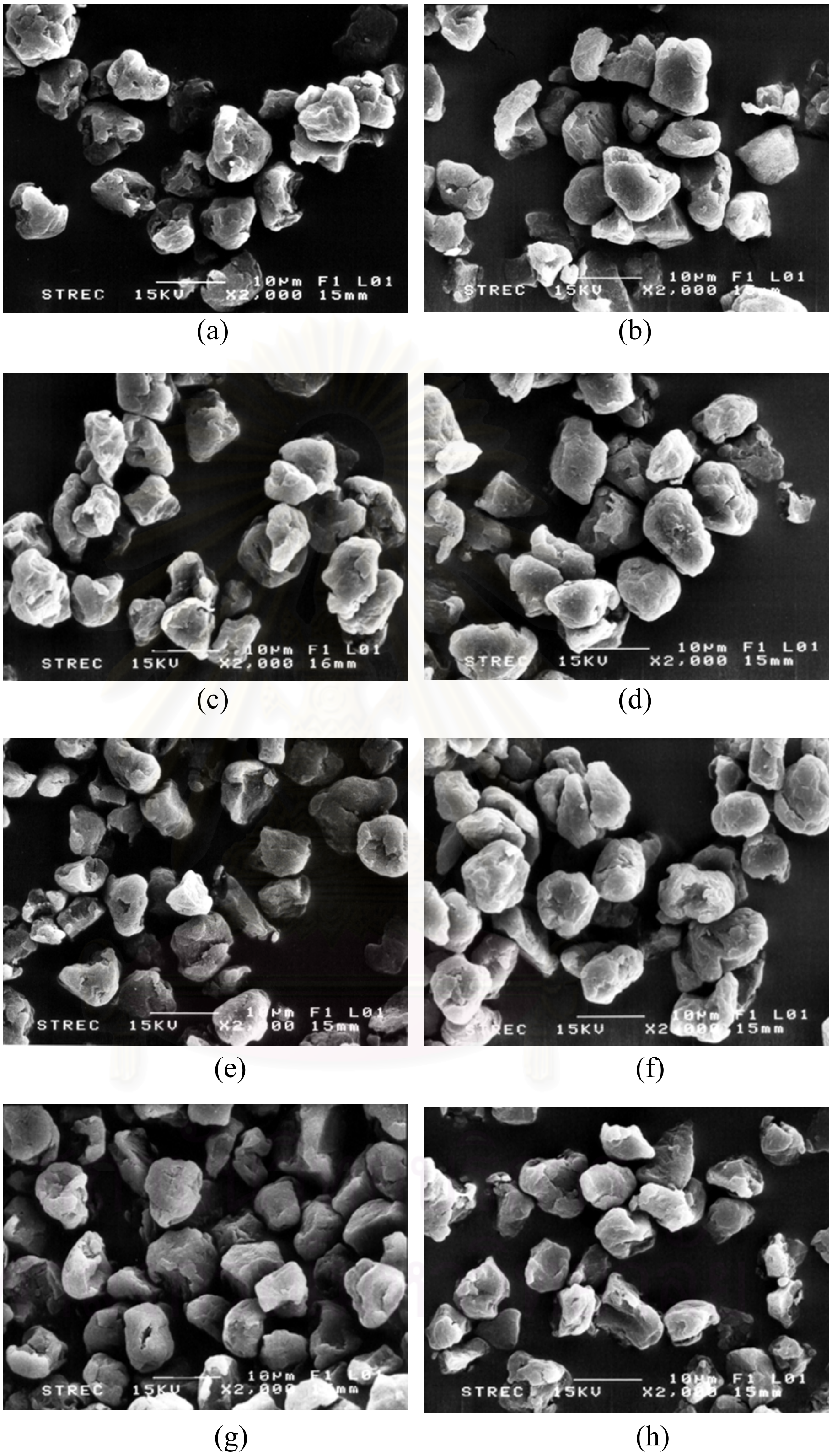


Figure 4-1 SEM photographs of toners particles: (a) CT-01b, (b) CT-01b-1, (c) CT-01b-2, (d) CT-01b-3, (e) CT-01, (f) CT-01a, (g) CT-01c, and (h) CT-01d toner (×2,000)

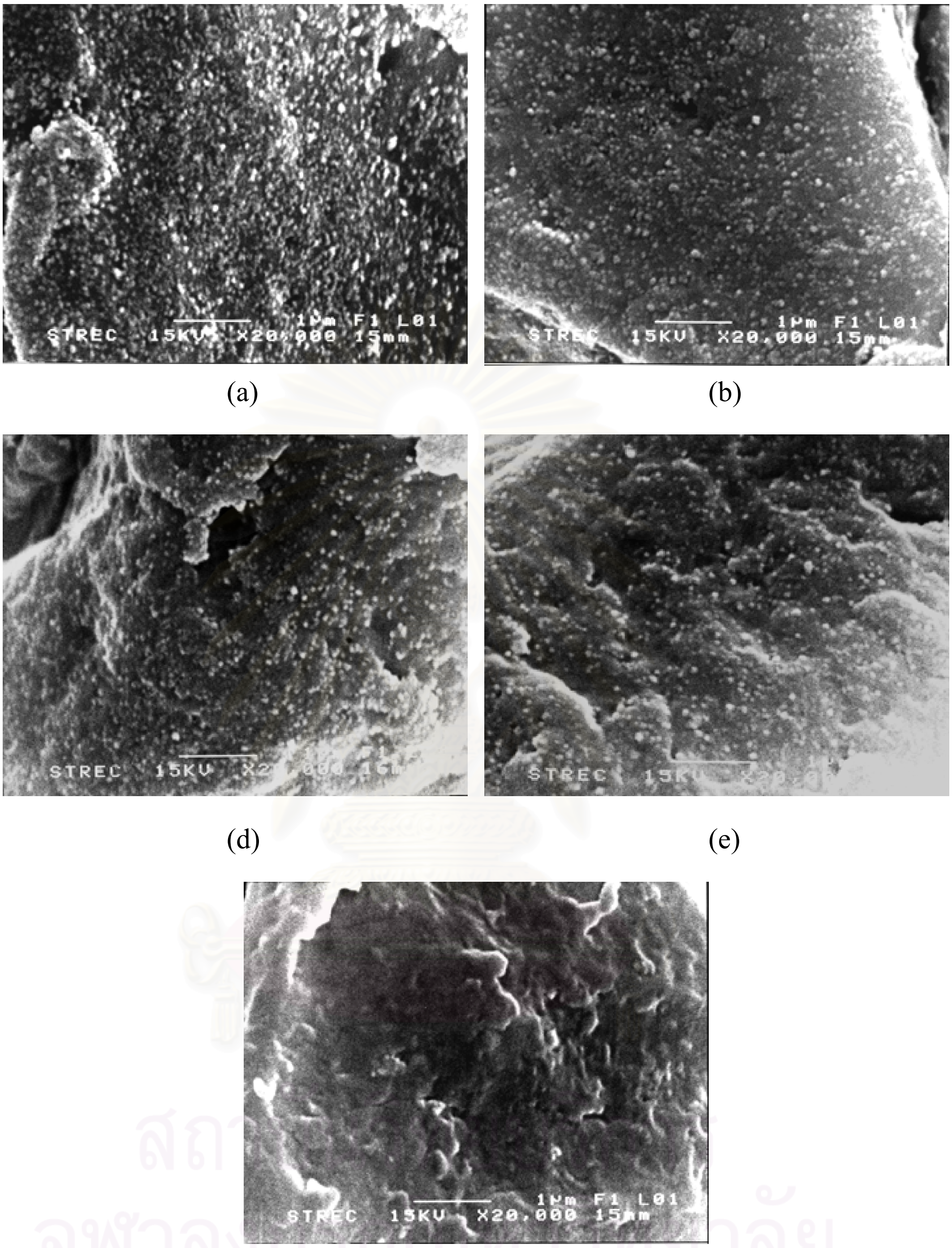
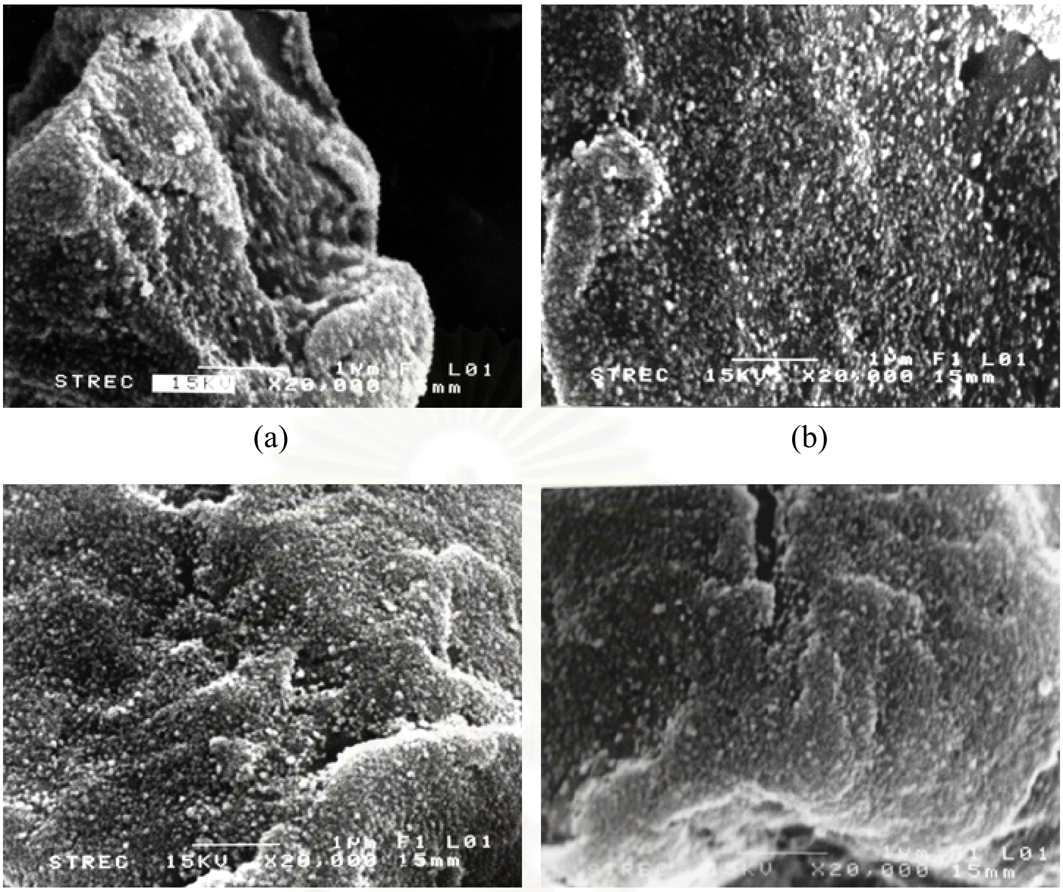


Figure 4-2 Scanning electron micrographs of toners surface covered by various silica concentrations (wt %) : (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt %; and (e) CT-01 toner without silica (×20,000)

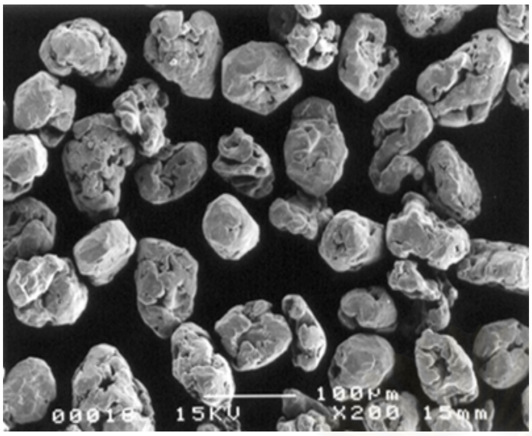


(a) (b)

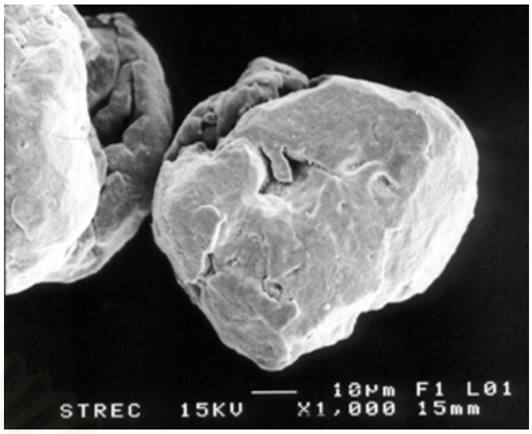
(c) (d)

Figure 4-3 SEM photographs of toner surface covered by various silica concentrations through different numbers of attachment force : (a) CT-01a, 1/2 time; (b) CT-01b, 1 time; (c) CT-01c, 2 times; and (d) CT-01d, 4 times (×20,000)

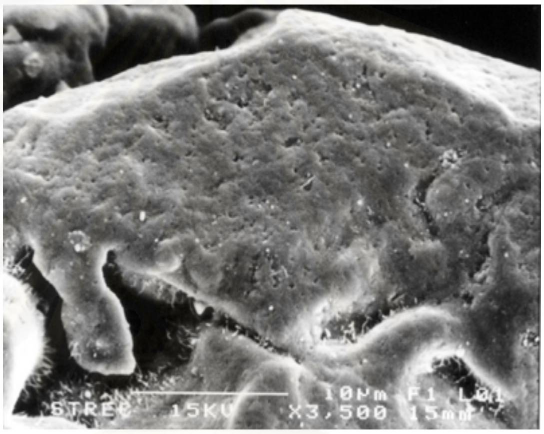
Figure 4-5 shows the relationship between the q/m values and the rotating time at rotating speed of 600 rpm. The data show that silica additive can clearly provide negative charging in the polyester toner. Each curve resulted from different silica concentrations shows a similar tendency of q/m values. The toner charge increases rapidly with an increase in the rotating time especially at the short time region and reaches a quasi-static state very slow changes at 240 seconds.



(a)



(b)



(c)

Figure 4-4 SEM photographs of TSV-200 carrier, (a) ×200, (b) ×1,000, and (c) ×3,500

As can be seen clearly that the q/m values of the CT-01b toner are higher than those of the CT-01b-1, CT-01b-2 and CT-01b-3, respectively. The toner with a higher silica coverage toner has higher flow ability. Therefore, the number of frictions or contacts between toner and carrier particles increases. This phenomenon generates the higher q/m values.

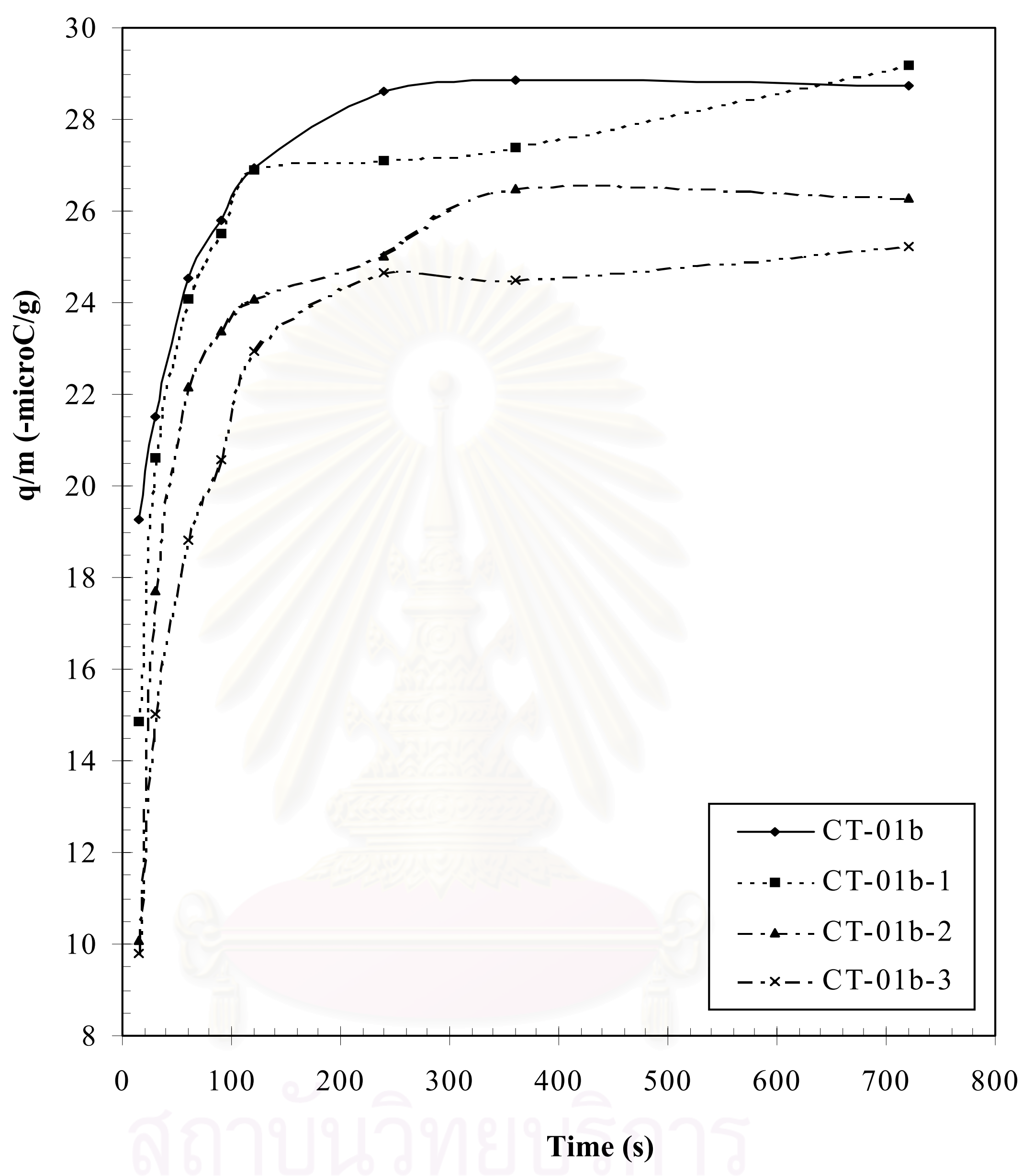


Figure 4-5 Dependence of q/m values on the rotating time for CT-01b, CT-01b-1, CT-01b-2 and CT-01b-3 toners at the rotating speed of 600 rpm

Figure 4-6 shows the tribocharging curves influenced by the rotating time at the rotating speed of 1,000 rpm for the toners containing varied concentrations of silica from 0 to 1 wt %. Almost all the q/m curves are increased rapidly at 15 to 90 seconds, and they change slowly and then reach a saturation status after 360 seconds of developing time. The charges of the CT-01 toner are the lowest while the other toners show the similar tendency to those curves with the respective toners in Figure 4.5 in which the q/m values increase with increasing silica concentrations.

Figure 4-7 and 4-8 show the relation between q/m values and the rotating time of the toners at 800 and 1,200 rpm, respectively. The q/m values of the toners, which were covered by silica particles, show a similar increasing trend with an increase in the silica concentration. Considering the CT-01 without any silica coverage, the q/m values show some interesting tendency. At the higher rotating speed (1,200 rpm), the q/m curves of CT-01 toner are in the middle range at the short developing time. After 240 seconds, the q/m values decline rapidly. In the case of 800 rpm rotating speed, the q/m curves of the CT-01 toner is relatively stable.

This peculiar behavior is related to "the carrier contamination by CCA".[20] The CCA molecules fall from the toner surface and deposit on the carrier surface during mixing. If the toners without CCA are used for tribocharging, no charge are produced. It is obvious that the q/m values should decrease steadily.

Furthermore, the silica particles may be removed and fall onto the carrier surface to cause the "carrier contamination with silica" that can reduce the toner charge significantly.[23]

More importantly, another major cause to reduce the q/m values is the plunging of the toner particles into the cracked surface of the carrier as shown in

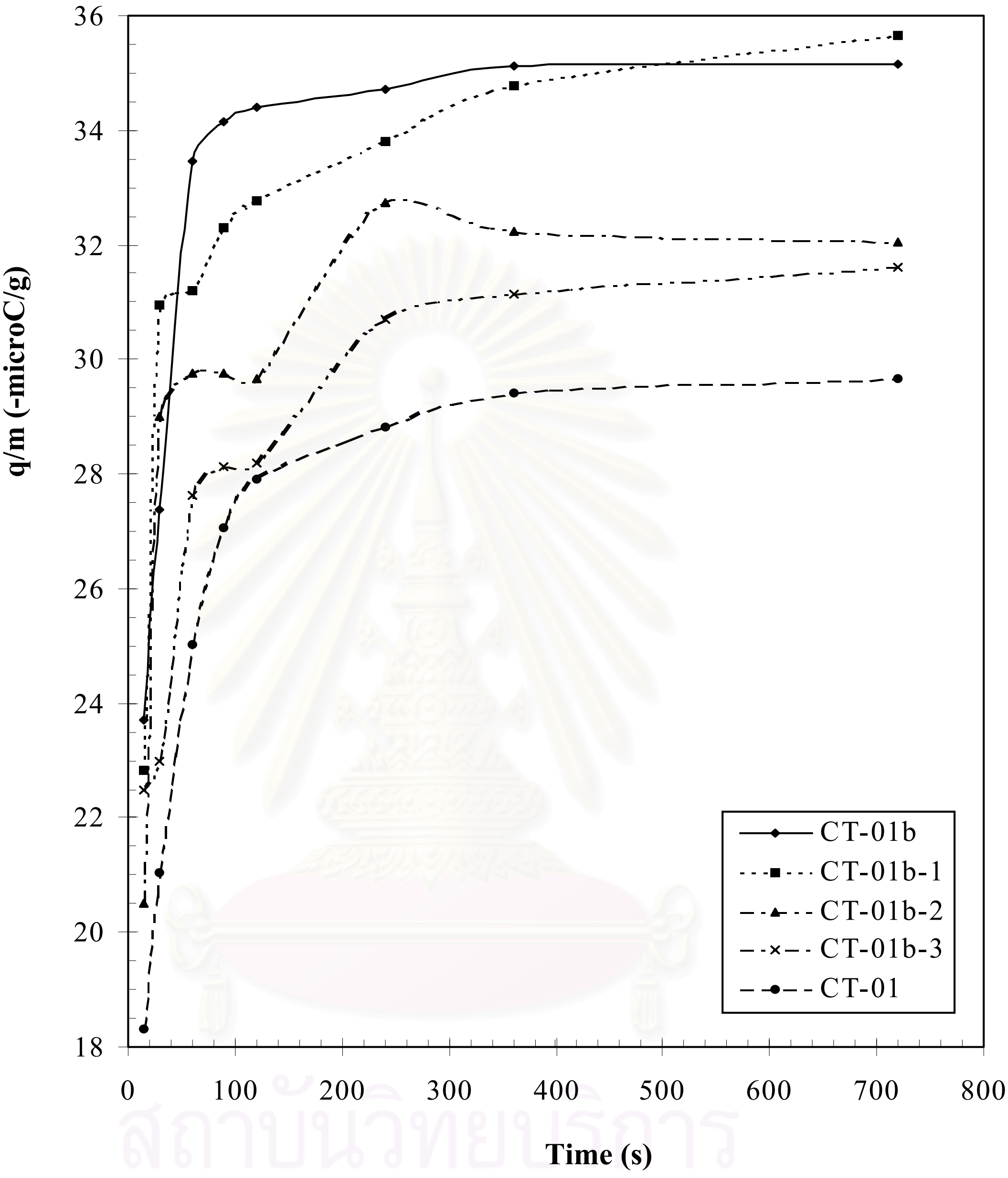


Figure 4-6 Dependence of q/m values on the rotating time for CT-01b, CT-01b-1, CT-01b-2, CT-01b-3 and CT-01 toners at the rotating speed of 1000 rpm

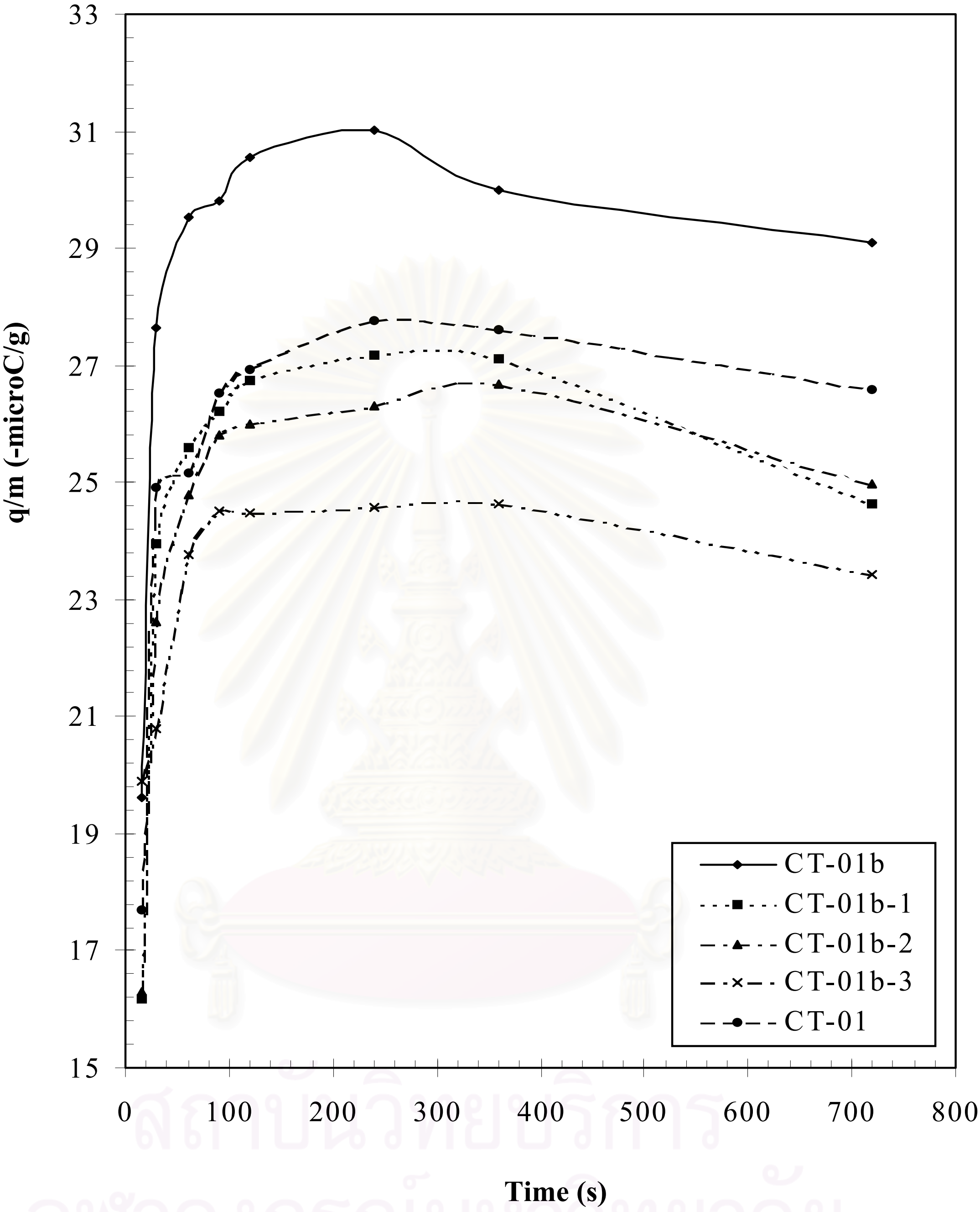


Figure 4-7 Dependence of q/m values on the rotating time for CT-01b, CT-01b-1, CT-01b-2, CT-01b-3 and CT-01 toners at the rotating speed of 800 rpm

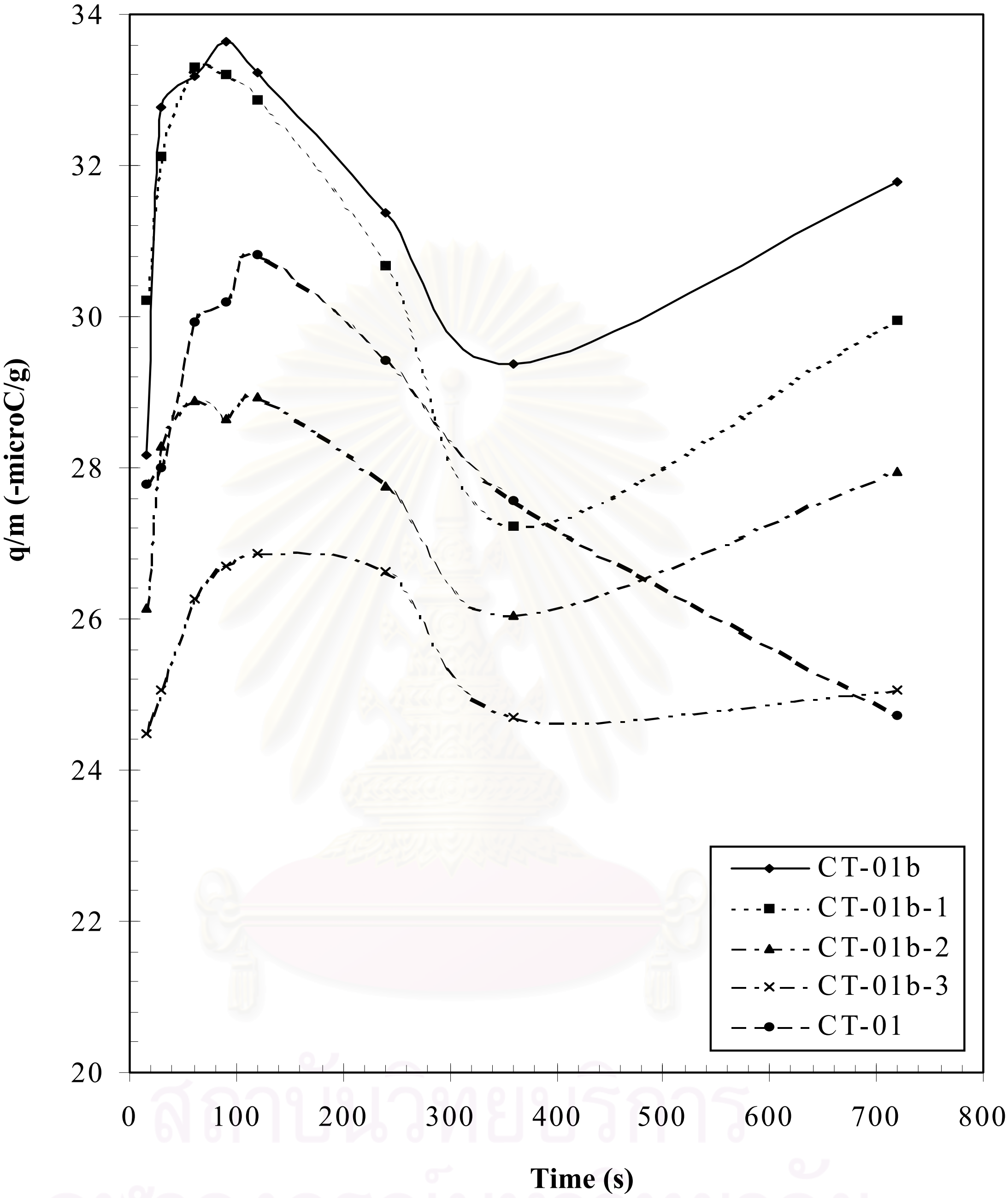


Figure 4-8 Dependence of q/m values on the rotating time for CT-01b, CT-01b-1, CT-01b-2, CT-01b-3 and CT-01 toners at the rotating speed of 1200 rpm

This phenomenon can vitally reduce both the toner and carrier charging sites. Nonetheless, when increasing the rotating time, the burial toner particles could be split away from hole in the cracking surface, and may increase the q/m values. Contrary to this case, the burial toners may be deeply plunged into the cracking hole with increasing rotating times, which cause a decrease of the q/m values. Comparison of the q/m curves of the toners with and without the fumed silica, their charge tendency is almost the same (Figure 4-8). Presume that, the toner without silica could be deeply plunged in the cracked surfaces of the carrier with increasing rotating times, the q/m values are low. This is because of the toner's poor flow ability and higher adhesion force with the carrier that a stronger detachment force must be applied to generate a higher q/m value. On the other hand, the toner with silica are easily split from the carrier surface by increasing the rotating time because the toners have the rougher surfaces with higher free flowing (as shown in Section 4.7.1), and the lower adhesion force with the carrier surface.

Figure 4-9 SEM micrographs showing the burial toner particles in the inner holes of the carrier surface

To this point, we can state that the silica concentration strongly affect the toner charging ability. A linear increase in q/m value of the toner is created as shown in Equation 4-1.

$$q/m \propto \alpha\, a + \beta (1-a) + \gamma\, a\, (1-a) \qquad (4\text{-}1)$$

where α is the charging ability of silica surface, β is the charging ability of no silica surface, γ is the effective rate constant for the charging process, a is silica coverage ratio. Equation 4-1 indicates that the toner surface percent coverage is a direct linear function of silica concentration (weight percent).[24] The $\gamma a(1-a)$ is an interaction term that can be negligible.

According to our results and the earlier Equation (4-1), the effects of silica concentration on the toner charge could be explained by the following equation.[17]

$$q_i = |q^-_t| + |n\, q^-_s| \qquad (4\text{-}2)$$

where q_i is the integrated tribocharge, q_t is the toner tribocharge, q_s is the silica tribocharge and n is the number of silica particles on the toner surface. When the integrated tribocharge are combined with the toner tribocharge on the charging sites of the toner surface, and silica tribocharge on the charging site of the silica surface, it is no surprise that the increase of n can be induced by increasing the integrated tribocharge.

In summary, the addition of fumed silica in the toner can completely change the charging behavior of the toner. Evidence showed that this is due to the surface coverage of the toner particles by the fine particulate fumed silica. The results indicated the negative tribocharge of the developer increases with the increase in silica concentration. Although, the toners without silica coverage showed inconsistent tendency of q/m values, the wrong-sign toners probably occurred because of its non-uniform surface.[23]

4.3 Dependence of the toner charge characteristics on silica attachment force.

The dependence of the toner charge-to-mass ratio (q/m) on the silica attachment forces was studied using the toners, prepared by applying various forces for silica attachment. The number of times for attached forces of the silica particles for CT-01a, CT-01b, CT-01c and CT-01d toners are ½, 1, 2 and 4 times, respectively. Each toner was mixed, with TSV-200 carrier at 5 wt % toner, at the rotating speeds from 800 to 1,400 rpm.

Figure 4-10 shows the relationship between the q/m values and the rotating time for CT-01a, CT-01b, CT-01c and CT-01d toners at the rotating speed of 800 rpm. The results are found that the q/m values of each toner except the CT-01d were not clearly different. A similar tendency is found as that the q/m values initially increased rapidly with the rotating time. The charges of the toners were unstable during 15 to 120 seconds, but they reached a saturation value after 120 seconds. Concerning the CT-01d toner, the q/m values increased rapidly from 15 to 60 seconds and decreased suddenly before reaching a saturation value after 120 seconds of mixing time.

As it can be seen in Figure 4-11, the relation between the q/m values of the developers at the rotating speed of 1,000 rpm is exhibited. The q/m values of each

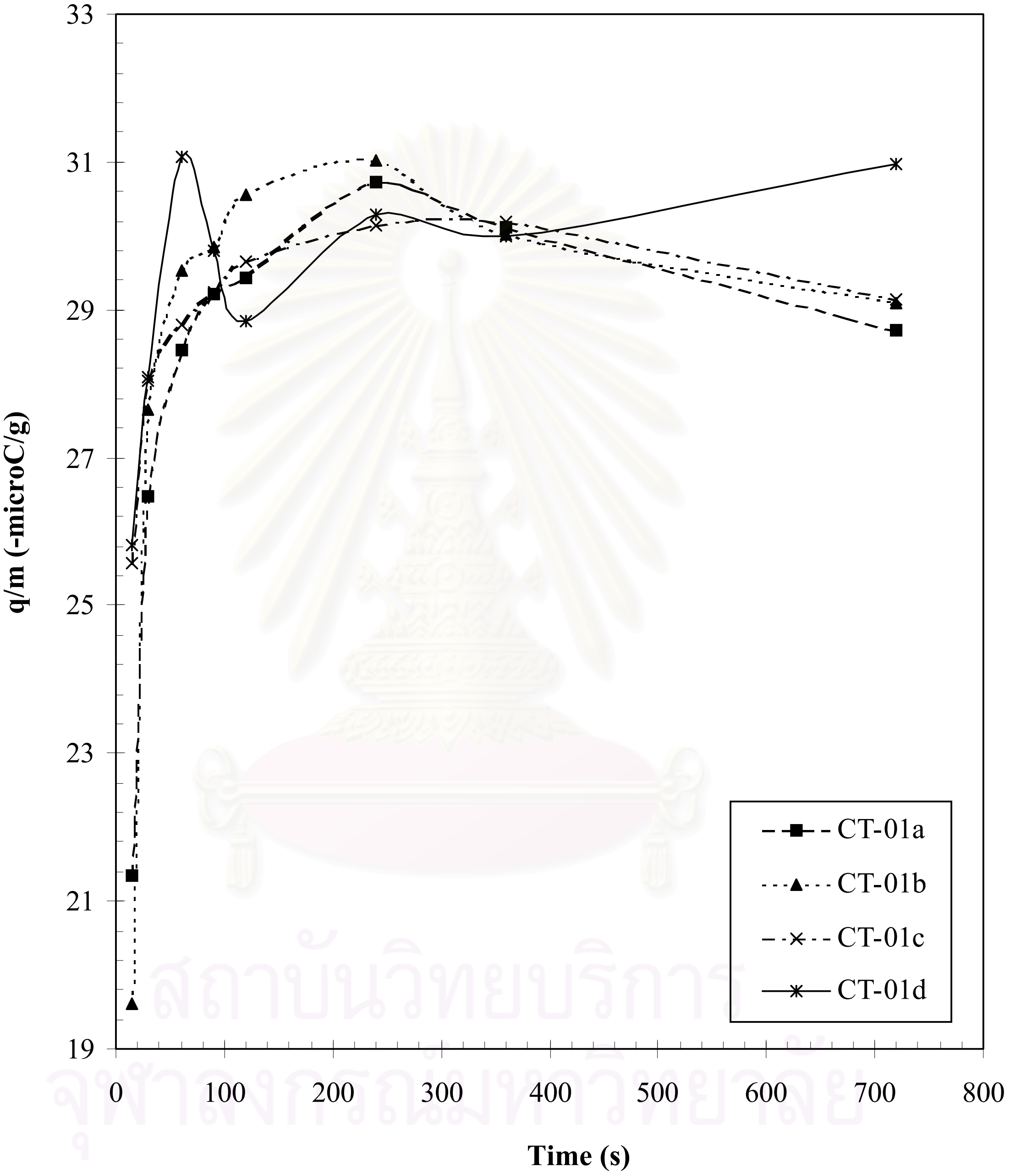


Figure 4-10 Dependence of q/m values on the rotating time for toners applied by various silica attachment forces at the rotating speed of 800 rpm

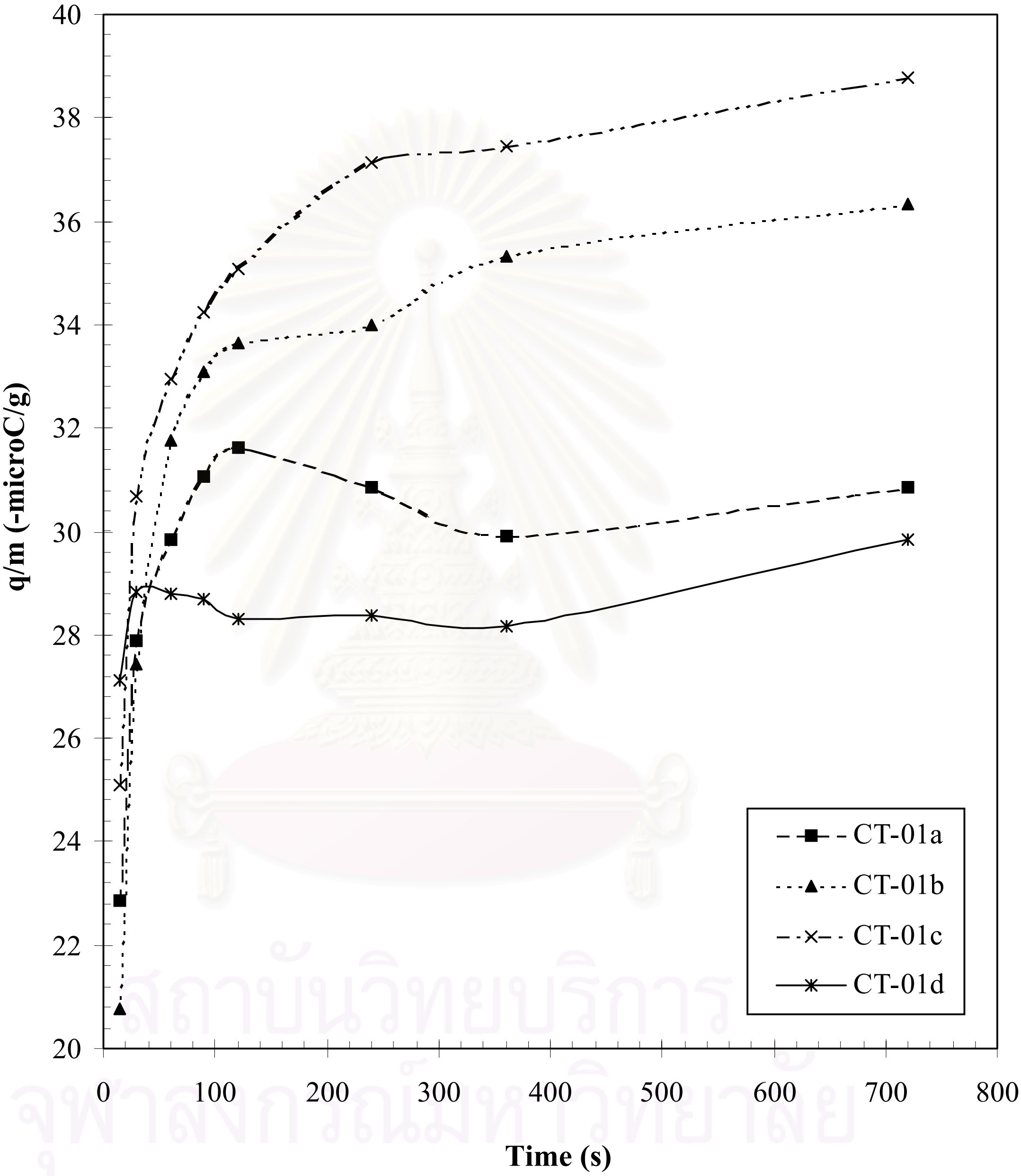


Figure 4-11 Dependence of q/m values on the rotating time for toners applied by various silica attachment forces at the rotating speed of 1,000 rpm

toner are clearly different, but they show a similar tendency that these values are rapidly increased at the rotating time 15 to 60 seconds, and then they approach a quasi-static value with very slow changes. The toner charges of CT-01c are higher than those of the CT-01b and CT-01a toner, respectively, while the q/m values of CT-01d toner are the lowest.

Figures 4-12 and 4-13 indicate the plots between the q/m values and the rotating time of the developers at the rotating speeds of 1200 and 1400 rpm. At 1,200 rpm, the q/m values of the CT-01a, CT-01b and CT-01c toners are rapidly increased from 15 to 30 seconds and then they gradually decreased. After that, (from 120 to 360 seconds), the q/m values are slowly decreased and then they slightly increased at 720 seconds. The q/m values of the CT-01a toner are higher than those of the CT-01b and CT-01c toners, respectively. The charges of the CT-01d toner increased from 15 to 90 seconds of mixing time and slightly decreased from 90 to 720 seconds. At rotating time of 720 seconds, the q/m values of the CT-01a are higher than those the CT-01b, CT-01c and CT-01d toners, respectively. At the rotating speed of 1400 rpm, the q/m values of the toners are rapidly increased from 15 to 60 seconds, after that the toner charges are gradually raised in a similar tendency. The q/m values of the CT-01a was higher than the charges of the CT-01b, CT-01c and CT-01d toners, respectively.

Almost all the results so obtained indicate that the charges of the toners are based on the applied force for silica attachment either in a form of an agglomeration or a high dispersion of the silica particles on the toner surface. However, these phenomena were also depended on the mixing force between the toner and the carrier particles. Basically rubbing force between the toner and the carrier particles affects to the silica position charging.

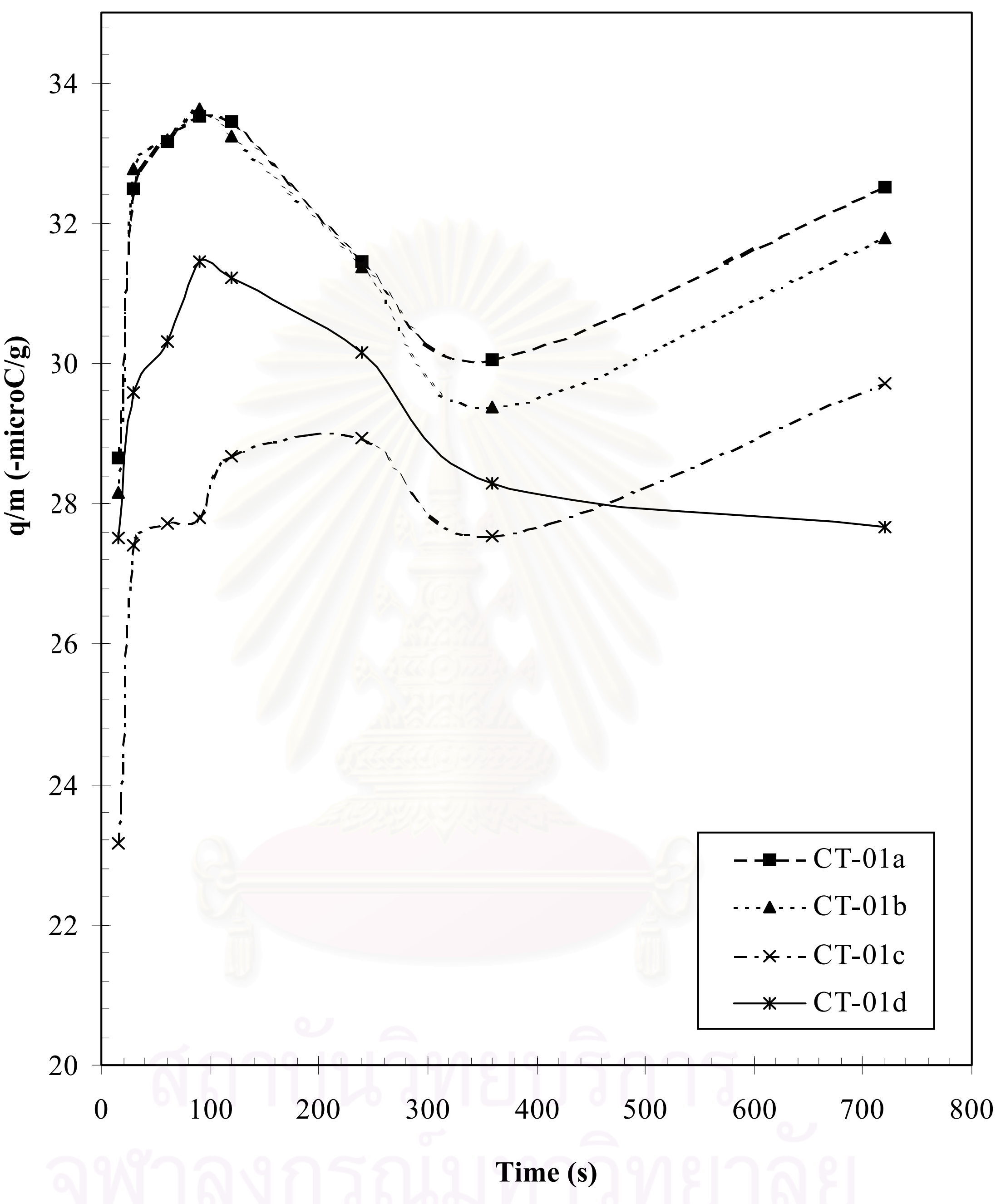


Figure 4-12 Dependence of q/m values on the developing time for toners applied by various silica attachment forces at the rotating speed of 1,200 rpm

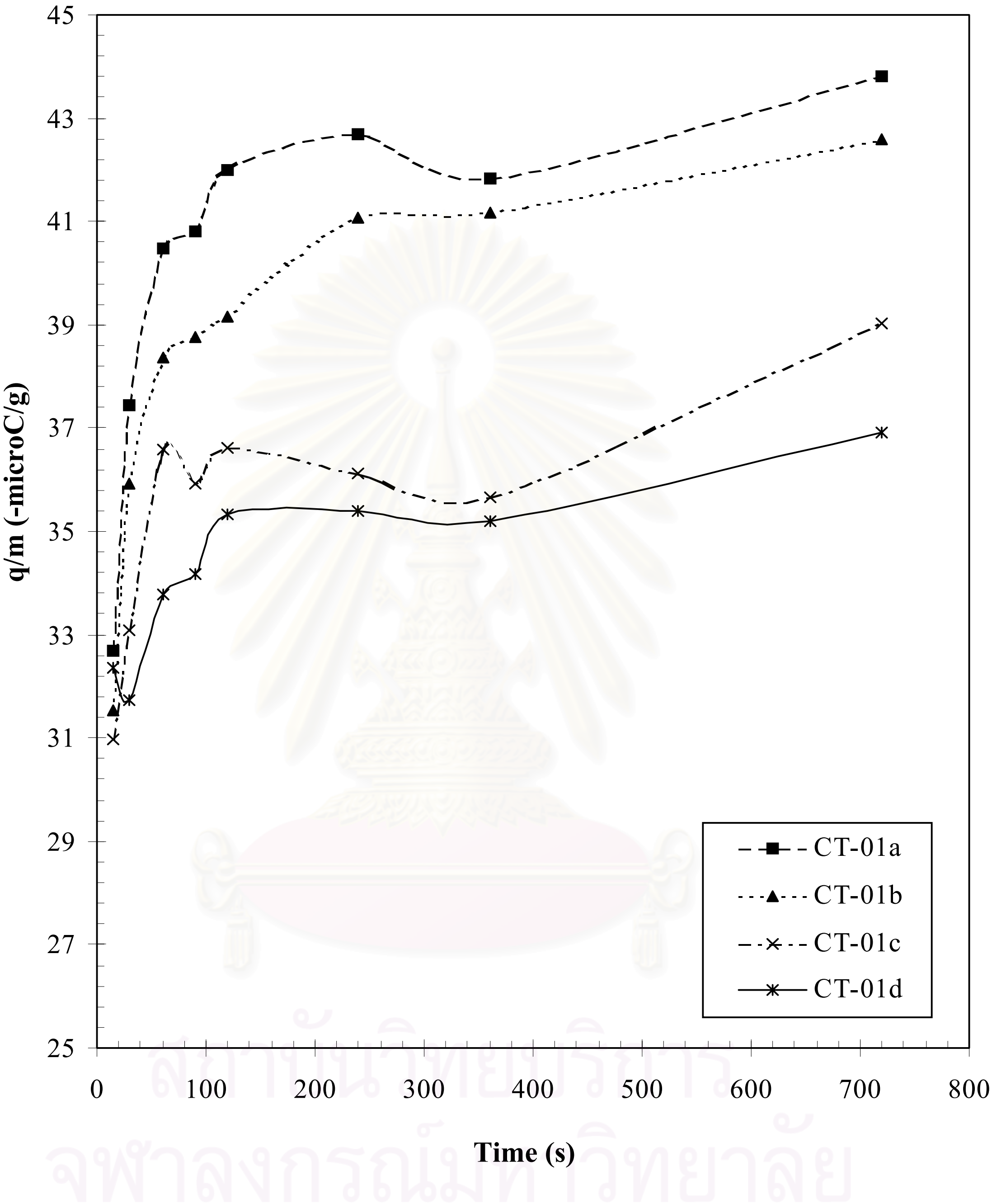


Figure 4-13 Dependence of q/m values on the developing time for toners applied by various silica attachment forces at the rotating speed of 1,400 rpm

To explain this phenomenon, we assume that both toner and silica particles are spherical, and the silica particles are adhered on the toner particle uniformly and well dispersed. The location of the silica particles on the toner surface can be assessed as shown in the Figure 4-14, when the number of times for attached forces to taking place the silica particles on the toner surfaces of CT-01a, CT-01b, CT-01c and CT-01d is ½, 1, 2 and 4 times, respectively.

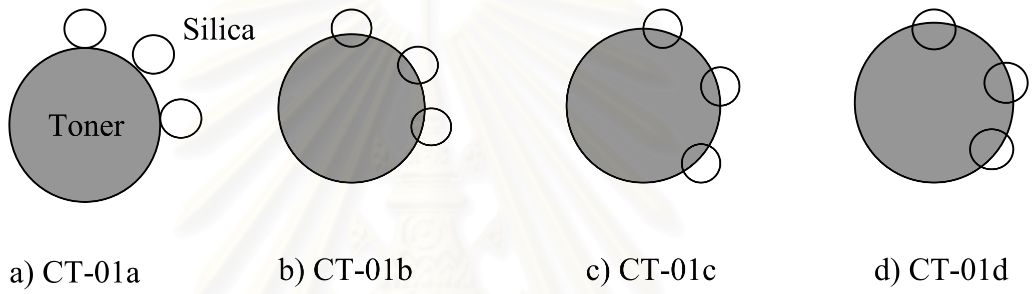


Figure 4-14 the cross-section models of the silica particles on the toner surfaces.

From these models, the surface area of silica particle can be calculated by Equation (4-3).

$$S = 4\pi\, r_s^2 \tag{4-3}$$

where S is the surface area of the silica particle and r_s is the radius of the silica particle. For CT-01a, the surface area of the silica particles is nearly $4\pi\, r_S^2$ because they are slightly attached on the toner surface. Conversely, the silica particles may be largely embed into the CT-01d toner surface and leave a small portion of the surface area on the toner surface, which can be rubbed with the carrier surface and generate the tribocharge. According to the Equation 4-3 and the cross-section models in Figure 4-14, the surface area of the silica particles on the surface of CT-01a toner is higher than those of CT-01b, CT-01c and CT-01d toners, respectively. An increase of the silica particle surface area affects the increasing level of contact charging due to the higher charging opportunity on the silica surface.[15]

As mentioned previously, the rubbing force between the toner and the carrier affects the attachment of the silica particles on the toner surface. It causes the silica particles to plunge inside the toner surface. At the high rubbing force (1200 and 1400 rpm), the q/m values of the CT-01a is higher than those of CT-1b, CT-01c and CT-01d toner, respectively. The surface of the toner was changed accordingly as silica particles were plunged into the inner of the toner.[16] The possible changes of the silica particles on the toner surface after rubbing with the carrier ware shown in Figure 4-15. The surface area of the silica particles on the surface of the CT-01a toner is higher than those of CT-1b, CT-01c and CT-01d toners, respectively.

The silica particles slightly attached on the toner surface can be dropped from the toner surfaces even by a low rubbing force. Therefore, the q/m values of these toners were close at the rotating speed of 800 rpm; and the q/m values of the CT-01a toner is smaller than those of the CT-01b and CT-01c toners at the rotating speed of 1,000 rpm.

In conclusion, the q/m values depend on the silica attachment force, which is related with the rubbing force between toner and carrier particles. The experimental results show the following summaries, (a) the position of silica particles on the toner surface can be changed by rubbing force between the toner and carrier particles, (b) the charge levels of the toners are not different at the low rubbing force, but are very different at the high rubbing force between the toner and carrier particles, and (c) the the force for the silica particle attachment on the toner surface influences the surface area of silica particles, which directly affects the charging results.

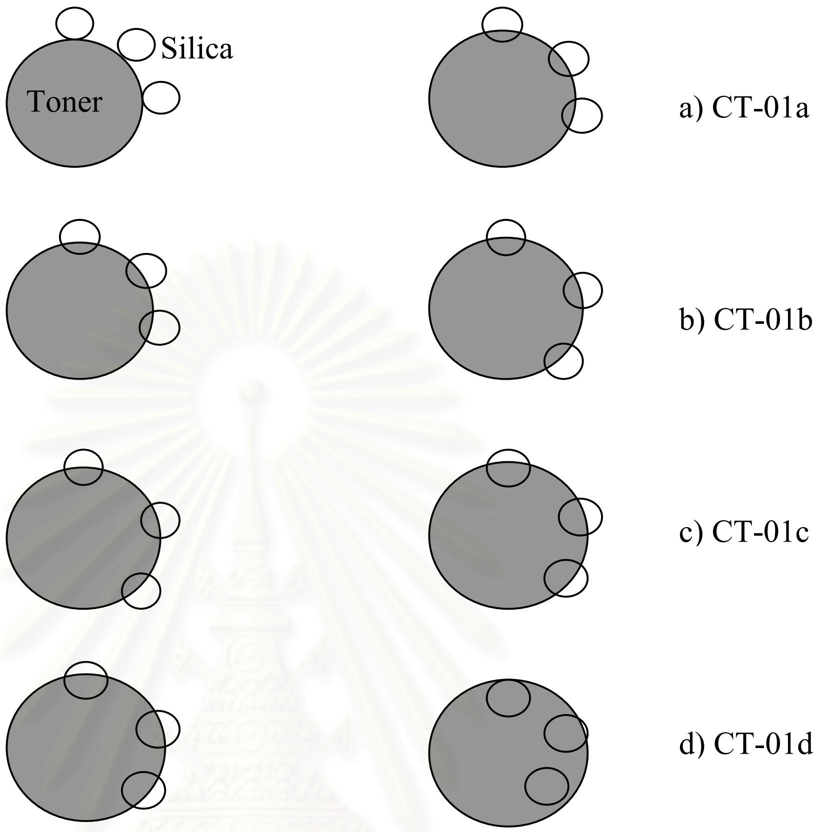


Figure 4-15 The models for the changes of the silica attachment on the toner surface: (left), before charging, (right), after charging; at the rotating speeds of either 1,200 or 1,400 rpm

4.4 Toner charge dependence on the toner concentration

Three types of toner, CT-01, CT-01b-1 and CT-01b were mixed with the TSV-200 carrier. These developers were prepared by various concentrations of the respective toners at 1, 3, 5, 7 and 10 wt %, at a rotating speed of the glass cell at 800 rpm.

As can be seen from Figures 4-16 to 4-18, the relationship between the q/m values of the developers and the rotating time gives the slopes with a similar tendency that the toner charges changed rapidly when the rotating time of the developer was continued from 15 to 90 seconds. After that, the q/m values reach a quasi-static state that changes very slowly.

Figure 4-16 shows the q/m curves of the CT-01 toner. The q/m values of 1 wt % toner are the highest whereas the q/m values of 10 wt % toner are the lowest. In Figures 4-17 and 4-18 show the q/m values of the CT-01b-1 and CT-01b toners, respectively. The result agrees with those shown in the Figure 4-16, which state that the toner charge values decreased with an increase in the toner concentration.

Moreover, Figures 4-19 to 4-21 display the relationship between the q/m values and the toner concentration at different developing times. The curves of these developers also show a similar tendency. For the CT-01b toner, the curves decrease linearly when the toner concentration increases. For the CT-01b-1 and CT-01 toners, the curves also decrease when the toner concentration increases.

The relationship between the $q/m_{(max)}$ or $m/q_{(max)}$ values with the toner concentration is shown in Figure 4-22 and 4-23, respectively. As can be seen that the curves of $q/m_{(max)}$ values decrease, while the $m/q_{(max)}$ values are linearly increased with increasing of the toner concentration. These observations are similar to the previous work.[11,17]

The q/m value dependence on the toner concentration is increasing toner concentration decreases the q/m values. At the high toner concentration, the coverage of the toner particles on the carrier surface is higher and occupies more than one layer. The outer layer has some free toner particles that can not be charged by rubbing with

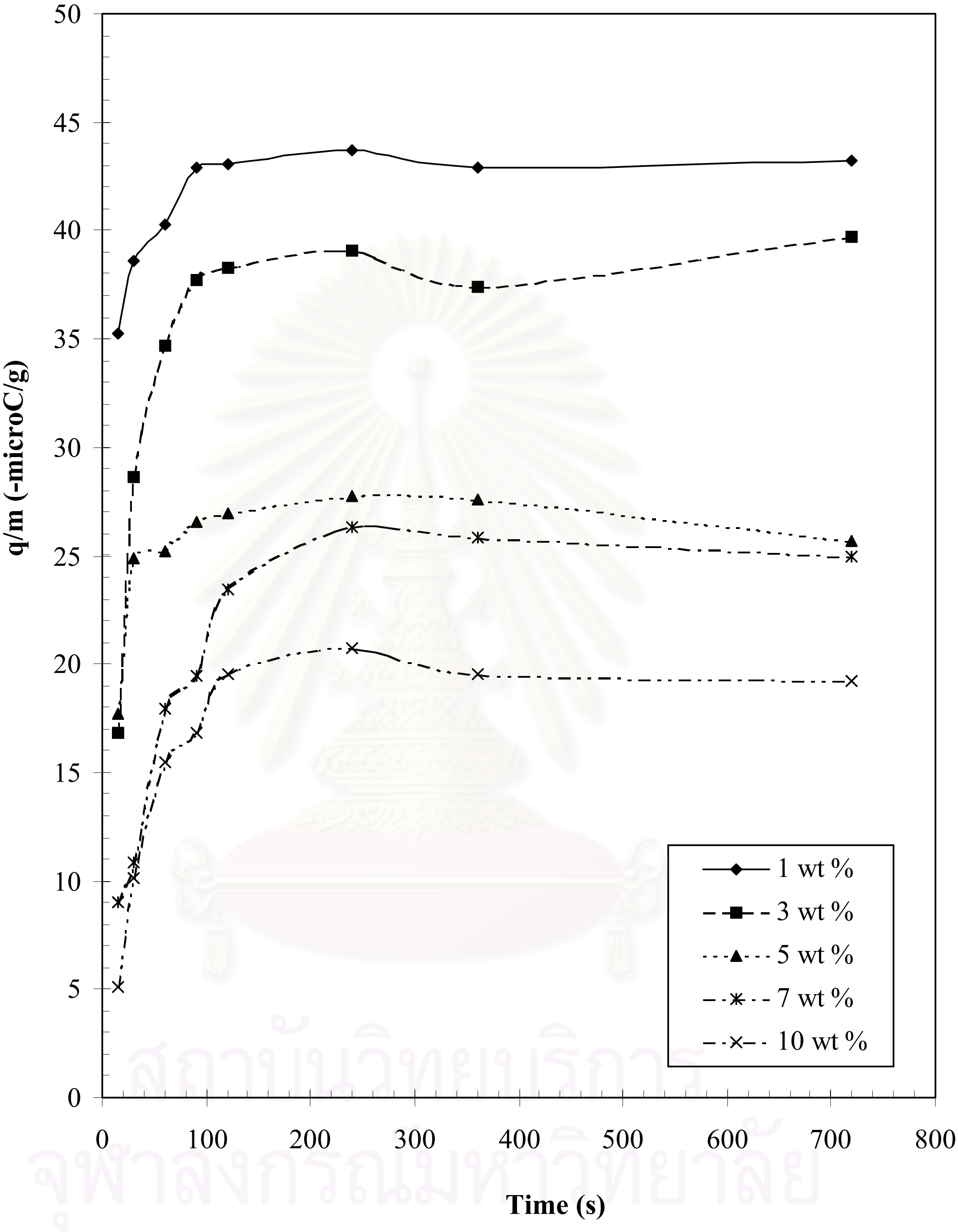


Figure 4-16 Dependence of q/m values on the developing time for the CT-01 toner at the rotating speed of 800 rpm

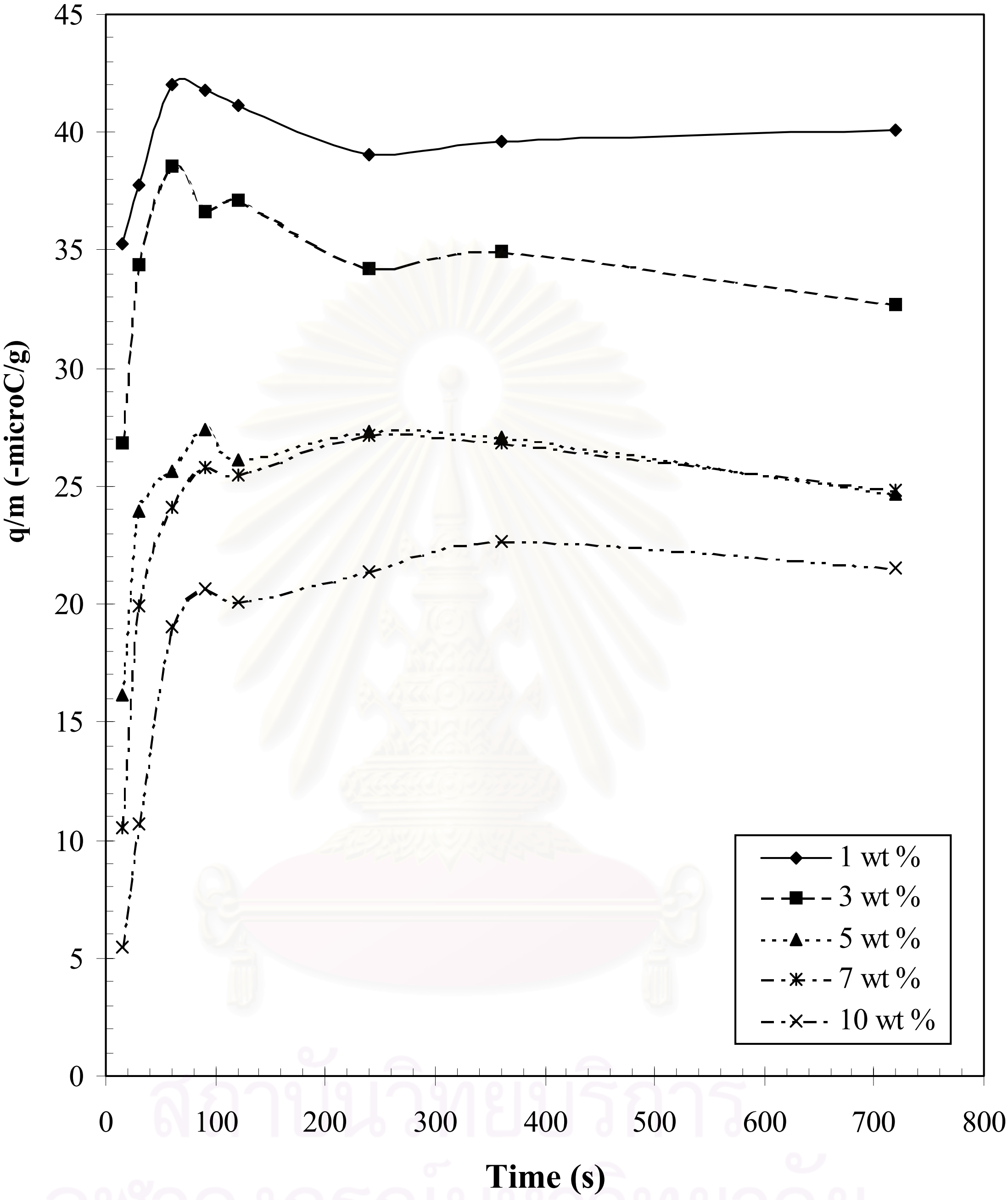


Figure 4-17 Dependence of q/m values on the developing time for the CT-01b-1 toner at the rotating speed of 800 rpm

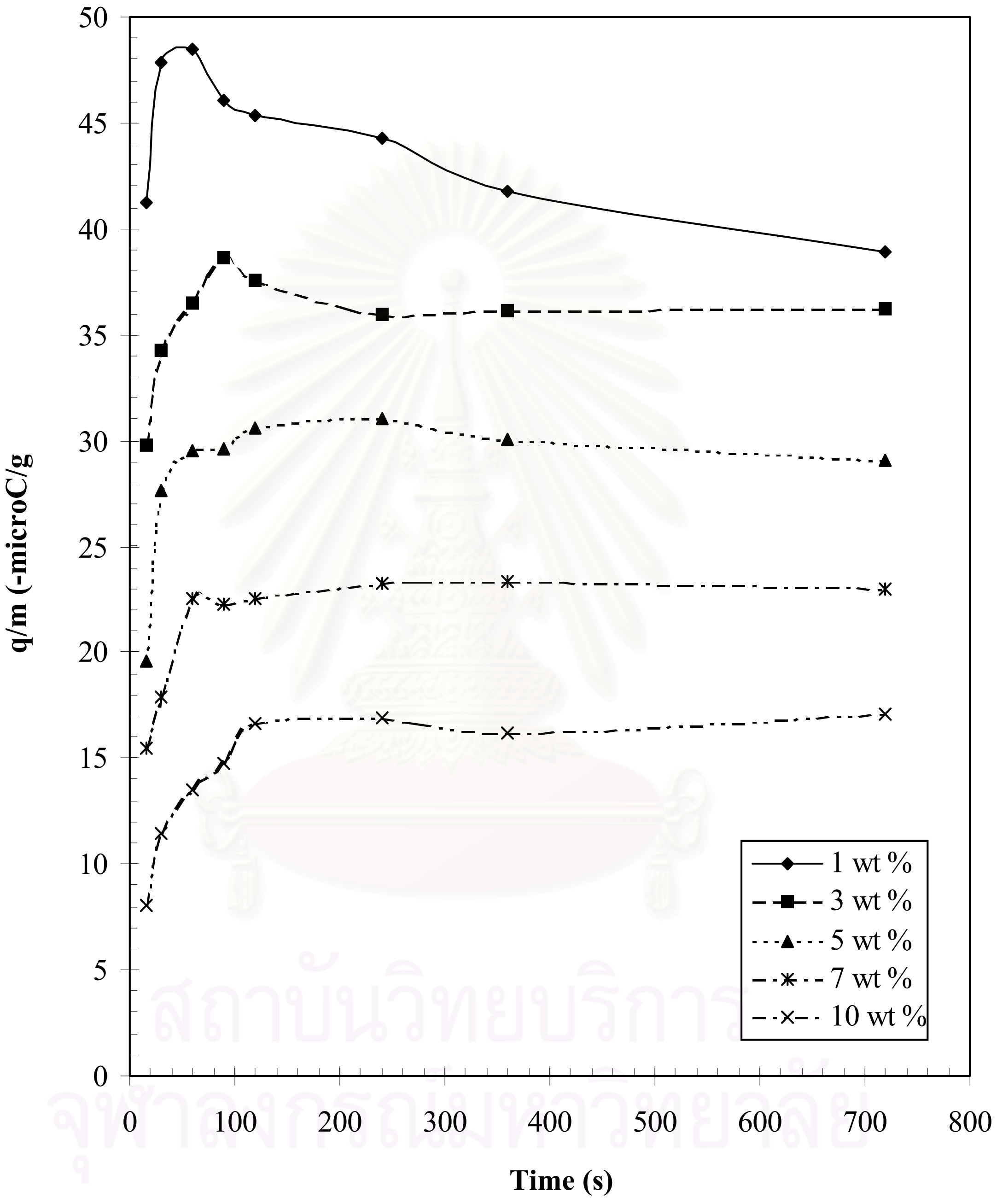


Figure 4-18 Dependence of q/m values on the rotating time for the CT-01b toner at the rotating speed of 800 rpm

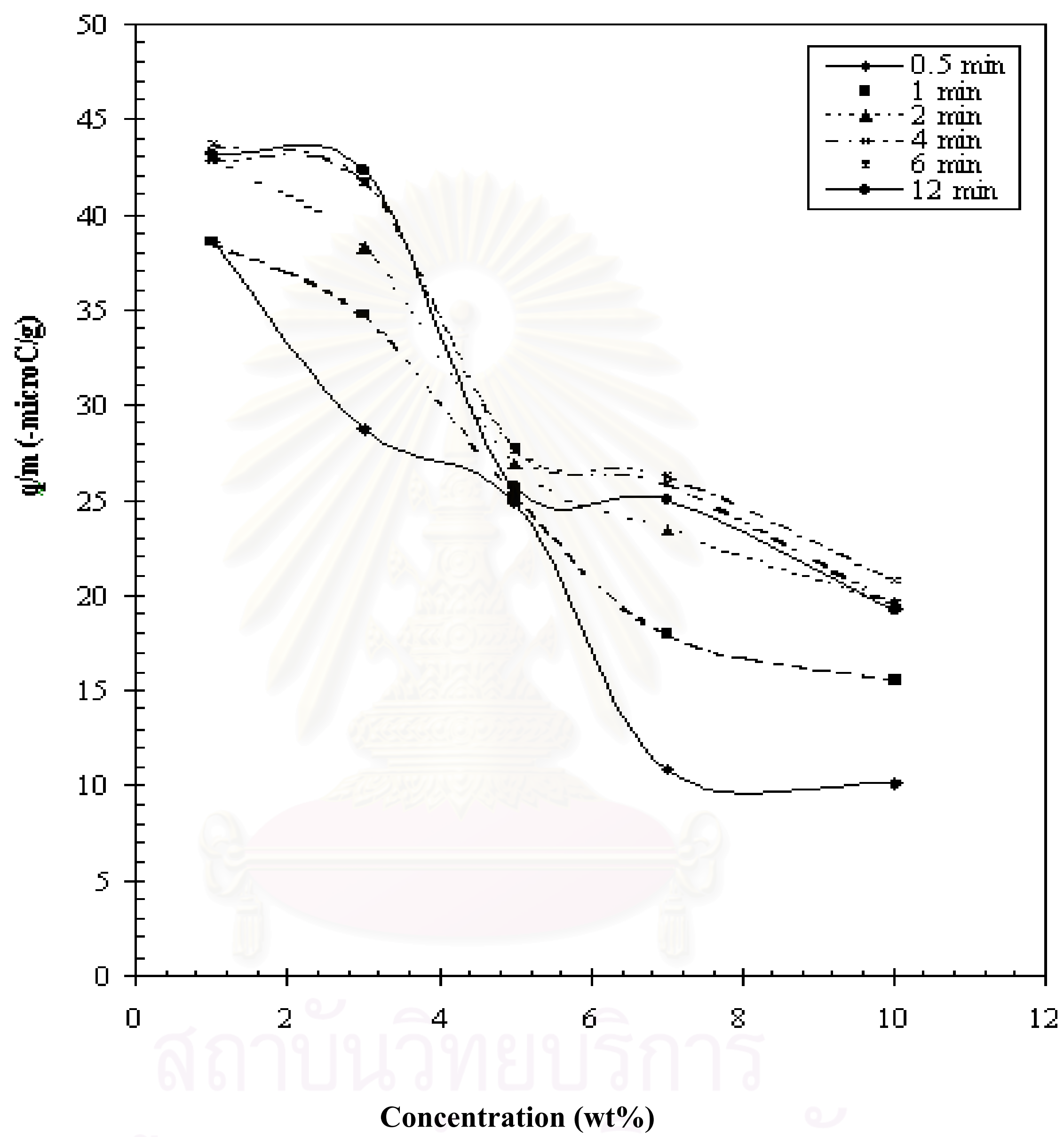


Figure 4-19 Dependence of q/m values on the toner concentration of the CT-01 toner at the different developing times

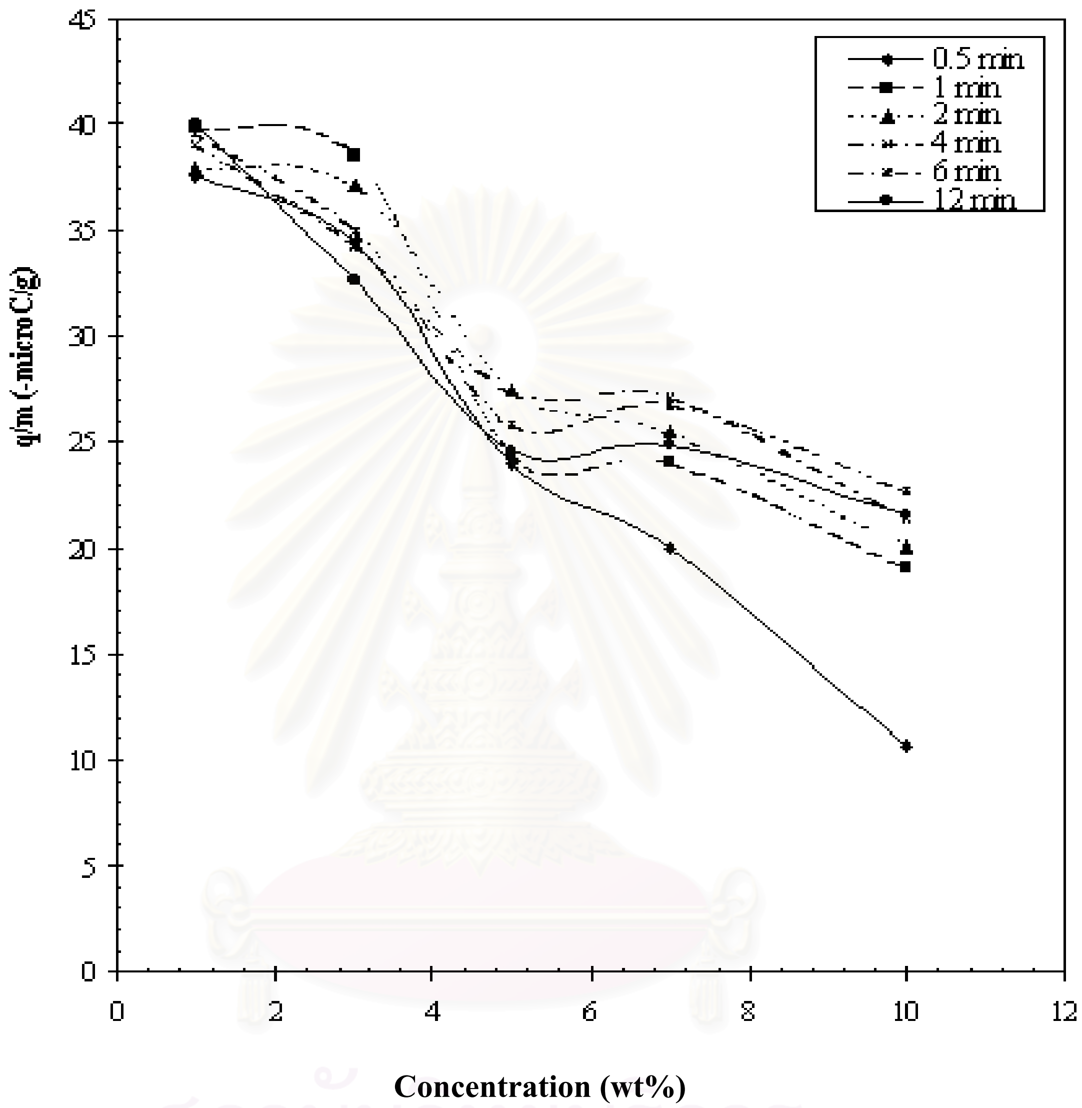


Figure 4-20 Dependence of q/m values on the toner concentration of the CT-01b-1 toner at the different developing times

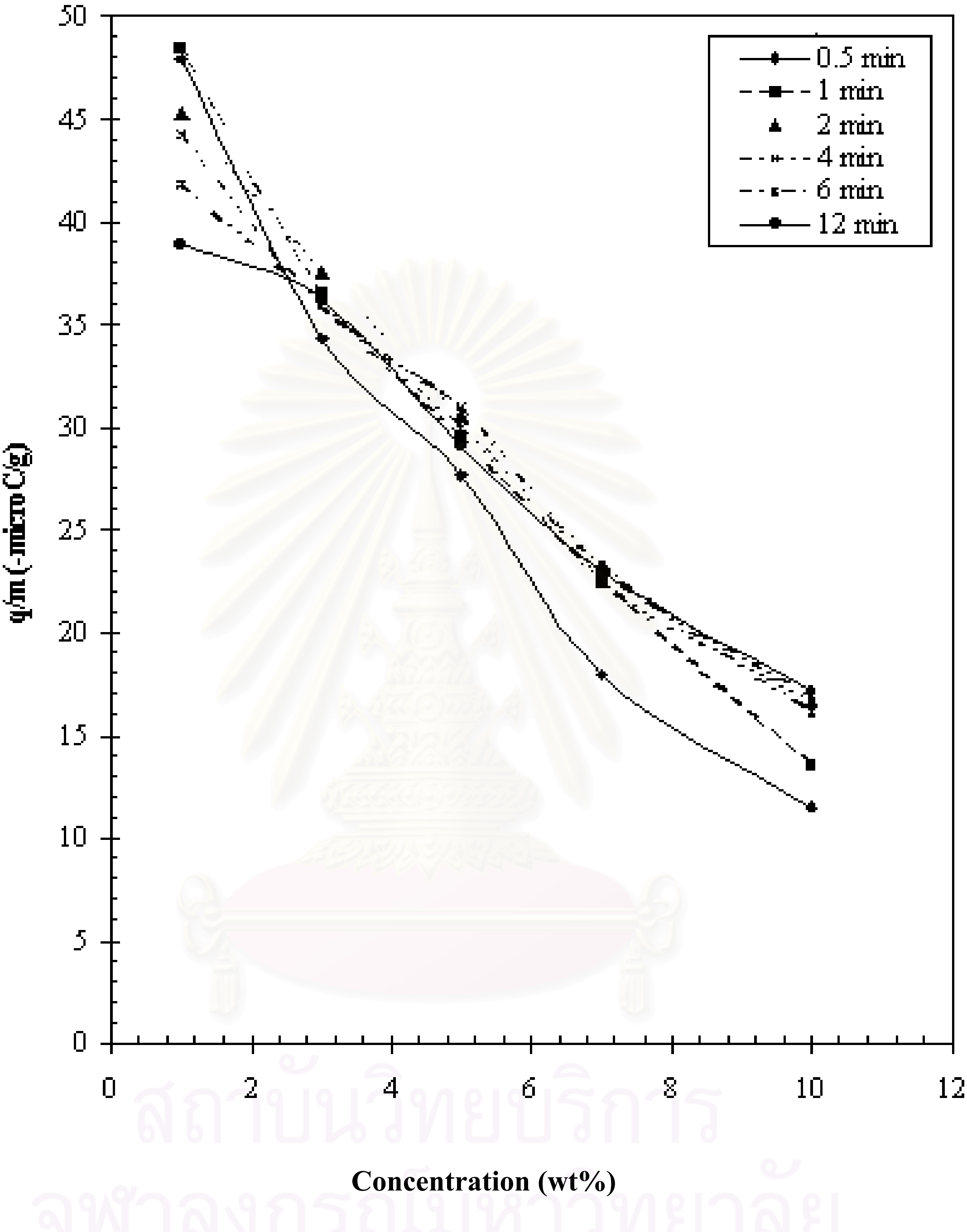


Figure 4-21 Dependence of q/m values on the toner concentration of the CT-01b toner at the different developing times

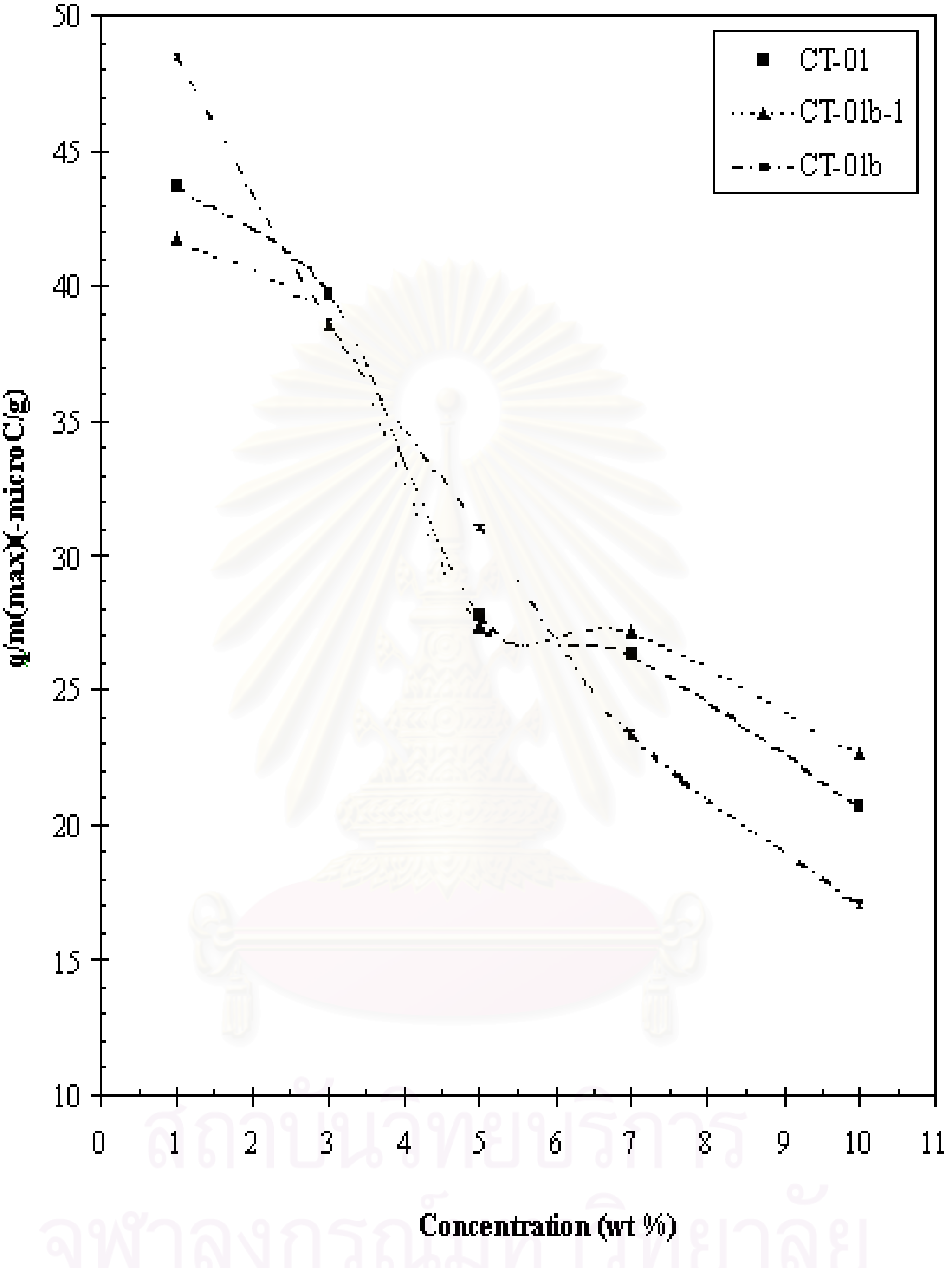


Figure 4-22 Dependence of q/m(max) values on the toner concentration (wt %) for the CT-01, CT-01b-1, and CT-01b toners at the rotating speed of 800 rpm

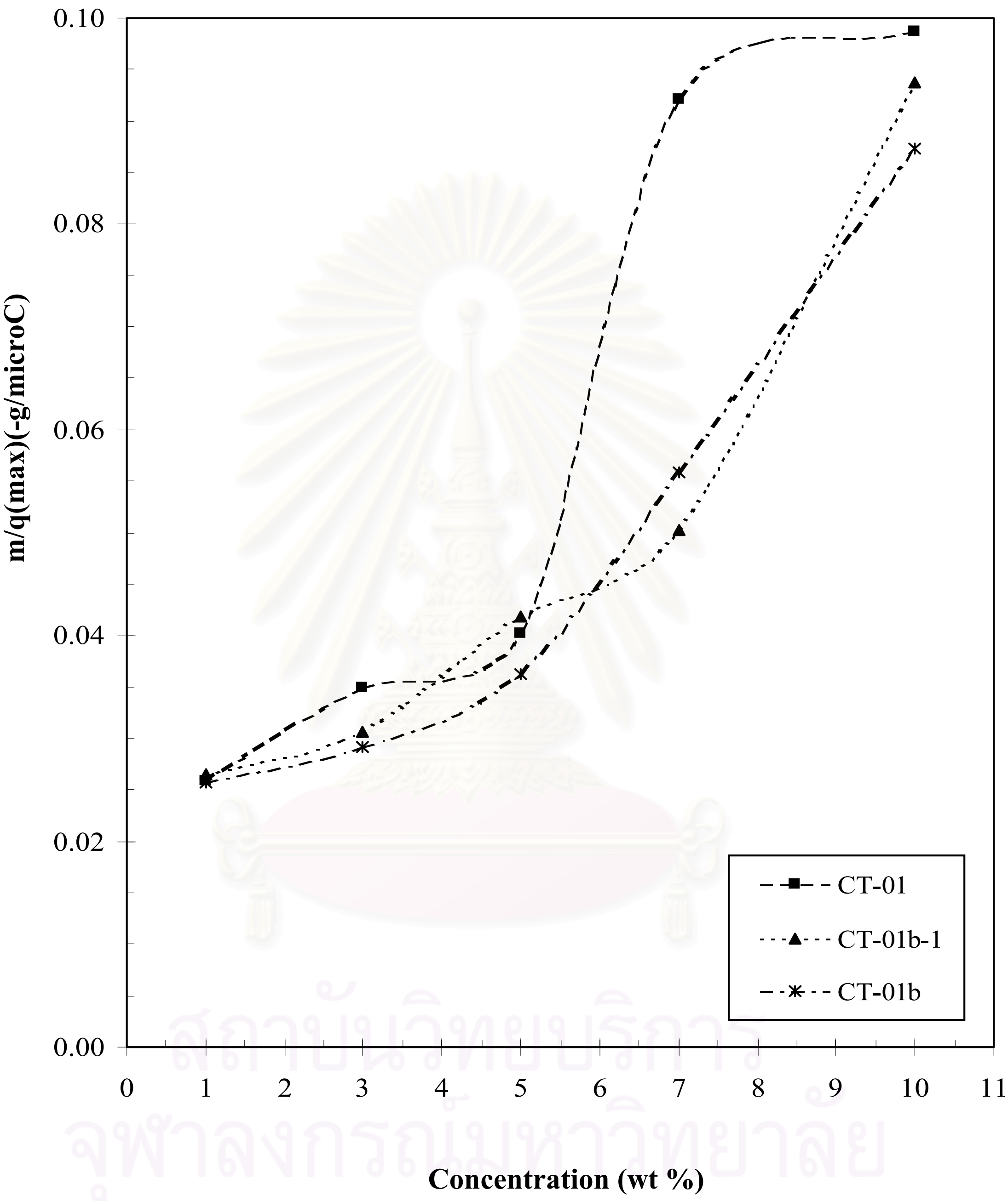


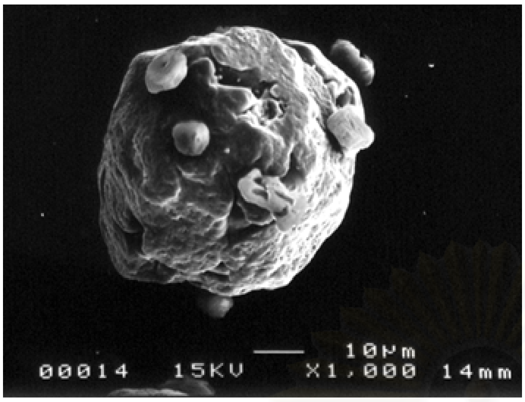
Figure 4-23 Dependence of m/q(max) values on the toner concentration (wt %) for the CT-01, CT-01b-1, and CT-01b toners at the rotating speed of 800 rpm

the carrier particles.[17] Therefore, the q/m values are decreased with increasing toner concentration. The experimental results are in agreement with the proposed triboelectric charge model as indicated in type II case where Nc is smaller than Nt.[10] (Nc, and Nt are the maximum number of the charging sites of carrier and toner, respectively.)

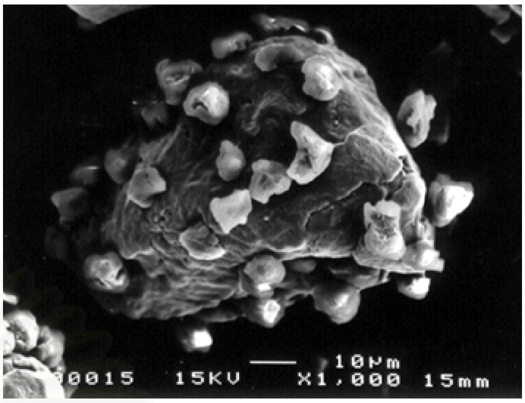
4.5 Morphology appearance of developer surface

The scanning electron micrographs of the developers of the CT-01b toner and the TSV-200 carrier as a function of toner concentration for 1, 3, 5, 7 and 10 wt %, at the rotation speed of 800 rpm for 240 second rotating time are shown in Figure 4-24. The SEM micrographs show that the coverage of the toner on the carrier increases with increasing toner concentration.

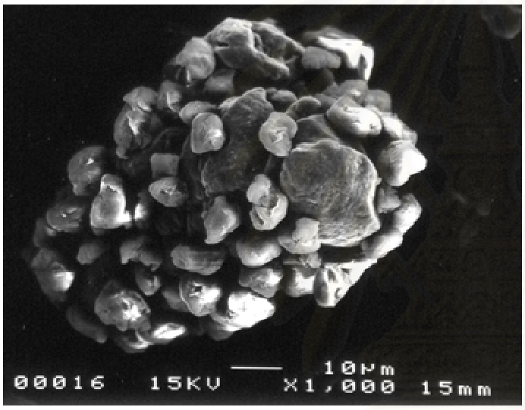
The calculation of the toner coverage on the carrier surface is shown below. Assuming that an irregularly-shaped toner particle can be approximated as a sphere of radius r_t and having a mass density ρ_t. The carrier particle is also of a spherical shape which, radius and mass density are R_c and ρ_c, respectively. One toner particle attached on the carrier surface is shown in Figure 4-25.



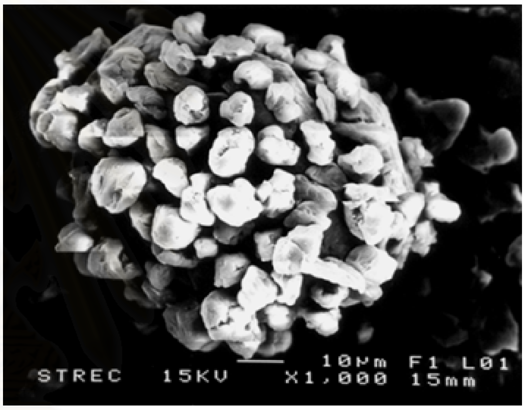
(a)



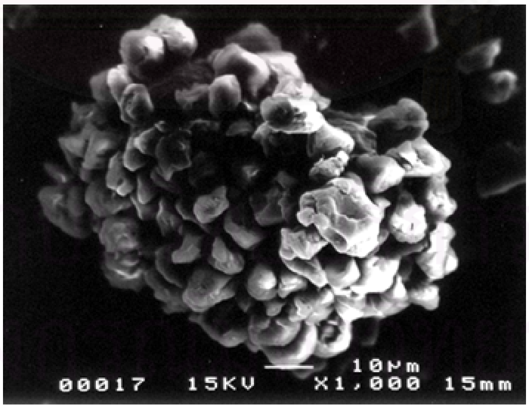
(b)



(c)



(d)



(e)

Figure 4-24 Scanning electron micrographs of the developers, CT-01b toner and TSV-200 carrier, with various toner concentration: (a) 1 wt %, (b) 3 wt %, (c) 5 wt %, (d) 7 wt % and (e) 10 wt %

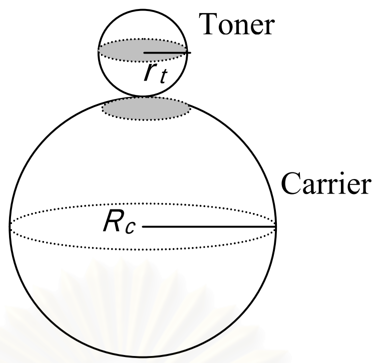


Figure 4-25 Schematic diagram of a toner particle on a carrier surface

$$C_t = \frac{m_t}{m_c + m_t} \times 100 \qquad (4\text{-}4)$$

where m_t and m_c represent the mass of the toner and the carrier particle, respectively. C_t is the toner concentration (wt %). The weights of the toner and the carrier particle are $\frac{4}{3}\pi\, r_t^3\, \rho_t$ and $\frac{4}{3}\pi\, r_c^3\, \rho_c$, respectively. C_t was calculated by Equation 4-5.

$$C_t = \frac{\left(\frac{4}{3}\pi\, r_t^3\, \rho_t\right)k_t}{\left(\frac{4}{3}\pi\, R_c^3\, \rho_c\right)k_c + \left(\frac{4}{3}\pi\, r_t^3\, \rho_t\right)k_t} \times 100 \qquad (4\text{-}5)$$

where k_t and k_c are a total number of toner and carrier particles in the two-component developer, respectively.

$$\frac{C_t}{100} = \frac{r_t^3 \rho_t}{R_c^3 \rho_c \frac{k_c}{k_t} + r_t^3 \rho_t} \tag{4-6}$$

$$\frac{k_t}{k_c} = \frac{R_c^3 \rho_c}{r_t^3 \rho_t \left(\frac{100}{C_t} - 1 \right)} \tag{4-7}$$

When S_c is the surface area of one carrier particle and $\sum S_t$ is the total coverage area of the toner particles on one carrier surface, the maximum number of the toner particles on one carrier surface, $n_{\max}$ is given by Equation 4-8, and the percentage coverage is governed by Equation 4-9.

$$n_{\max} = \frac{S_c}{\sum S_t} \tag{4-8}$$

$$\text{Coverage (\%)} = \frac{\frac{k_t}{k_c}}{n_{\max}} \times 100 \tag{4-9}$$

When one carrier is focused, the schematic diagram of the position for the toner particles on the carrier surface is presented in two ways as shown in Figures 4–26 and 4-27.

Let's first assume that the position of the toner particles that covered on the carrier surface is shown in Figure 4-26. The coverage area of toner particles is an inclusion of the toner effective cross-sectional area.[21] Accordingly, the maximum number of the toner particles on one carrier surface is calculated by Equation 4-10, and the coverage percentage is given by Equation 4-11.

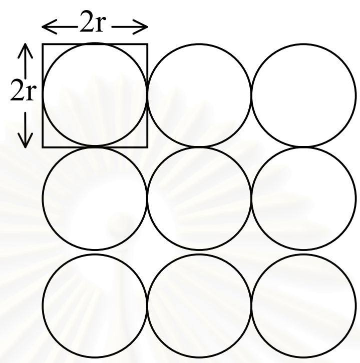


Figure 4-26 The effective cross-sectional model of the toner particles on one carrier surface (case I).

$$n_{\max} = \frac{4\pi R_c^2}{4 r_t^2} \quad (4\text{-}10)$$

$$\text{Coverage (\%)} = \frac{\frac{k_t}{k_c}}{n_{\max}} \times 100 \quad (4\text{-}9)$$

$$= \left(\frac{R_c \rho_c}{\pi r_t \rho_t}\right)\left(\frac{100 C_t}{100 - C_t}\right) \quad (4\text{-}11)$$

In addition, the adhered toner particles on one carrier surface can be assumed as shown in Figure 4-26. The coverage area of the toner particles on one carrier surface approximately includes the cross-sectional area of the toner particles.

Therefore, Equation 4-12 gives the maximum number of the toner particles on one carrier surface. The percentage coverage is then given by Equation 4-13.

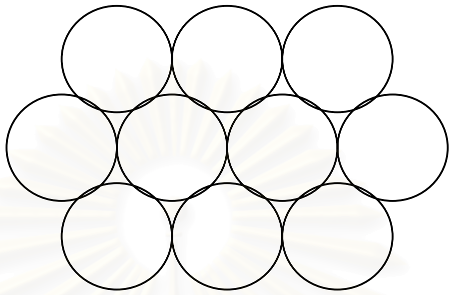


Figure 4-27 The effective cross-sectional model of the toner particles on one carrier surface (case II).

$$n_{\max} = \frac{4\pi\ R_c^2}{\pi\ r_t^2} \tag{4-12}$$

$$\text{Coverage (\%)} = \frac{\frac{k_t}{k_c}}{n_{\max}} \times 100 \tag{4-9}$$

$$= \left(\frac{100C_t}{4(100 - C_t)}\right)\left(\frac{R_c\ \rho_c}{r_t\ \rho_t}\right) \tag{4-13}$$

In summary, when the toner concentration on the carrier surface increases, the percentage coverage also increases. Equation 4-11 and 4-13 give an approximation of toner coverage on a carrier surface. The coverage efficiency depends mainly the toner distribution on the carrier surface.

Lets assume the density of the toner (ρ_t) = 1.1 g cm^{-3}, density of the carrier (ρ_c) = 7.87 g cm^{-3}, radius of the toner(r_t) = 4 µm and radius of the carrier (R_c) = 25 µm. The relationship of the toner concentration (wt %), the coverage (%) and the number of the toner particles on one carrier particle is shown in Table 4-1.

Table 4-1: The relationship of the toner concentration (wt %), the coverage (%) and number of the toner particles per carrier particle.

Toner concentration (wt %)	Coverage (%)	Number of toner particles per carrier particle
1	6-15	18
3	35-44	54
5	59-75	92
7	84-107	131
10	124-158	194

4. 6 Toner charge dependence on the charging mechanism.

The CT-01b toner and TSV-200 carrier were mixed together by several mixing methods using hand shaking (H), vertical shaking (R1), and horizontal rotating (R2). The charges of the toner were generated by the contact and the friction with the carrier.

As can be seen from Figure 4-28, a comparison of the toner charges resulted from the 3 wt % toner concentration by several mechanisms as mentioned above was performed. The toner q/m values produced by the hand shaking method are the highest and reach a saturation within a short time. The toner charges generated by the vertical shaking and horizontal rotating are in the same magnitude, the q/m values of the toner generated by the horizontal shaking are lower than the other one (R1) at the beginning charging and become quite higher after 60 seconds of shaking.

Figures 4-29 and 4-30 show the relationship between the q/m values and the charging times of the CT-01b toner at 5 and 7 wt % toner concentration, respectively. The q/m values of each mechanism show a similar tendency with 3 wt % concentration in Figure 4-28, but with a lower magnitude.

The charging property, q/m, of the toner depends on the charging mechanism, which is a result of many factors such as mixing intensity, consistency, and type and size of a charging cell. As such, the q/m values at the equilibrium state of the developer of the current work are similar to some part of the work of Poomtien et al.[19] An explanation to this occurrence is that the different mixing intensities and consistency created toner/carrier contact area differences.[24] Besides this, each

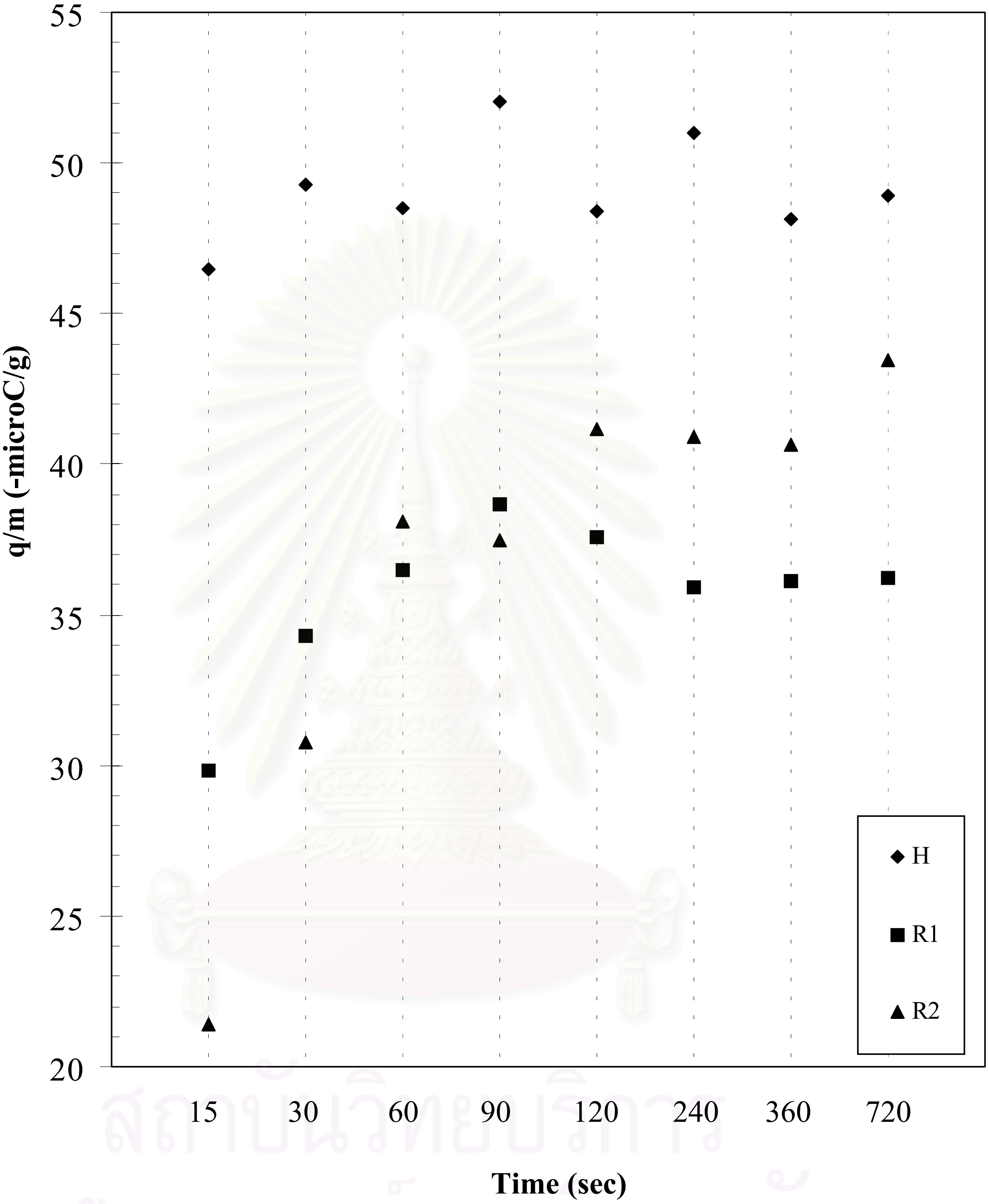


Figure 4-28 Dependence of q/m values on charging mechanisms of the CT-01b toner at 3 wt % toner concentration.; the hand shaking(H), the vertical rotating (R1) and the horizontal rotating (R2)

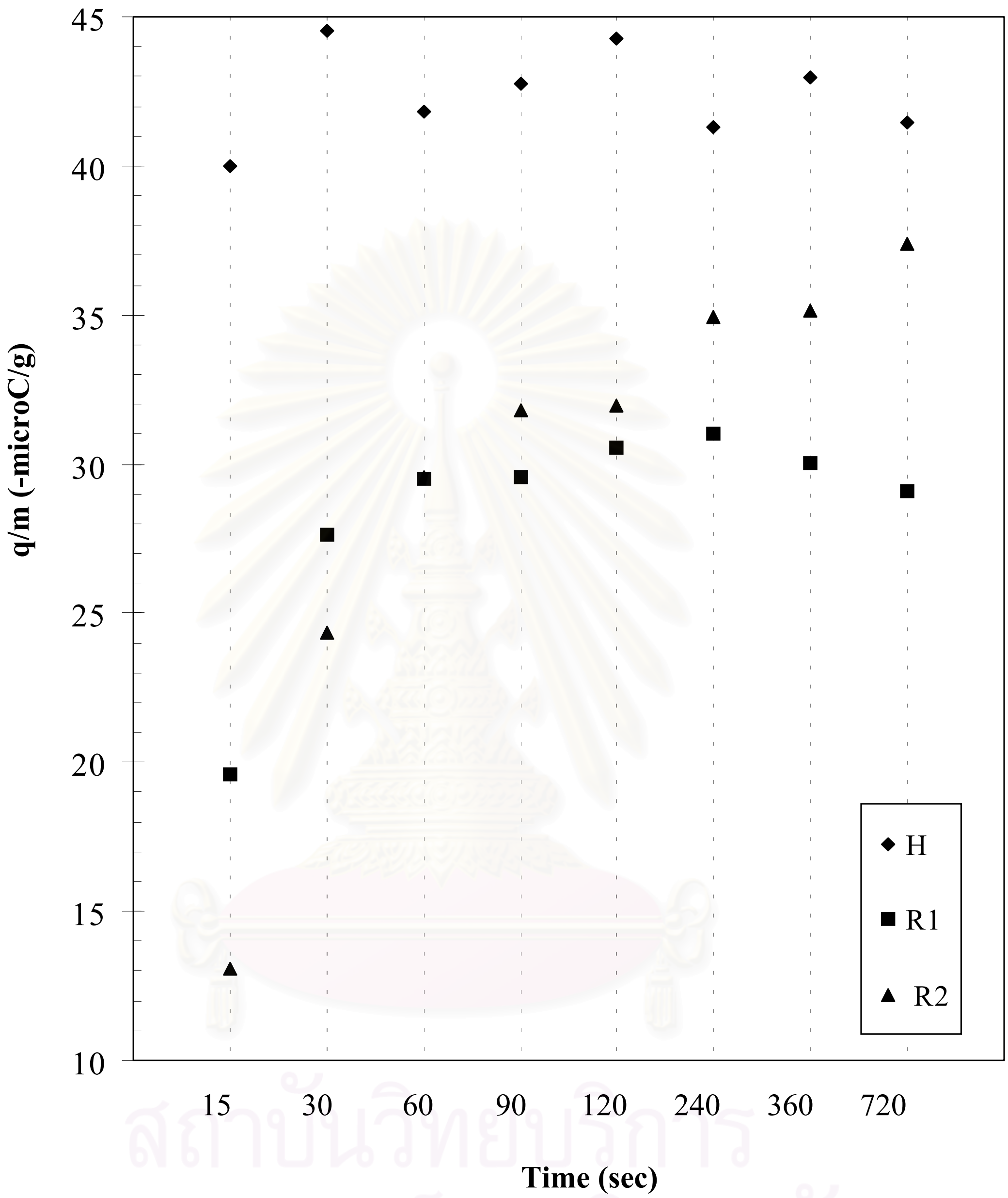


Figure 4-29 Dependence of q/m values on charging mechanisms of the CT-01b toner at 5 wt % toner concentration.; the hand shaking(H), the vertical rotating (R1) and the horizontal rotating (R2)

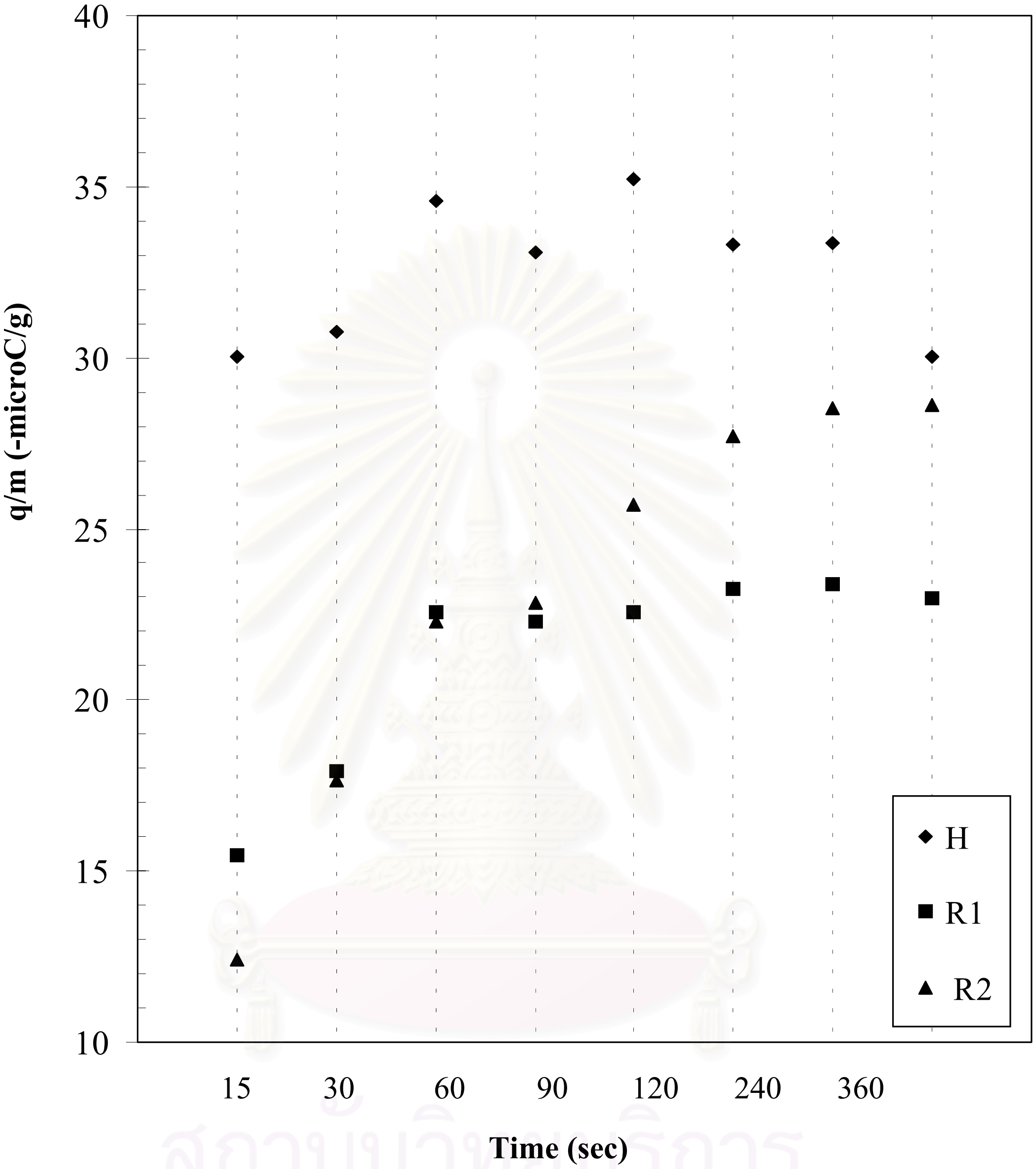


Figure 4-30 Dependence of q/m values on charging mechanisms of the CT-01b toner at 7 wt % toner concentration.; the hand shaking(H), the vertical rotating (R1) and the horizontal rotating (R2)

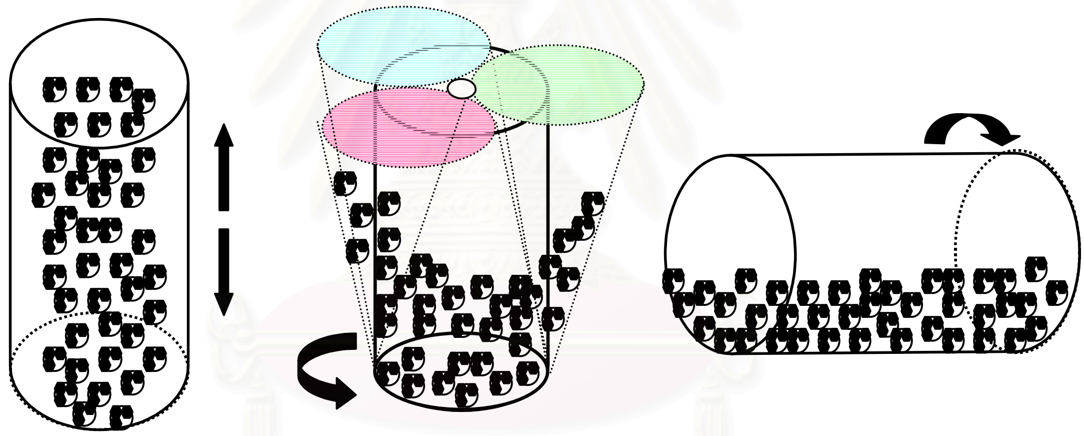
mechanism gives a different frequencies or opportunities for contact between toner/carrier particles leading to the different toner charges.

The toners charged by the hand shaking method has given a high q/m values the charging sites between toner and carrier are higher than another methods. Both the toner and carrier particles were moved up and down along the length of glass cell in order to increase contact areas between them.

With regard to the toner charging by the vertical shaker and horizontal rotator, the q/m values are lower than that by hand shaking charging. These phenomena can be explained by intensity mixing force and cylindrical wall effect. For both vertical and horizontal chargings, the contact possibility of developer surface with the cylindrical wall in the direction of the glass cell movement is higher than the contact made by hand shaking. The shorter or lower contact decreases the toner charging density.

Comparing between the vertical and horizontal charging, initially, the q/m values of the horizontal rotating are lower than the vertical shaking, but become higher at the equilibrium state. Mixing action of the horizontal cylinder cell consists of two types, a shearing force and a diffusive action. Initially, the mixing action is the shearing force, whereas as the particles tumble down the surface toward the bottom of the cell cause the diffusive action to occur.[25] The shearing action affects the rubbing of the toner and the carrier particles between adjacent layer induced the lower charge exchanged. While diffusive action enhances the particle diffusion and scattering of the separate particles results in redistribution. The fractional opportunities between the toner and the carrier particles are highly productive.

The vertical glass cell is vertically rotated with eccentricity. This eccentricity induces the developer powder to scatter upward from the bottom of the glass cell. At an initial state, the scattering action induces the greater diffusion of the particles, the higher rubbing opportunities between the toner and the carrier particles occur. However, the diffusion of the particles is limited by the flinging and slipping toward the glass wall. Especially, at an equilibrium state more developer particles attach with the glass cell. This occurrence is reasonably ascribed to decreasing the charging sites between the toner and the carrier particles.[25]



a) Hand shaking b) Vertical rotating c) Horizontal rotating

Figure 4-31 Schematic models of developer mixing: (a) hand shaking, (b) vertical rotating, and (c) horizontal rotating.

4.7 Toner flow ability

4.7.1 Dependence of toner flow ability on silica concentration

Flow ability of the toners was measured by a powder tester from Hosokawa micron (PT-E model), which has a mesh with different sizes, 350, 250 and 150 μm in diameter. A 20 gram sample of the toner was passed through the meshes stacked from the larger mesh to the smaller size in 30 seconds, at 25 °C and 30 %RH. The results of this experiment are shown in Table 4-2 and Figure 4-32.

Table 4-2: Effect of silica concentration on flow ability of the toners.

Toner	% silica coverage	Weight of remaining toner on the mesh (g /20g)			Total remaining toner (g /20g)	Passed through toner (g /20g)
		350 μm	250 μm	150 μm		
CT-01b	100	0.07	0.07	0.10	0.24	19.76
CT-01b-1	50	0.08	0.12	0.13	0.33	19.67
CT-01b-2	25	0.12	0.15	0.16	0.43	19.57
CT-01b-3	12.5	0.12	0.16	0.20	0.48	19.52
CT-01	0	0.91	2.68	7.53	11.12	8.88

As can be seen from Table 4-2 and Figure 4-32 that the total weight of the remaining toner for the CT-01 toner is 11.12 grams which is higher than those for the CT-01b3, CT-01b-2, CT-01b1 and CT-01b toner, respectively. The total remaining toner weight of CT-01b of 0.24 grams indicates that it can pass freely through the

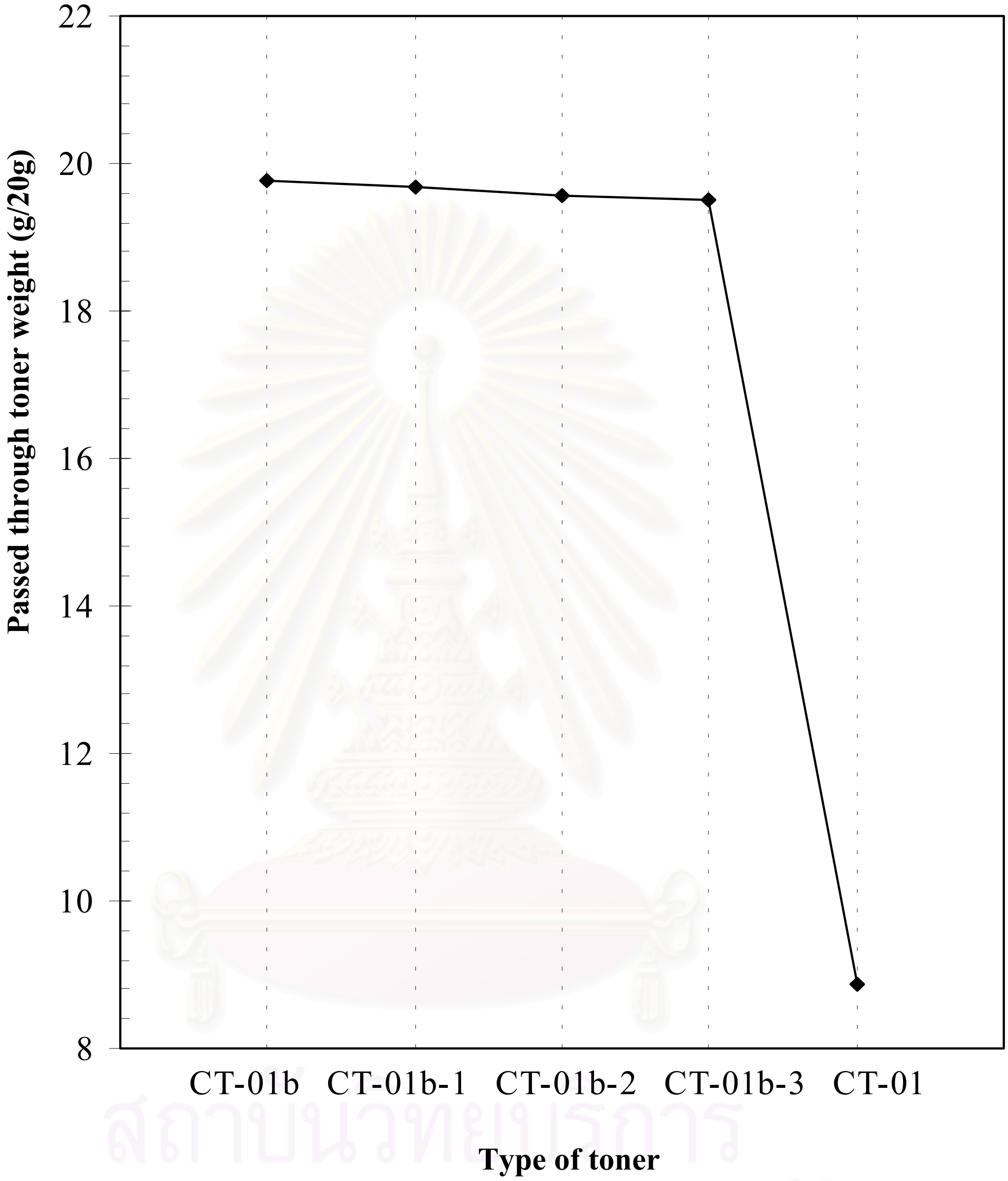


Figure 4-32 Effect of silica concentrations in toners on flow ability

meshes, while the CT-01 toner has a poor flow ability. All the data show that increasing silica particles attached on the surface of the toner particles improves the toner flow ability. This mechanism is presumably explained by the particulate silica serving as asperities that reduce adhesion or cohesion by roughening the surface, preventing intimate contact between the toner particles.[14,18]

4.7.2 Dependence of toner flow ability on silica attachment force

Flow ability of the toner particles containing 1 % silica developed by various attachment forces measured by the same technique, as mentioned in Section 4.3.1, is shown in Table 4-3.

Table 4-3: Effect of silica attachment force on toner flow ability

Toner	Force for silica attachment (times)	Weight of remaining toner on the mesh (g /20 g)			Total remaining toner (g/20g)	Passed through toner (g/20g)
		350 μm	250 μm	150 μm		
CT-01a	1/2	0.07	0.08	0.11	0.26	19.74
CT-01b	1	0.07	0.07	0.10	0.24	19.76
CT-01c	2	0.07	0.09	0.12	0.28	19.72
CT-01d	4	0.06	0.09	0.11	0.26	19.74

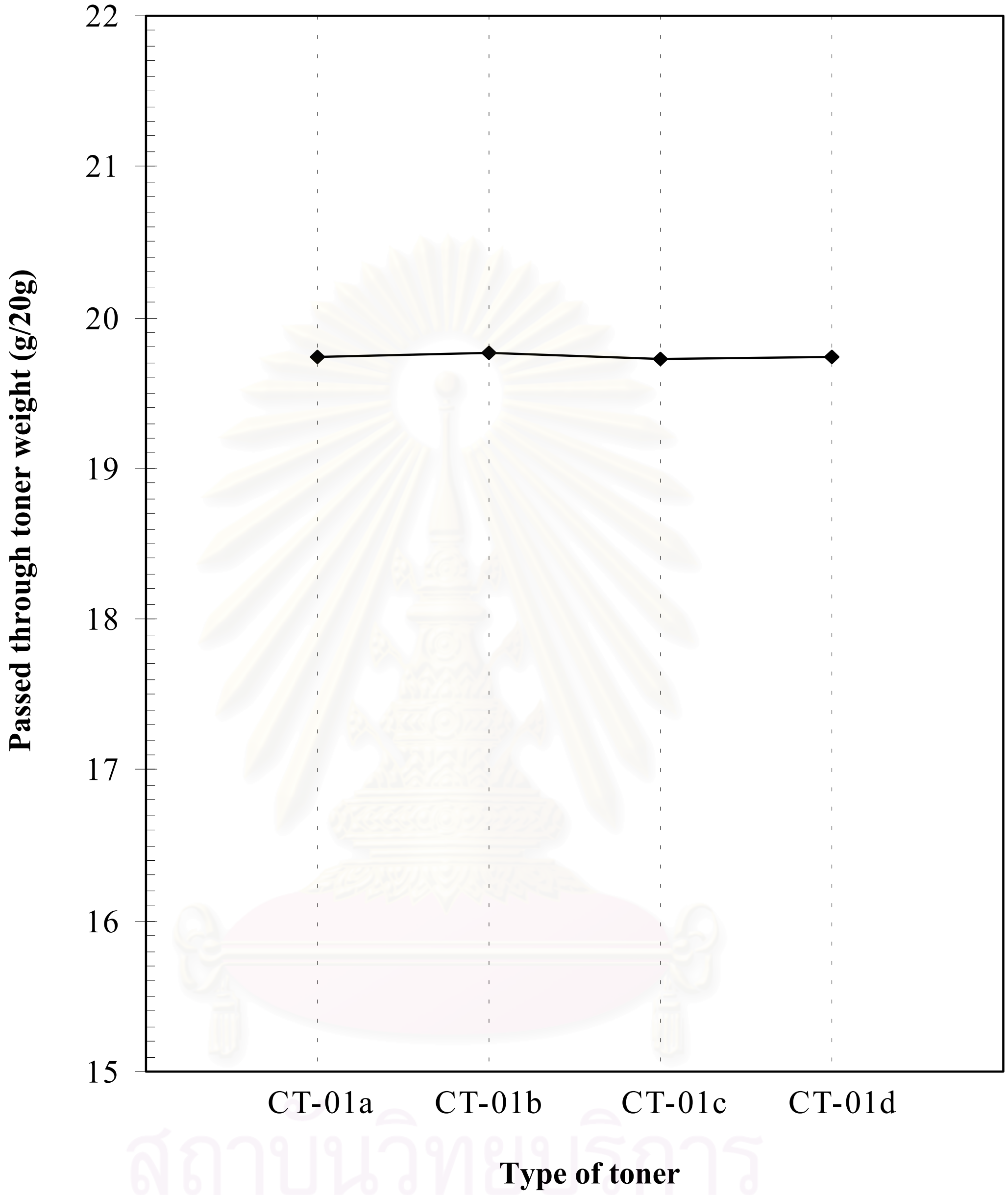


Figure 4-33 Effect of silica attachment forces in toners on flow ability

The results in the Table 4-3 and Figure 4-33 show that the CT-01b toner can freely flow and pass through the meshes leaving a minute remaining toner particles on the meshes.

This experiment clearly discloses that silica addition (1 wt %) is a very effective method to assist toner free flowing, regardless of any extent of silica attachment forces given to the toner.

4.8 q/m by E-SPART analyzer

The toners, CT-01b-1, CT-01b-2, CT-01b-3 and CT-01 were selected to measure their charge properties and particle size by the E-SPART analyzer. The data are shown in Table 4-4.

Table 4-4: Experimental results for toner samples obtained by E-SPART analyzer.

Toner name	Silica concentration (wt %)	d_{v50} (μm)	q/m (μC/g)	q_{av} (f C)
CT-01b-1	0.5	7.96	-22.89	-5.60
CT-01b-2	0.25	7.23	-29.08	-5.25
CT-01b-3	0.125	7.88	-22.65	-5.56
CT-01	0	9.18	-12.33	-5.29

The data show that the average size (d_{v50}) of all toners is nearly 8 μm in diameter. The amounts of average charges per particle (q_{av}) are not so different. As can be seen from the q/m values of each toner that the addition of fumed silica strongly affects the toner charge behavior in an increasing negative way.

Comparison of the q/m values between the toners covered by various silica concentrations, their charges show a similar tendency with the data of blow off technique as mentioned in Section 4.2. The q/m values increase with the increase in silica concentration, resulting in the data of the CT-01, CT-01b-3 and CT-01b-2 toner. Considering the CT-01b-1 toner containing 0.5 wt % silica concentration, its charge inclined from that tendency. The q/m value is –22.89 μC/g and lower than the CT-01b-2 toner, which was covered by 0.25 wt % silica concentration. This phenomenon may be affected by the ambient condition such as a relative humidity, the charge of the toner with silica correlates well with the water content of the silica alone.[15,26] Many previous papers reported that the increase in relative humidity affects the decrease in toner charge.[14,15,26] Unquestionably, as the relative humidity is similarly conditioned, the water content of toner with higher silica concentration should be higher. The more coverage area of silica on the toner surface induces the water more cover. Thus the decrease in triboelectric charge of the CT-01b-1 toner that highest silica concentration with relative humidity is reasonably ascribed to the increase in water content of the silica with relative humidity.

4.9 Print quality evaluation

All toners were evaluated for their print qualities using uncoated paper and printed by OKI 400 micro line CL printer. Ten print-outs were printed with each type of the toners with a test form as shown in Figure 4-34. The solid density, background

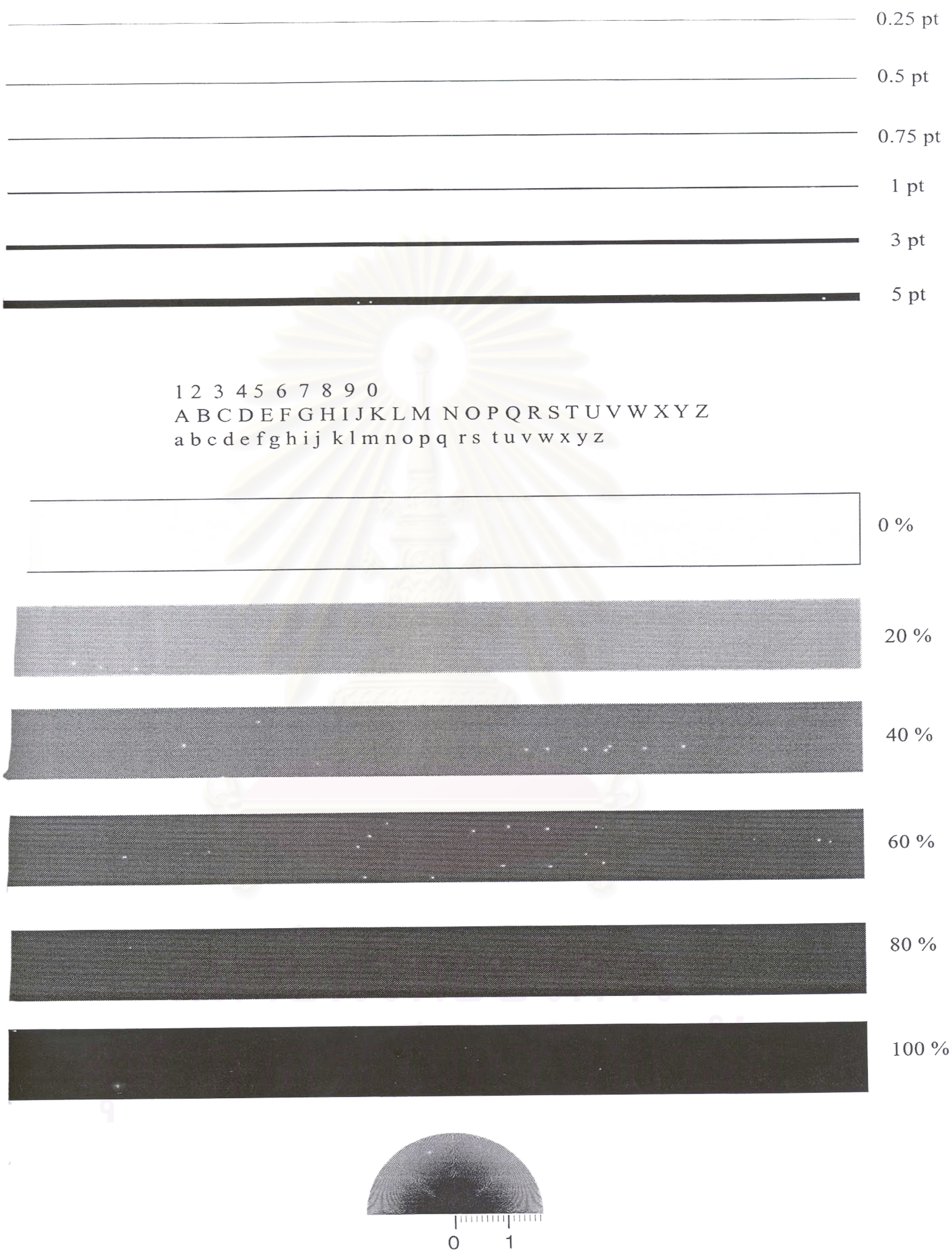


Figure 4-34 The test form

density and dot gain percentage of the print-outs were measured by a reflection densitometer.

The edge raggedness of characters, lines and dot structure were observed by the image analyzer.

4.9.1 Dependence of print quality on various toners by silica concentration

The toners containing various silica concentrations (wt %) were evaluated for their print qualities. Figure 4-35 shows that increasing silica concentration is significantly effective to increase the solid density. The higher charge toners are picked up less by the photoreceptor drum, so the higher transfer to the paper by electric field.[27] The background densities of print-outs by various toners with different silica concentrations are lower than that toner without silica as shown in Figure 4-36. The CT-01 toner without silica has a lower q/m value, poor flow ability and causes a wrong sign toner to occur. Besides these, its poor flow ability tends to prevent the particles from being uniformly transfered.[27] Therefore, this toner is possibly attached out of the image area, resulting in a higher background density.

Comparison between original dot area produced by digital the data and dot reproduction, dot gain percentage, is shown in Figure 4-37. The dot gain percentage at the highlight area is increased slightly before reaching the highest values at the midtone area, and decreasing at the shadow area. For 20 and 40 % halftone, some toners produced the dot loss. As can be seen that the dot gain percentage is increased when increasing silica concentrations. For such a result, it could be postulated that the adhesion between toner particles themselves and the photoreceptor drum were

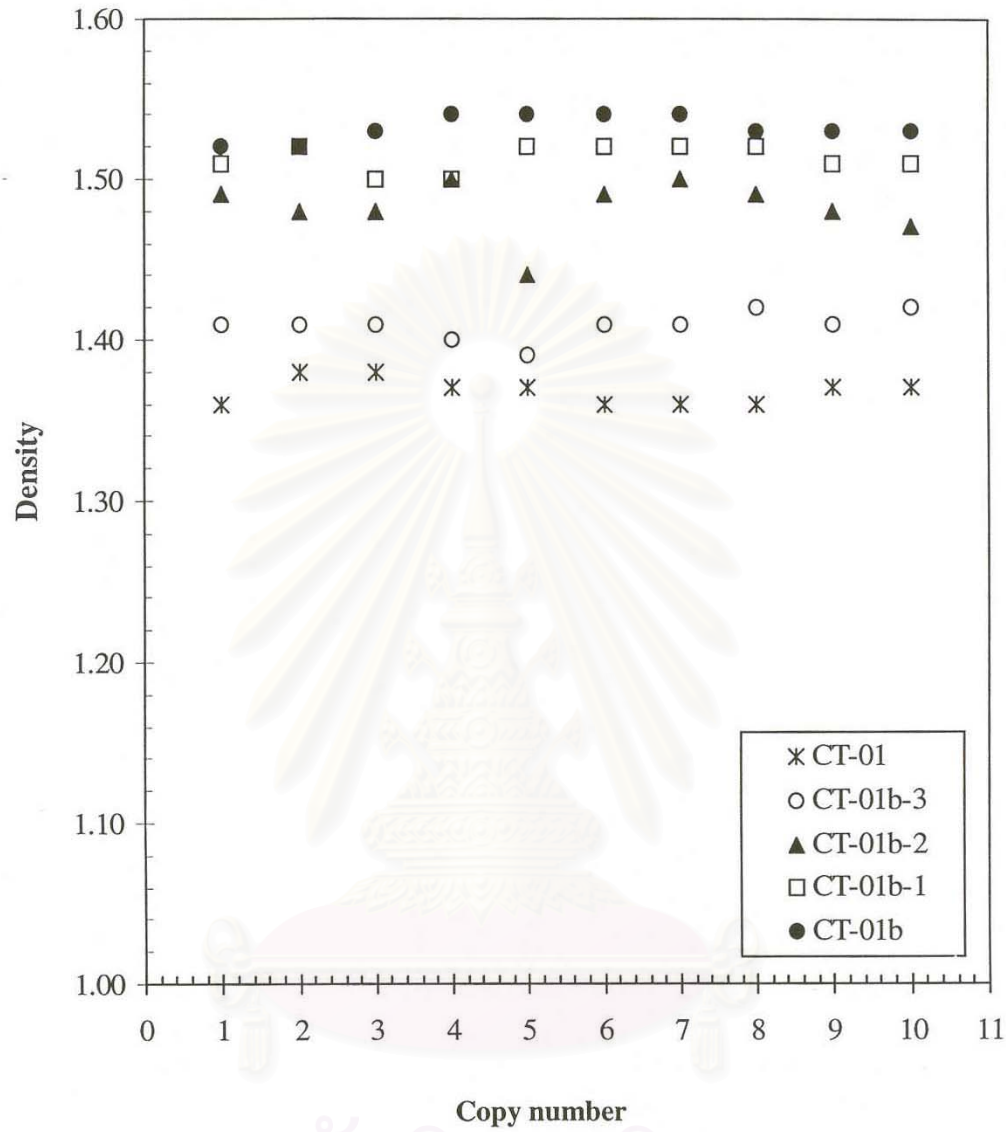


Figure 4-35 Dependence of maximum density on copy number for the toners having various silica concentrations (wt %)

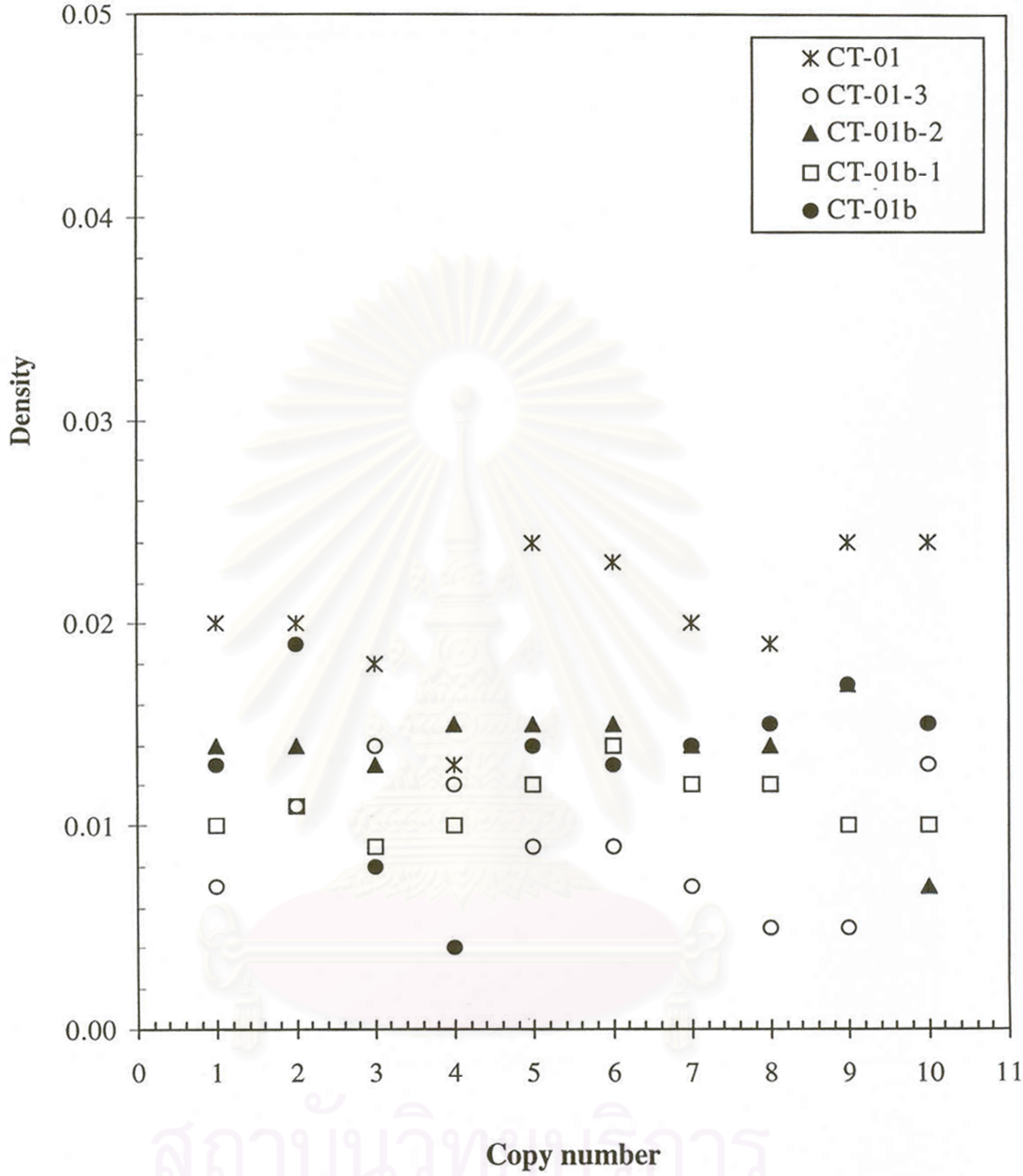


Figure 4-36 Dependence of background density on copy number for the toners containing various silica concentrations (wt %)

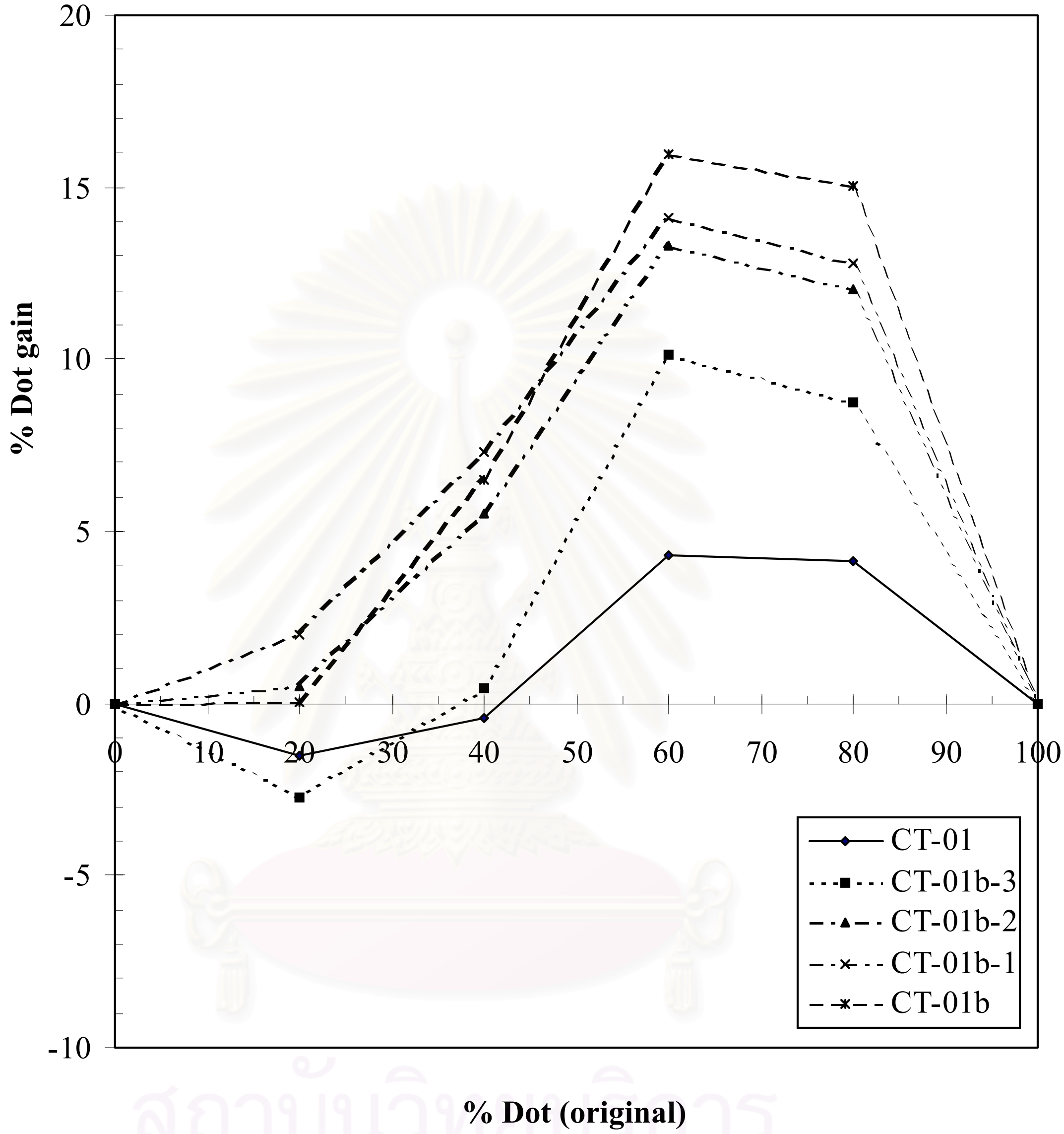


Figure 4-37 Dependence of % dot gain on various amounts of silica coverage on the toner surface

decreased by the silica coverage increases.[14, 19] The reduction cohesion between toner particles can cause dot explosion or expansion leading to dot gain occurrence. Figures 4-38 displays the dot structure of each toner at 50% screen ruling and 40% halftone, respectively. The toner without silica produced more dot lost.

The edge raggedness of the characters (a, E, f, g, 2 and 5) and the lines (8.8×10^{-5} m and 1.8×0^{-4} m point) of each toner evaluated by the image analyzer are shown in Figures 4-39 to 4-46, respectively. The characters and the lines printed with the toners containing fumed silica are generally more significantly completed than that toner without silica. The higher the silica coverage on the toner, the shaper the edges. This could possibly be explained by more uniform charging leading to the higher transfer toner efficiency. The toner without silica coverage has a poor flow ability, which causes the number of contacts between toner particles and the surface of the magnetic roller to decrease.[27] This phenomenon possibly affects the low charge, wide charge distribution and non-uniformity with wrong electrical sign. Therefore, this toner could not faithfully transfer from the photoreceptor drum to the paper.

4.9.2 Dependence of print quality on various toner silica attachment forces.

The solid densities of each toner are shown in Figure 4-47. The CT-01b toner gave the highest solid density, while the density of the CT-01c gave the lowest density.

Figure 4-48 shows the background densities on non-printing area of each toner. The background densities of the CT-01a toner are near the CT-01d (0.02-0.03) and are higher than those of the CT-01b and CT-01c toners (0.01-0.02), respectively. When the silica particles are attached on the toner surfaces either at a low or a high

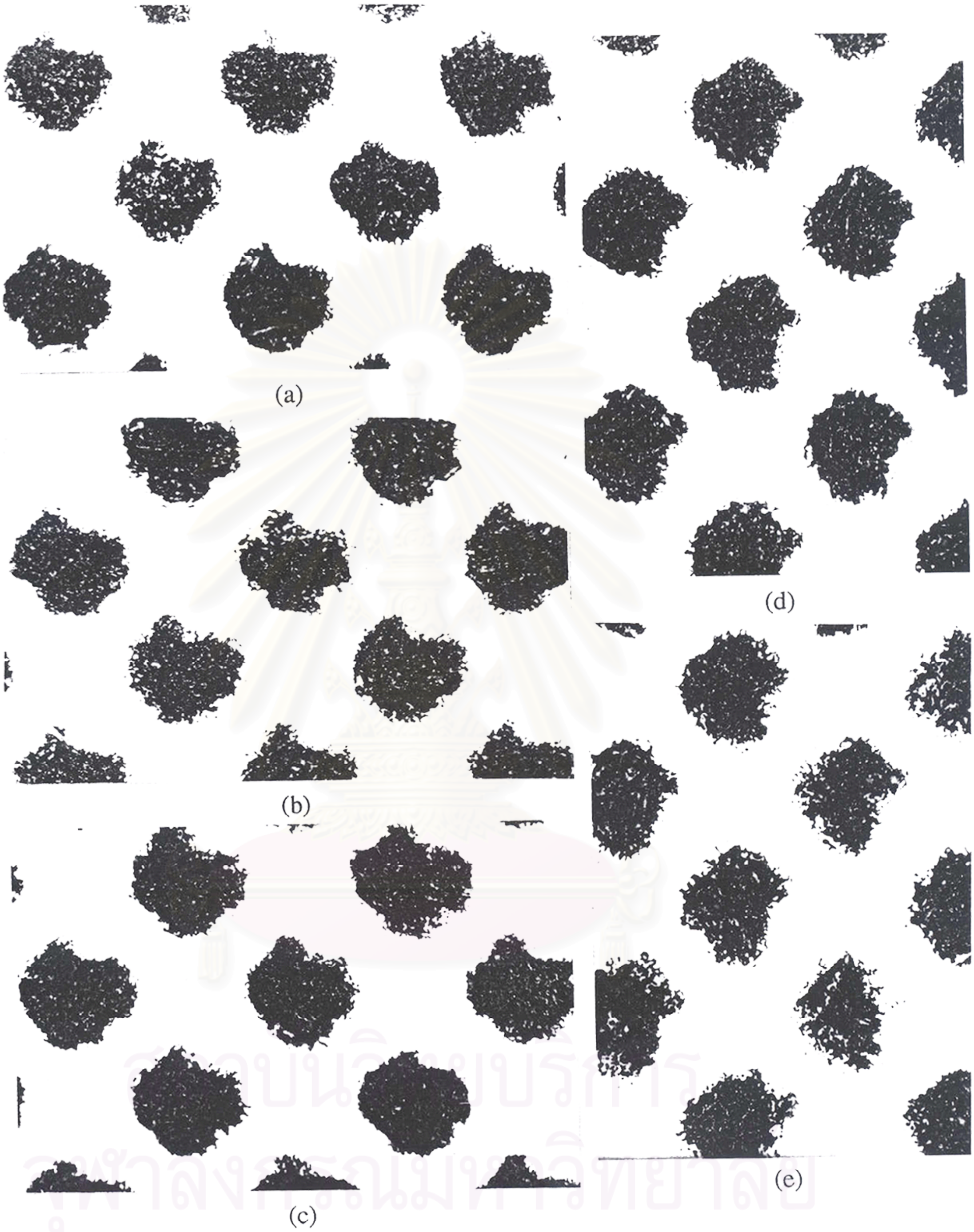


Figure 4-38 The photographs of the dot structures at 40% halftone, 50% screen rulling, produced by the toners containing various silica concentrations (wt %): (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt % and (e) CT-01, 0 wt %

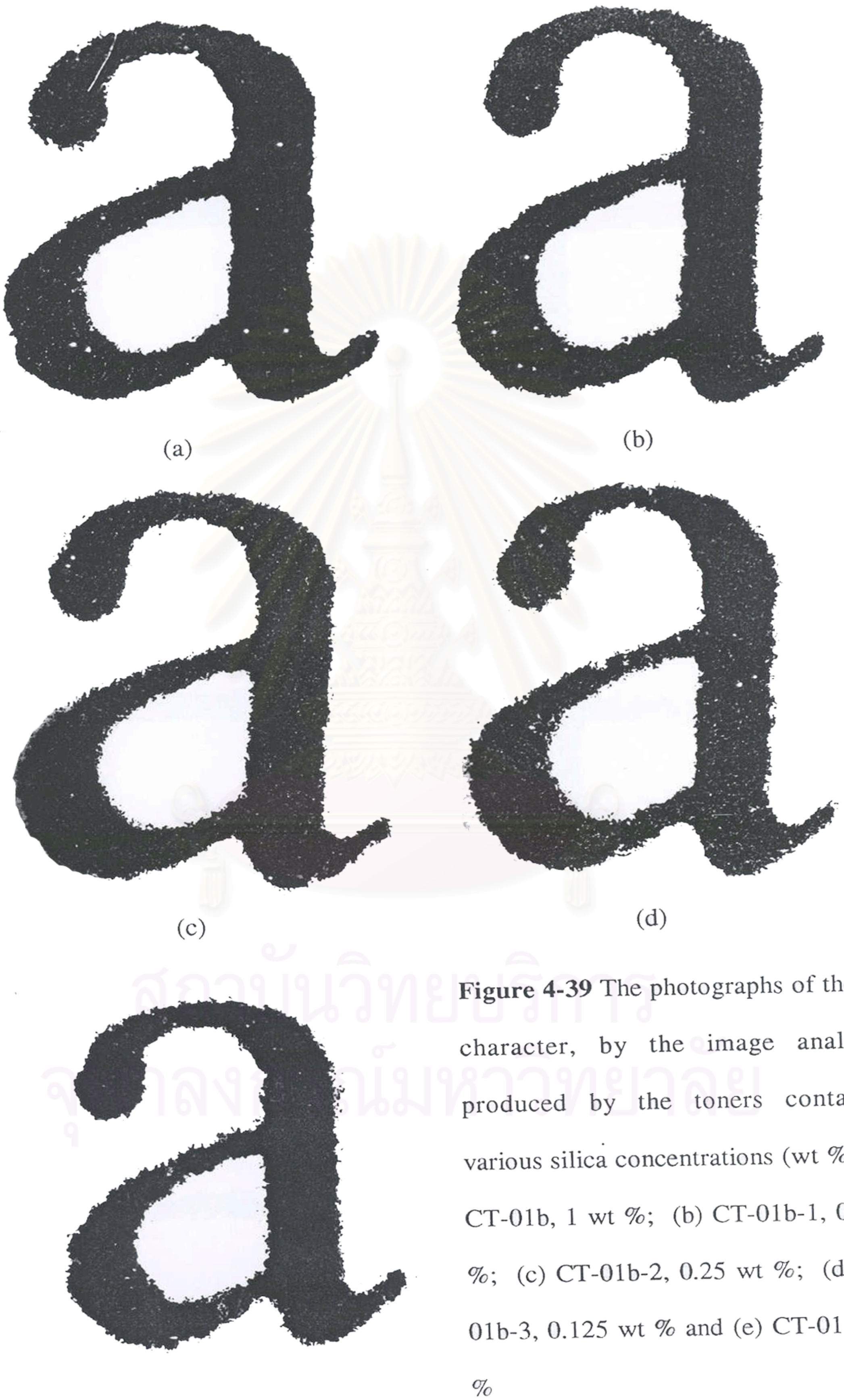


Figure 4-39 The photographs of the "a" character, by the image analyzer, produced by the toners containing various silica concentrations (wt %): (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt % and (e) CT-01, 0 wt %

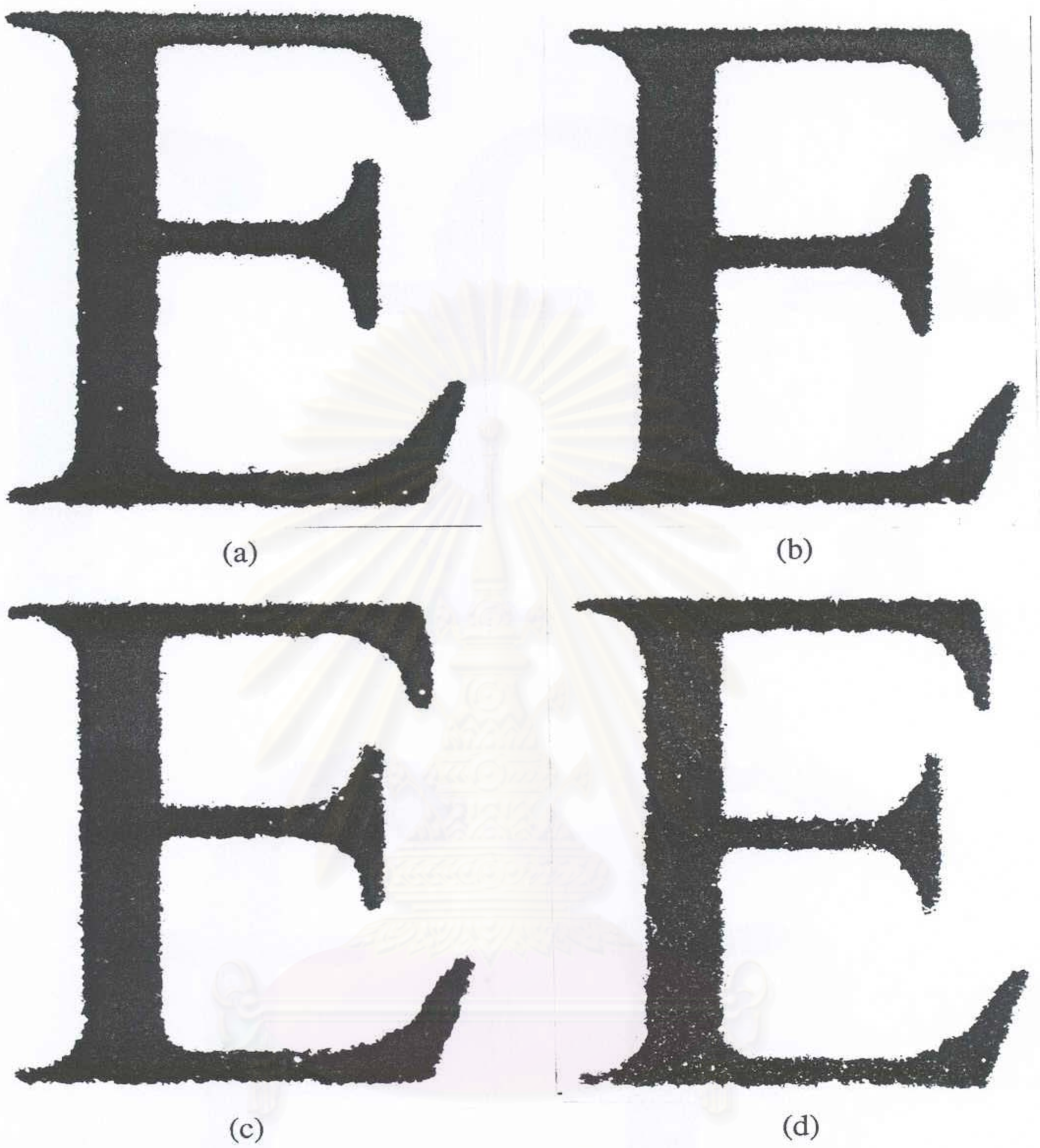


Figure 4-40 The photographs of the "E" character, by the image analyzer, produced by the toners containing various silica concentrations (wt %): (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt % and (e) CT-01, 0 wt %

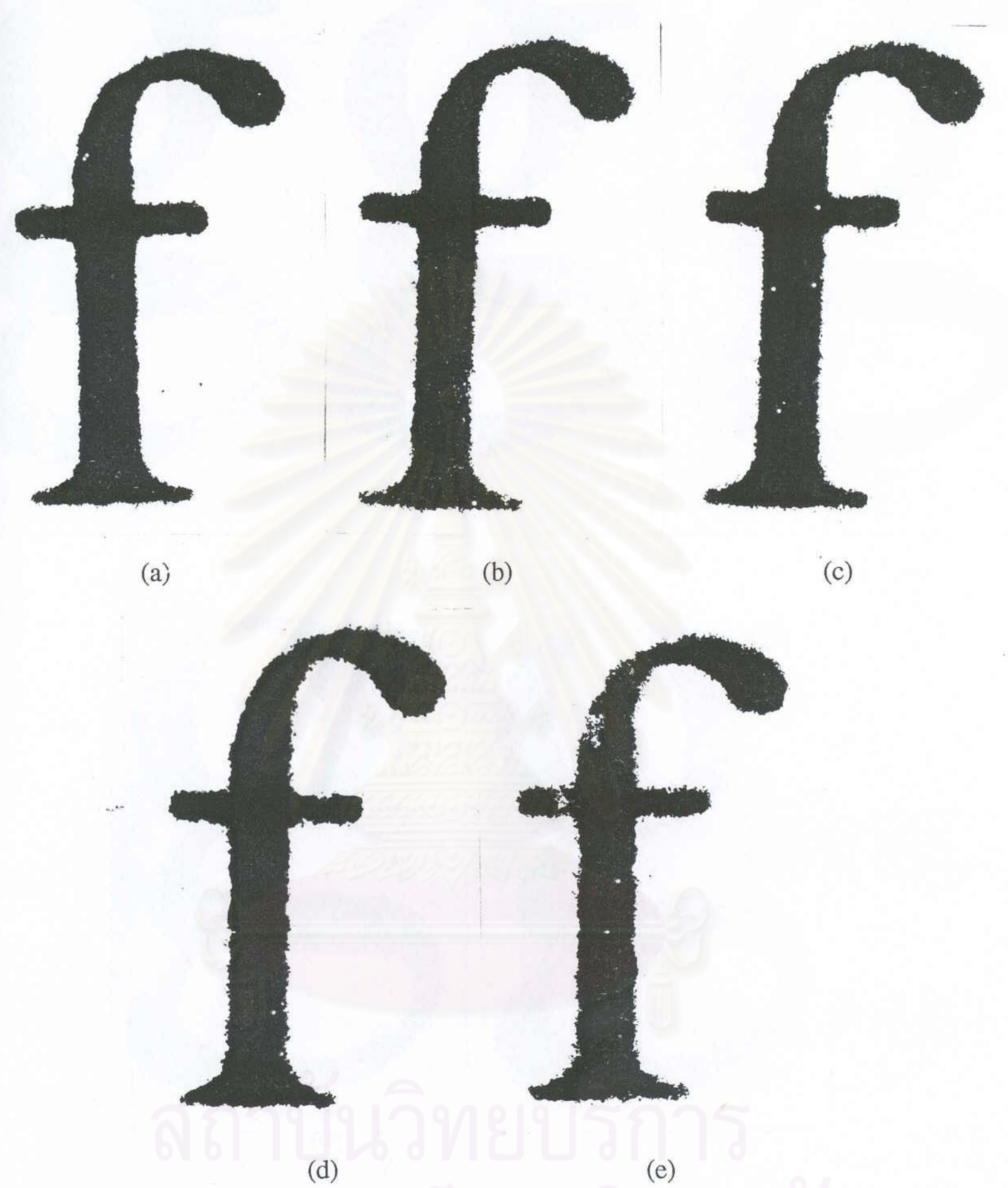


Figure 4-41 The photographs of the "f" character, by the image analyzer, produced by the toners containing various silica concentrations (wt %): (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt % and (e) CT-01, 0 wt %

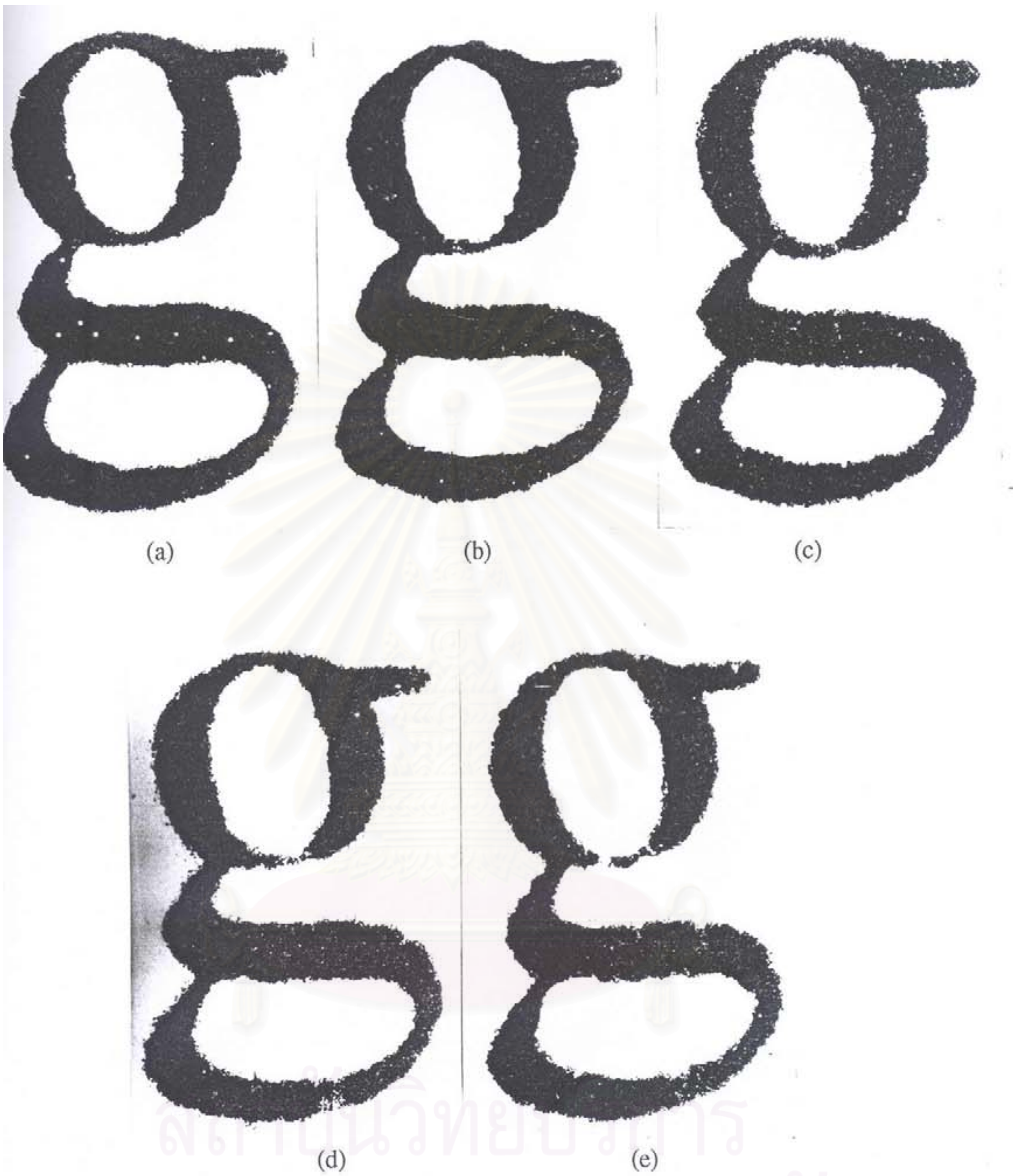


Figure 4-42 The photographs of the "g" character, by the image analyzer, produced by the toners containing various silica concentrations (wt %): (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt % and (e) CT-01, 0 wt %

Figure 4-43 The photographs of the "2" number, by the image analyzer, produced by the toners containing various silica concentrations (wt %): (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt % and (e) CT-01, 0 wt %

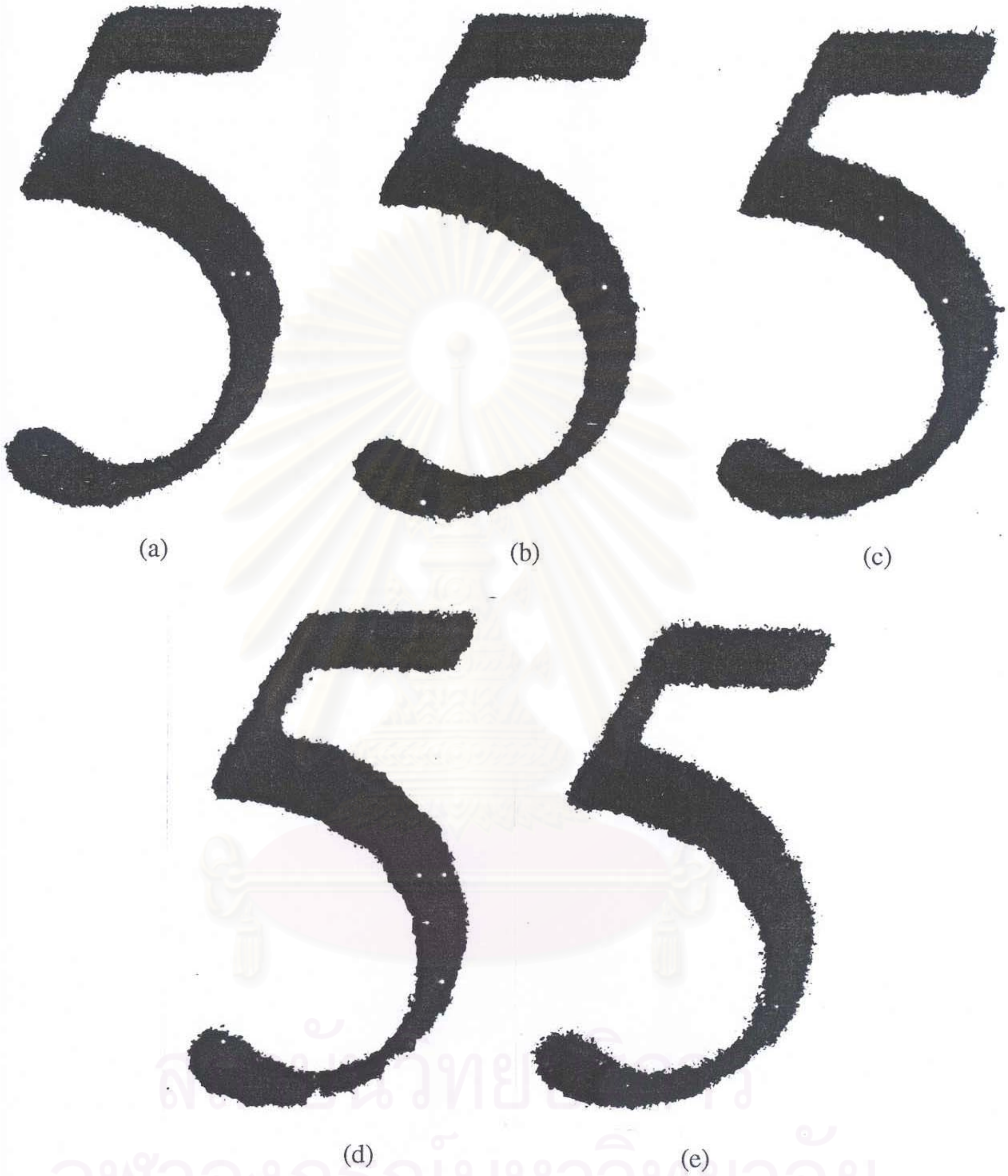


Figure 4-44 The photographs of the "5" number, by the image analyzer, produced by the toners containing various silica concentrations (wt %): (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt %, and (e) CT-01, 0 wt %

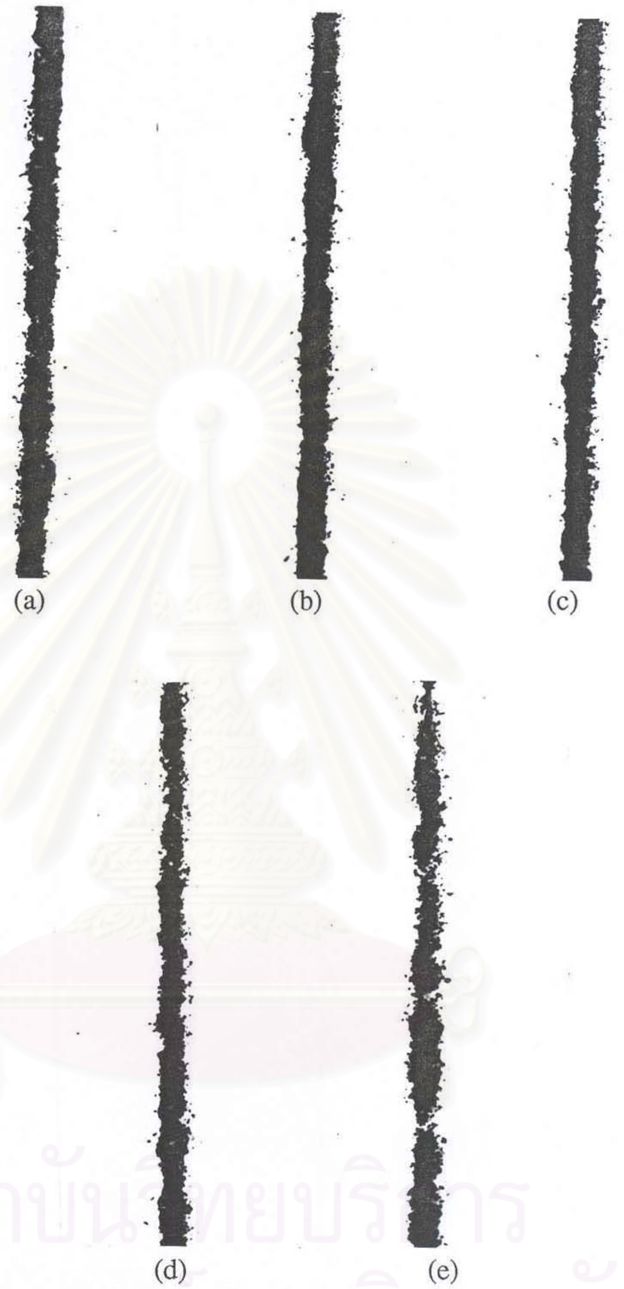


Figure 4-45 The photographs of the lines (8.8×10^{-5} m), by the image analyzer, produced by the toners containing various silica concentrations (wt %): (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt %, and (e) CT-01, 0 wt %

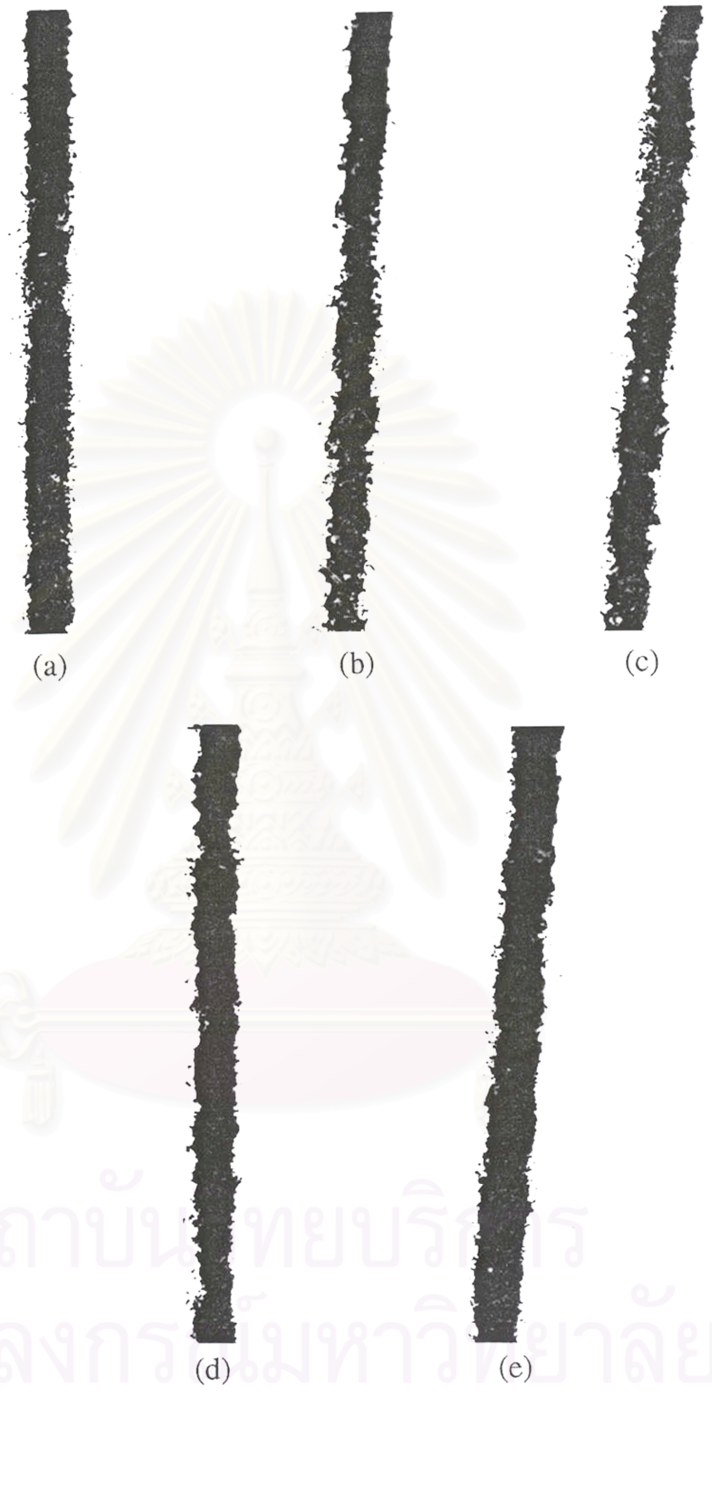


Figure 4-46 The photographs of the lines (1.8×10^{-4} m), by the image analyzer, produced by the toners containing various silica concentrations (wt %): (a) CT-01b, 1 wt %; (b) CT-01b-1, 0.5 wt %; (c) CT-01b-2, 0.25 wt %; (d) CT-01b-3, 0.125 wt %, and (e) CT-01, 0 wt %

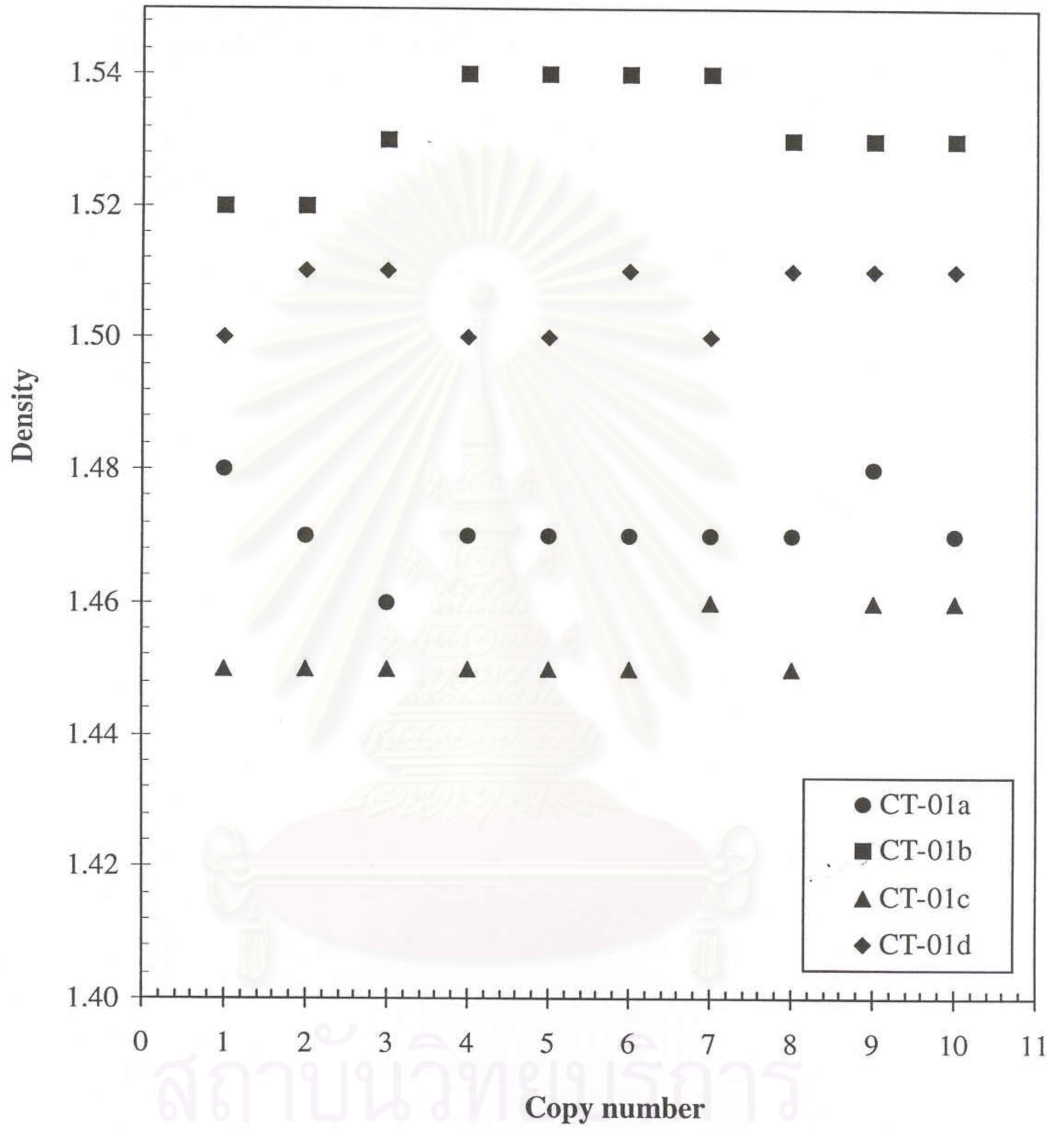


Figure 4-47 Dependence of maximum density on copy number for toners, CT-01a, CT-01b, CT-01c, and CT-01d

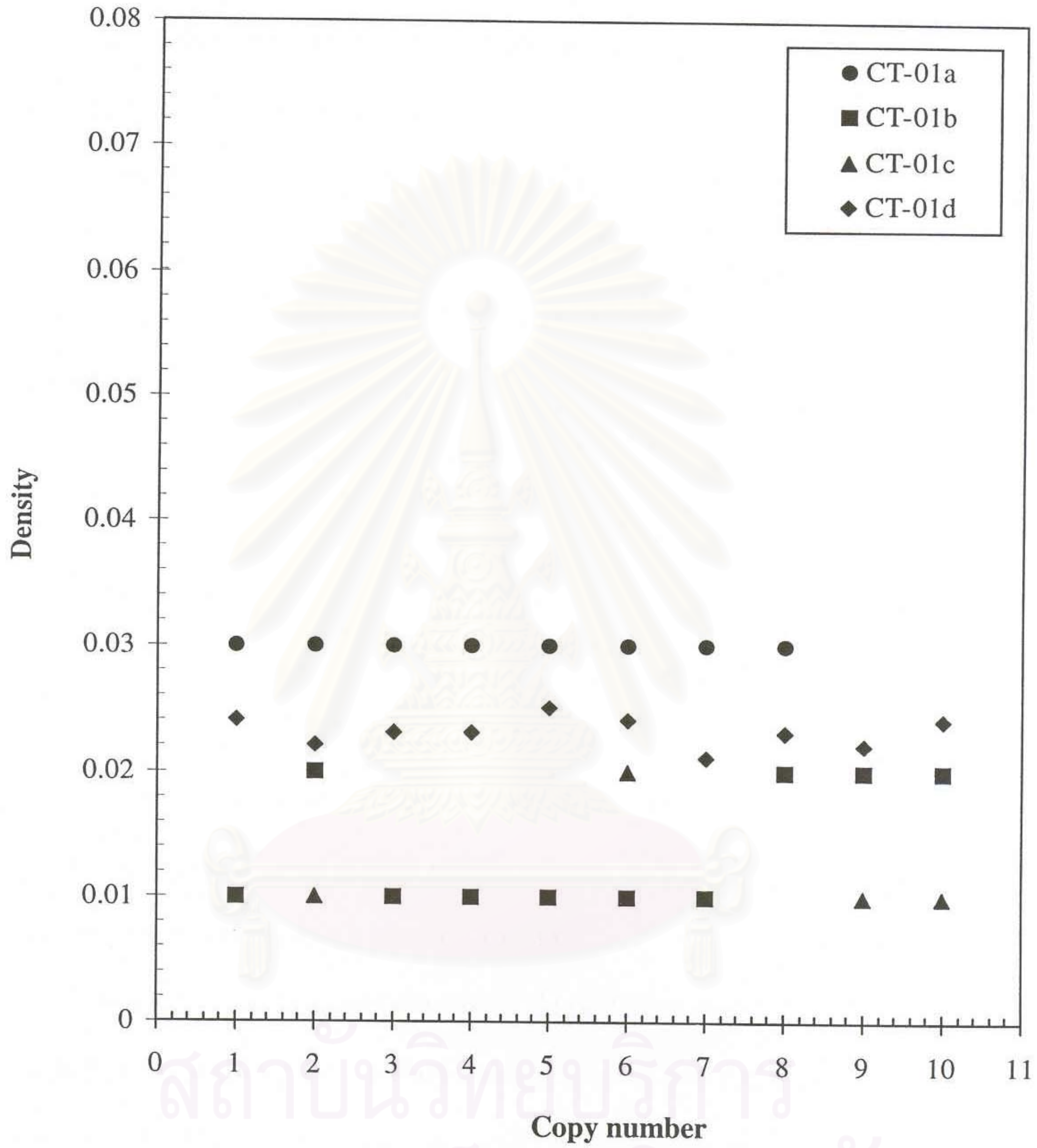


Figure 4-48 Dependence of background density on copy number for toners, CT-01a, CT-01b, CT-01c, and CT-01d

force level, high densities on non-image area are found. As mentioned in Section 4.3, the CT-01a toner has higher q/m values, however, the charges could still located outside the latent image areas. This phenomenon could be explained by the repulsive electrostatic force[13] due to the higher surface area of silica on the toner surface.[19] The CT-01d toner with deeply burial silica cause a lower q/m values and could possibly produced a non-uniformity charge. Therefore, this toner could be attached on the non-image area.

Figure 4-49 shows the dot gain percentages. When comparing the original dot area and the dot reproduction of print-outs, the dot gain percentage at highlight areas is slightly and gradually increased to reach the highest value at midtone areas before decreasing at shadow areas. As it can be seen that the dot gain percentage of the toners, CT-01a, CT-01c and CT-01d, is close to each other and higher than that of the CT-01b toner especially at highlight and midtone areas. Figures 4-50 shows the round dot structure of each toner at 50% screen ruling at 40 % halftone. As can be seen that most of all round dots are not clearly different.

The edge raggedness of the characters (a, E, f, g, 2 and 5), and the lines (0.25 and 0.5 point) of each toner are shown in Figures 4-51 to 4-58, respectively. As it can seen that the qualities of all the characters and the lines are similar. These results could be concluded that the deposited silica on the toner surface by various attached forces does not significantly affect the edge raggedness of the characters.

To conclude, these results indicate that various silica concentrations on the toner surface are more effective than various silica attachment forces in determining print quality.

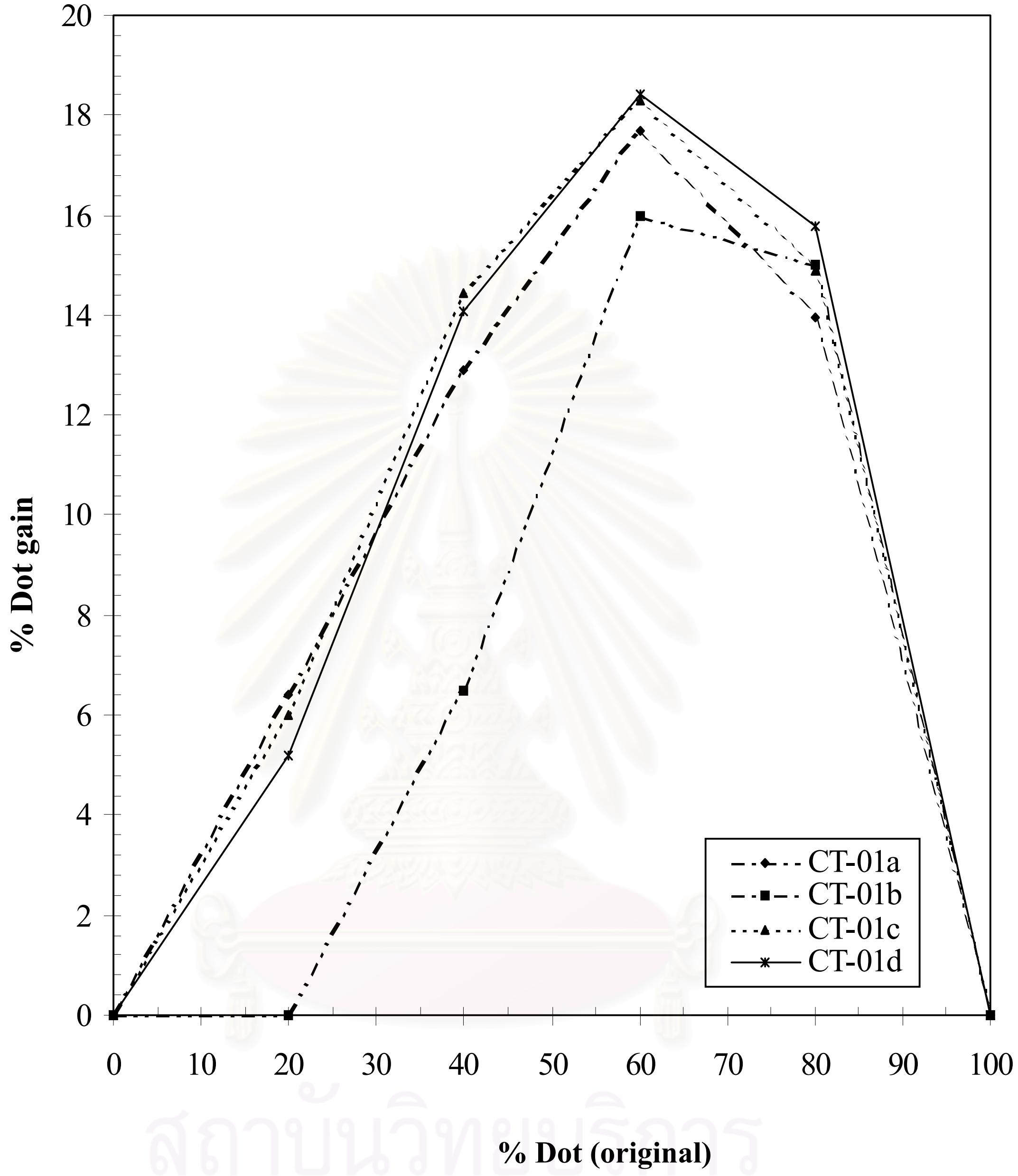


Figure 4-49 Dependence of % dot gain is % dot original on various silica attachments on the toners surface

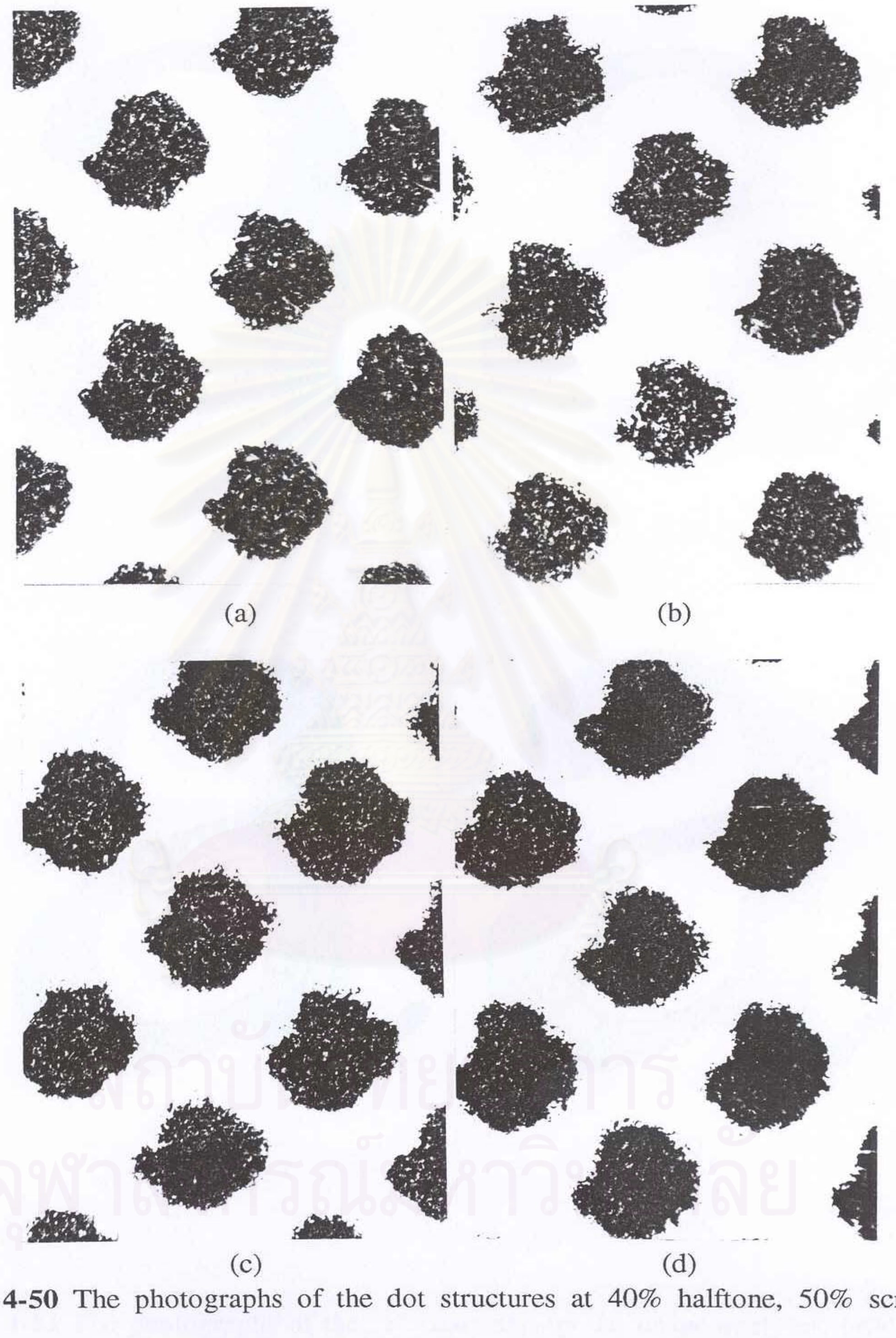


Figure 4-50 The photographs of the dot structures at 40% halftone, 50% screen rulling, produced by the toners containing various silica attachment forces (a) CT-01a, ½ time; (b) CT-01b, 1 time; (c) CT-01c, 2 times, and (d) CT-01d, 4 times

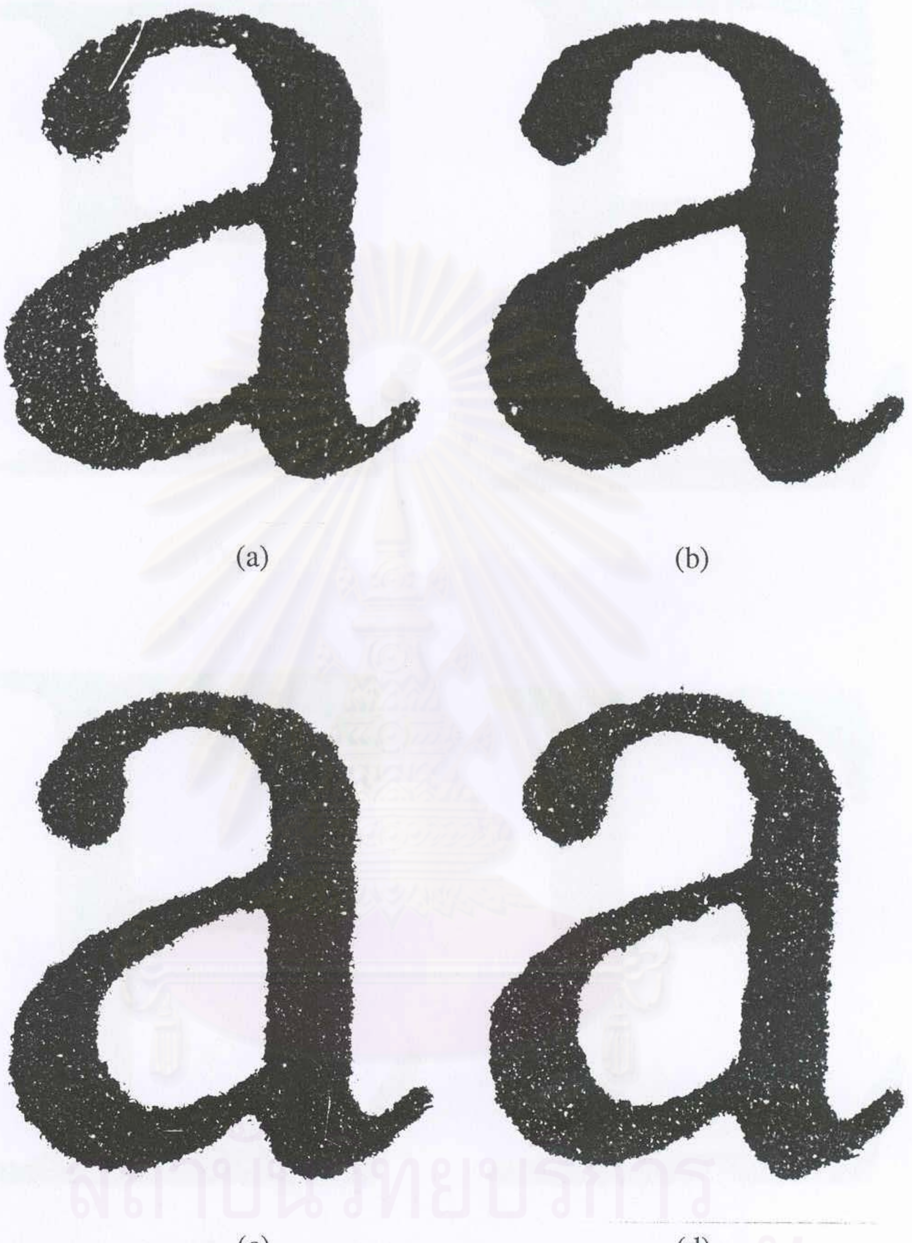


Figure 4-51 The photographs of the "a" character, by the image analyzer, produced by the toners containing various silica attachment forces: (a) CT-01a, ½ time; (b) CT-01b, 1 time; (c) CT-01c, 2 times, and (d) CT-01d, 4 times

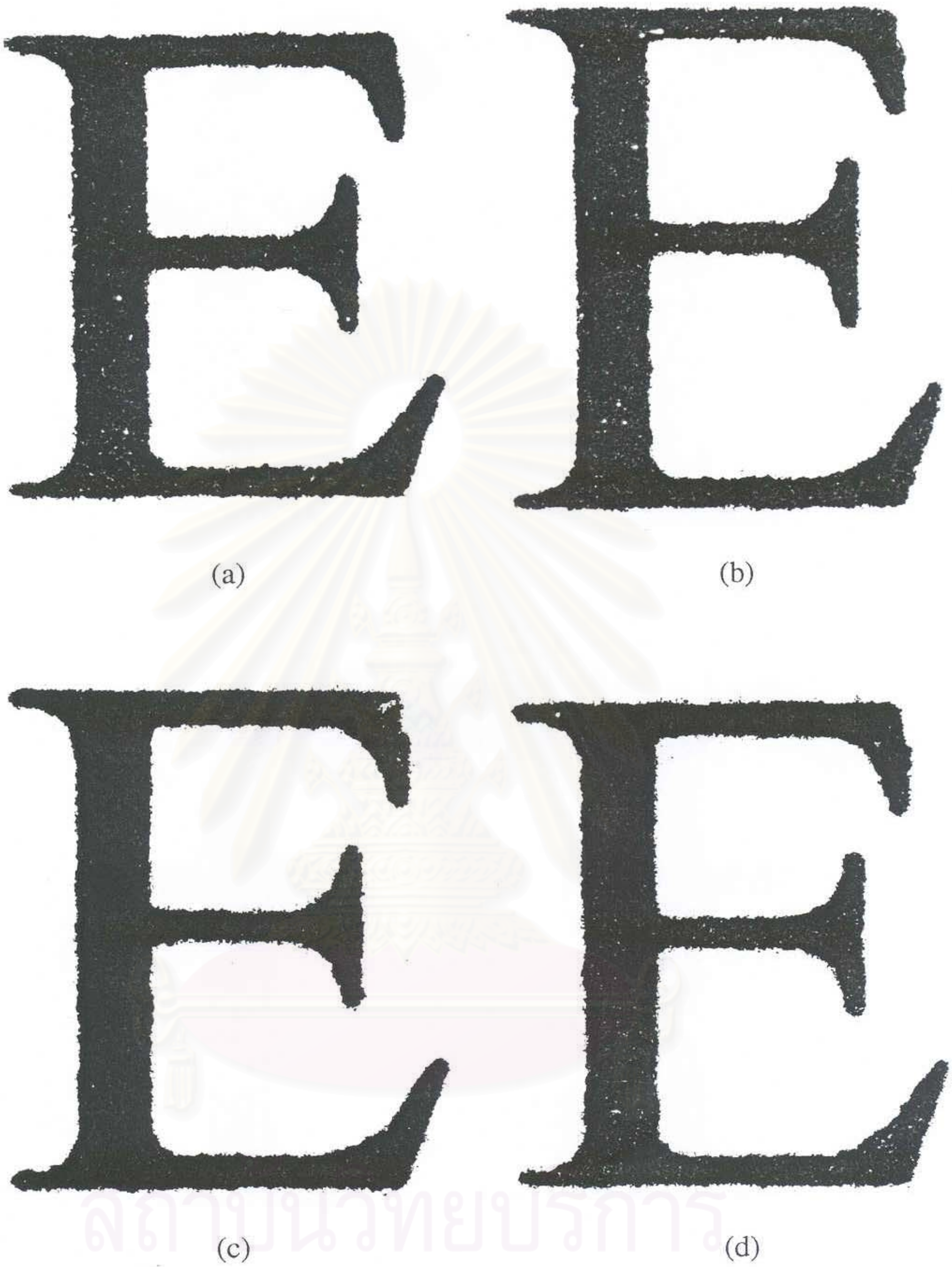


Figure 4-52 The photographs of the "E" character, by the image analyzer, produced by the toners containing various silica attachment forces: (a) CT-01a, ½ time; (b) CT-01b, 1 time; (c) CT-01c, 2 times, and (d) CT-01d, 4 times

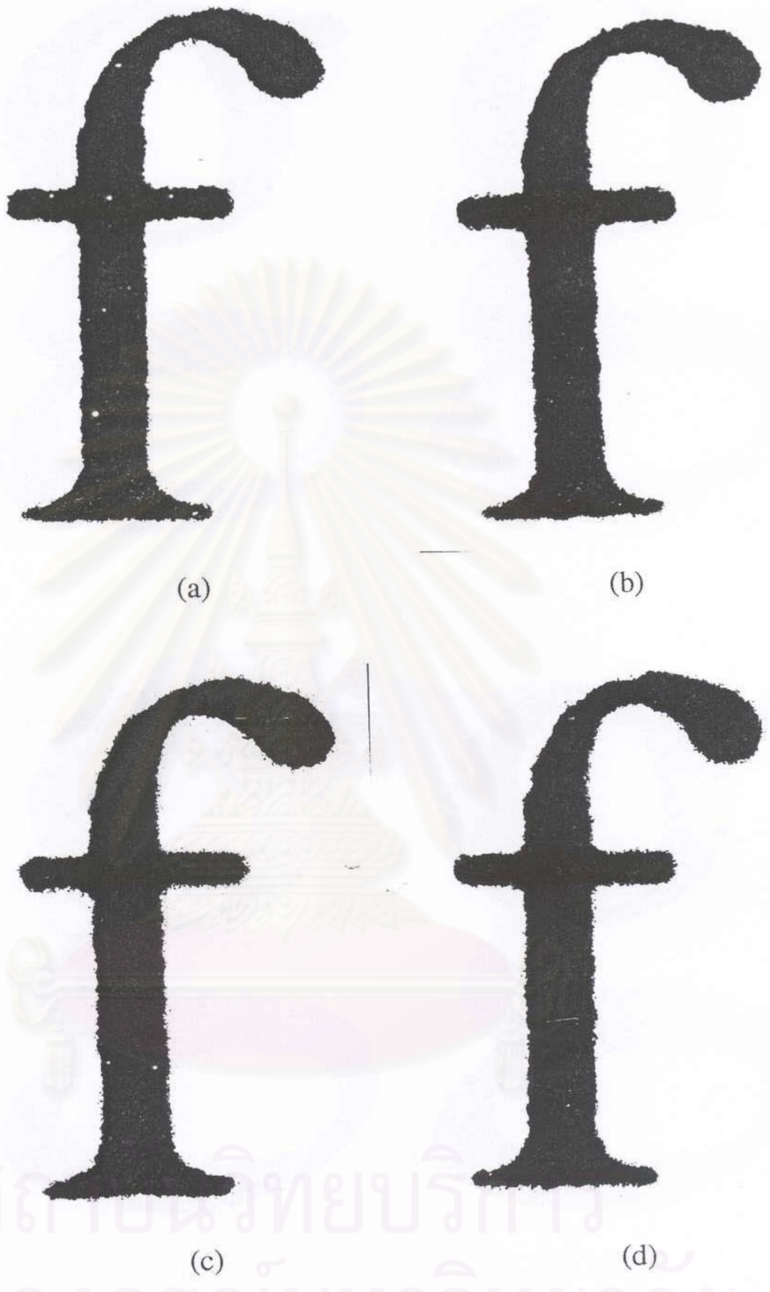


Figure 4-53 The photographs of the "f" character, by the image analyzer, produced by the toners containing various silica attachment forces: (a) CT-01a, ½ time; (b) CT-01b, 1 time; (c) CT-01c, 2 times, and (d) CT-01d, 4 times

Figure 4-54 The photographs of the “g” character, by the image analyzer, produced by the toners containing various silica attachment forces: (a) CT-01a, ½ time; (b) CT-01b, 1 time; (c) CT-01c, 2 times, and (d) CT-01d, 4 times

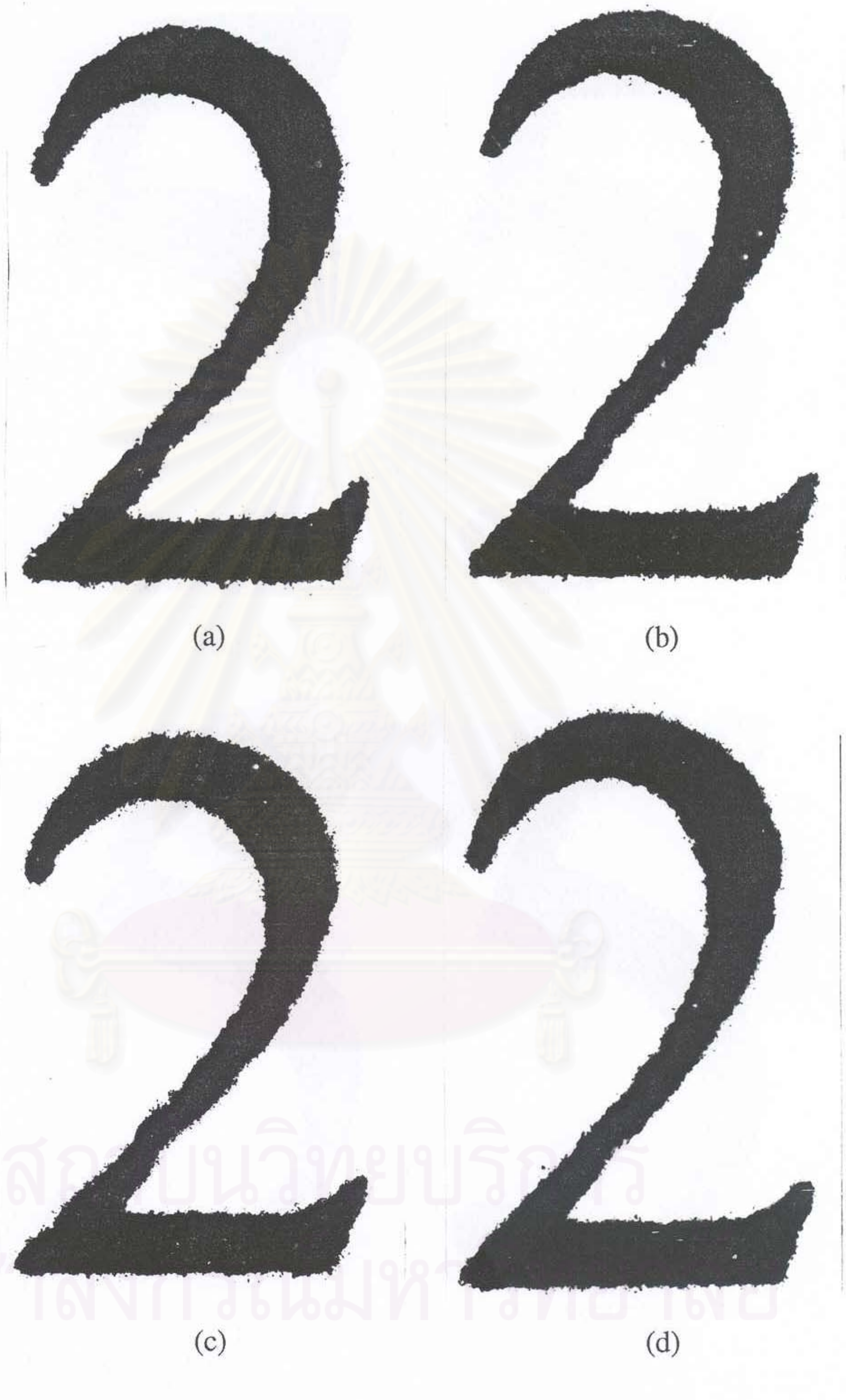


Figure 4-55 The photographs of the "2" number, by the image analyzer, produced by the toners containing various silica attachment forces: (a) CT-01a, ½ time; (b) CT-01b, 1 time; (c) CT-01c, 2 times, and (d) CT-01d, 4 times

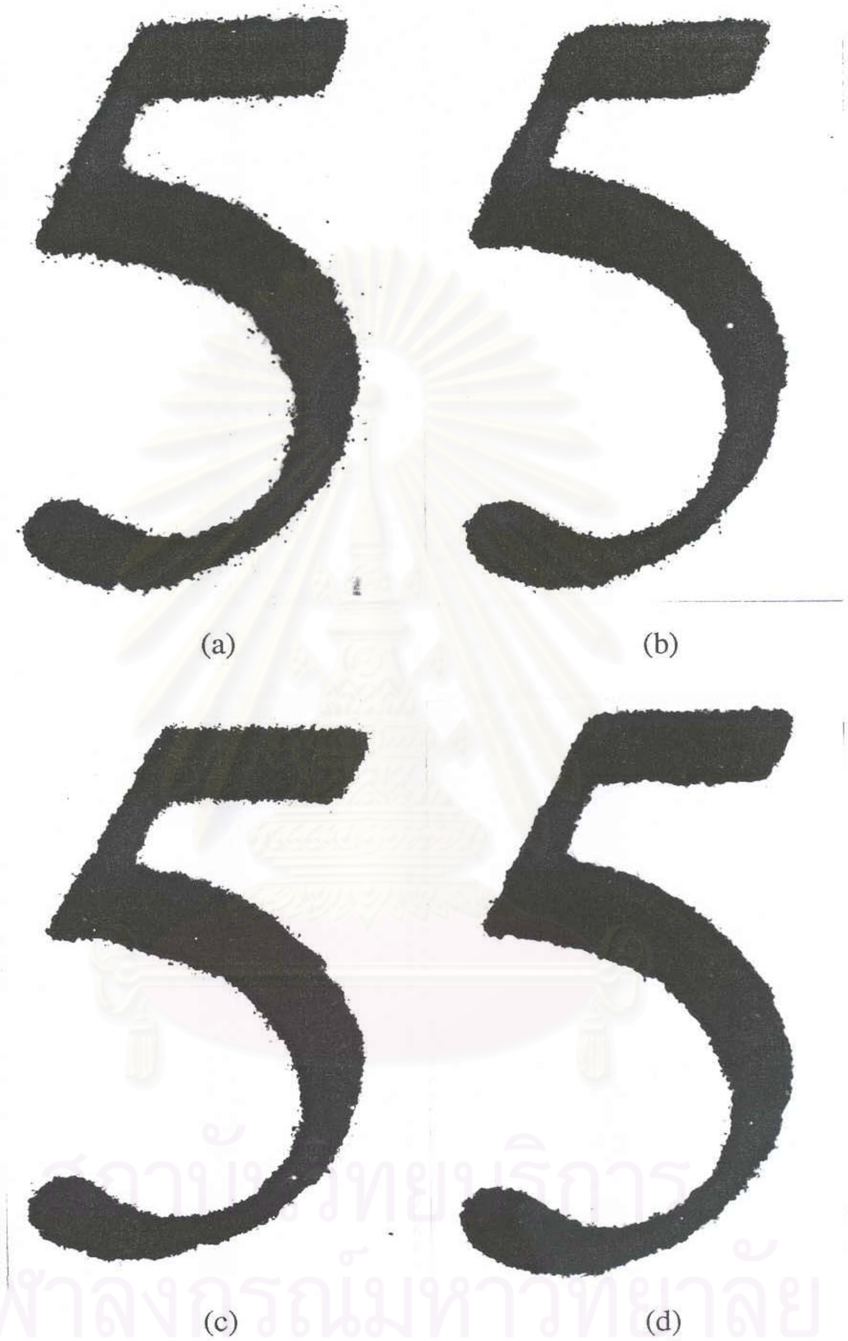


Figure 4-56 The photographs of the "5" number, by the image analyzer, produced by the toners containing various silica attachment forces: (a) CT-01a, ½ time; (b) CT-01b, 1 time; (c) CT-01c, 2 times, and (d) CT-01d, 4 times

Figure 4-57 The photographs of the lines (8.8×10^{-5} m) number, by the image analyzer, produced by the toners containing various silica attachment forces: (a) CT-01a, ½ time; (b) CT-01b, 1 time; (c) CT-01c, 2 times, and (d) CT-01d, 4 times

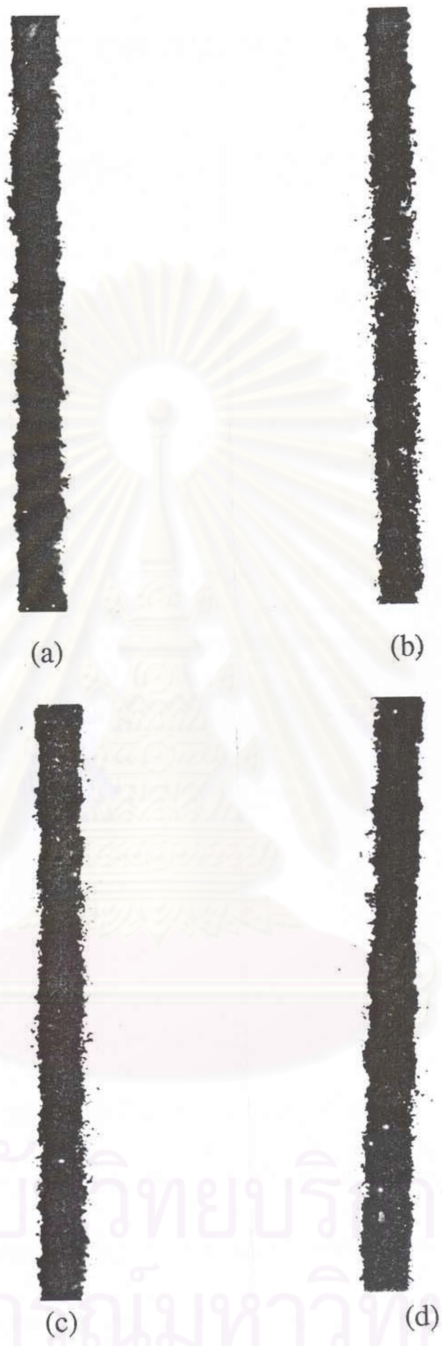


Figure 4-58 The photographs of the lines (1.8×10^{-4} m) number, by the image analyzer, produced by the toners containing various silica attachment forces: (a) CT-01a, ½ time; (b) CT-01b, 1 time; (c) CT-01c, 2 times, and (d) CT-01d, 4 times

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS

We investigated the dependence of the charge-to-mass ratio (q/m) of the two-component developer on the silica concentration, silica attachment force, the toner concentration, and the charging mechanisms. The dependence of toner flow ability on the silica concentration and silica attachment force was also investigated. Furthermore, the print qualities of all toners in term of the solid density, background density, and dot gain percentage of the print-outs were measured by densitometry. The edge raggedness and edge sharpness of the characters and lines, and the dot structure were analyzed by the image analysis.

Conclusions

The silica concentration and its attachment forces affect the electrical and mechanical properties of the toner that are directly related to the print quality. First, an increase in the silica concentration affects an increase in the negative tribocharge of the developer. On the contrary, the toner without silica shows an inconsistency of the charges. Second, the number of times for attachment forces of the silica particles on the toner surface affects an adherence state and the surface area of the silica, which can be changed again by rubbing with carrier particles. The charge levels of each toner are not different at the low rubbing force, but are very different at the high rubbing force between the toner and the carrier particles. Third, all non-zero silica concentrations clearly improve the toner flow ability, presumably explained by the particulate silica serving as asperities that reduce adhesion or cohesion by roughening the toner surface. On the other hand, the change of silica attachment forces made no difference on the toner flow ability. Fourth, the lower toner concentrations gave higher q/m values than those at the higher toner concentrations. When the toner concentration increases, the percentage coverage of the toners on the carrier surface accommodates more than one layer. The toners at the second layer could not be charged, therefore, the q/m values were lower. Finally, the various charging mechanisms give the different q/m values. The toner charges produced by hand shaking are the highest and reach a saturation within a short time, whereas the toner charges generated by the vertical shaking and horizontal rotating are lower because of the influence of impaction effect in the glass wall vessel.

The charging properties influence the quality of the printed images. The toners containing higher silica concentrations give the higher solid density and produce better edge sharpness. The toner without silica gives the lowest solid density and impairs more background density; the characters and the lines of this toner show more edge raggedness with voids. However, when the silica concentration is increased, the dots gain percentages increase. The various silica attachment forces on the toner surface do not clearly affect the print qualities. All toners produced the same image qualities.

Suggestions

Other important parameters, which impose effect to the charge-to-mass ratio, were not yet investigated. For example, the rubbing or contact force between the toner and the carrier, which is related to the change of silica attachment on the toner surface, is not investigated in more detail. Other carriers such as ferrite and iron carrier and their influence on the change of silica particle, have not been studied. Moreover, the treatment of the toner surface by varying the attachment forces for charge control agents (CCA) on the toner surface has not been explored. Almost all factors mentioned above are recommended for future work.

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APPENDICES

APPENDIX A

THE Q/M VALUES OF VARIOUS DEVELOPERS EVALUATED BY BLOW OFF MEASUREMENT UNIT

Table A-1 : q/m values of developer, CT-01b toner and TSV-200 carrier

by MS1 Minishaker, at 35 ± 5 % RH and 22 ± 3 °C

Rotation speed (rpm)	Concentration (wt %)	Rotating time (sec) q/m value (-μC/g) (Average/SD)							
		15	**30**	**60**	**90**	**120**	**240**	**360**	**720**
600	5	19.25 0.90	21.52 1.29	24.55 1.88	25.80 0.58	26.95 0.27	28.63 0.82	28.86 1.32	28.74 0.81
800	1	41.23 2.10	47.89 3.26	48.49 1.47	46.03 1.44	45.32 2.61	44.26 1.79	41.81 0.41	38.94 0.68
800	3	29.82 0.62	34.30 4.01	36.49 2.46	38.65 0.04	37.59 0.50	35.92 0.91	36.10 2.77	36.25 4.00
800	5	19.61 1.24	27.65 3.33	29.52 0.66	29.57 0.45	30.55 2.16	31.02 4.56	30.01 3.15	29.09 0.49
800	7	15.46 0.97	17.92 0.91	22.58 3.02	22.29 0.49	22.56 0.29	23.26 2.30	23.37 0.70	22.97 0.81
800	10	8.05 1.01	11.46 1.02	13.47 1.35	14.78 0.66	16.65 1.40	16.93 1.49	16.16 0.49	17.11 0.78
1000*	5	23.71 1.07	27.38 0.99	33.46 1.20	34.16 0.70	34.39 0.95	34.70 1.21	35.13 1.36	35.14 1.58
1000	5	20.77 0.96	27.42 1.10	31.76 1.58	33.08 0.60	33.66 1.64	34.01 0.56	35.34 0.80	36.34 1.03
1200	5	28.17 0.57	32.78 2.90	33.19 0.11	33.63 1.12	33.24 1.13	31.37 0.90	29.37 1.07	31.78 2.17
1400	5	31.52 2.73	35.93 0.87	38.37 2.61	38.77 0.69	39.15 1.98	41.08 1.41	41.17 1.28	42.60 1.04

55 ± 5% RH, 2(± °C

Table A-2 : q/m values of developer, CT-01b-1 toner and TSV-200 carrier

by MS1 Minishaker, at ±5 5 % RH an ±22 °C 3

Rotation speed (rpm)	Concentration (wt %)	Rotating time (sec) q/m value (-μC/g) (Average/SD)							
		15	30	60	90	120	240	360	720
600	5	14.86 0.52	20.63 0.88	24.08 2.23	25.50 0.30	26.89 1.04	27.11 2.80	27.39 3.16	29.18 1.33
800	1	35.30 1.15	37.75 1.97	42.00 3.79	41.75 0.63	41.17 2.23	39.02 1.87	39.60 1.89	40.07 1.93
800	3	26.82 1.18	34.43 0.48	38.54 4.45	36.65 1.58	37.11 0.93	34.22 0.90	34.93 1.90	32.68 1.00
800	5	16.19 0.60	23.95 0.57	25.60 1.90	27.42 0.99	26.13 1.02	27.30 0.92	27.12 1.41	24.63 1.30
800	7	10.52 0.91	19.93 1.80	24.08 0.81	25.77 0.56	25.47 1.64	27.16 1.19	26.80 1.96	24.81 1.01
800	10	5.48 2.99	10.67 0.88	19.07 1.76	20.64 0.37	20.06 1.13	21.35 0.61	22.69 1.26	21.53 1.90
1000	5	22.83 0.85	30.95 0.46	31.20 2.99	32.31 0.93	32.78 1.01	33.80 1.08	34.77 1.14	35.64 1.01
1200	5	30.22 0.51	32.13 0.89	33.29 0.46	33.20 0.90	32.86 1.35	30.67 3.82	27.24 0.79	29.95 2.58

* 55± 5% RH, 2± °C

Table A-3: q/m values of developer, CT-01b-2 toner and TSV-200 carrier

by MS1 Minishaker, at ±5 5% RH an ±22 °C

Rotation speed (rpm)	Concentration (wt %)	Rotating time (sec) q/m value (-μC/g) (Ave./SD)							
		15	**30**	**60**	**90**	**120**	**240**	**360**	**720**
600	5	10.08	17.73	22.18	23.39	24.09	25.04	26.51	26.30
		2.84	2.68	0.59	0.77	1.00	0.65	0.85	0.13
800	5	17.32	23.49	24.80	25.80	24.80	26.30	26.67	23.32
		3.83	1.21	0.92	0.30	1.06	2.23	0.49	1.29
1000*	5	20.52	29.00	29.75	29.76	29.67	32.73	32.24	32.06
		1.09	0.57	1.24	0.31	0.42	0.42	1.87	1.95
1200	5	26.15	28.28	28.88	28.66	28.95	27.76	26.05	27.94
		1.36	0.85	1.28	1.83	1.06	3.12	1.88	1.20

* 55± 5% RH, 2± °C

Table A-4 : q/m values of developer, CT-01b-3 toner and TSV-200 carrier

by MS1 Minishaker, at ±5 5% RH an ±2 °C 3

Rotation speed (rpm)	Concentration (wt %)	Rotating time (sec) q/m value (-μC/g) (Ave./SD)							
		15	**30**	**60**	**90**	**120**	**240**	**360**	**720**
600	5	9.79	15.04	18.82	20.59	22.94	24.64	24.49	25.22
		1.70	2.01	1.59	0.74	1.11	1.04	0.20	1.45
800	5	22.26	23.13	23.26	24.50	23.79	24.21	24.63	23.43
		2.72	1.56	1.36	2.39	1.73	2.22	0.77	1.31
1000*	5	22.50	22.98	27.63	28.13	28.20	30.70	31.14	31.16
		0.92	1.41	1.19	0.94	1.27	0.70	1.11	0.79
1200	5	24.47	25.07	26.27	26.70	26.86	26.63	24.69	25.05
		0.55	1.08	0.69	0.65	0.68	0.49	1.39	4.53

* 55± 5% RH, 2± °C

Table A-5 : q/m values of developer, CT-01 toner and TSV-200 carrier

by MS1 Minishaker, at ±5 5 % RH an ±22 °C

Rotation speed (rpm)	Concentration (wt %)	Rotating time (sec) q/m value (-μC/g) (Ave./SD)							
		15	**30**	**60**	**90**	**120**	**240**	**360**	**720**
800	1	35.24	38.58	40.26	42.88	43.07	43.73	42.91	43.20
		1.37	1.23	1.78	1.13	2.40	1.93	1.17	1.85
800	3	16.81	28.66	34.71	37.74	38.24	39.09	37.39	39.69
		1.38	1.63	1.52	2.12	2.16	1.62	1.86	0.97
800	5	17.68	24.90	25.16	26.54	26.94	27.76	27.61	26.59
		0.94	1.38	1.00	2.36	1.16	1.94	1.92	0.51
800	7	9.03	10.86	17.95	19.42	23.42	26.29	25.81	25.00
		2.87	1.40	1.50	0.80	0.97	0.74	0.54	0.87
800	10	5.09	10.14	15.51	16.86	19.56	20.76	19.51	19.19
		0.52	0.97	1.24	0.65	1.22	2.17	1.77	0.93
1000*	5	18.32	21.04	25.02	27.07	27.90	28.83	29.42	29.66
		0.82	1.05	0.67	0.42	1.43	1.52	1.21	0.99
1200	5	27.79	27.99	29.93	30.19	30.83	29.42	27.57	24.72
		0.64	0.84	2.77	2.23	2.64	1.59	0.93	1.39
1400	5	30.14	35.86	35.84	36.60	35.66	36.69	36.57	34.42
		1.37	0.53	1.24	0.88	0.49	2.31	0.74	1.15

* 55± 5% RH, 2± °C

Table A-6: q/m values of developer, CT-01a toner and TSV-200 carrier

by MS1 Minishaker, at ±5 5% RH and ±22°C 3

Rotation speed (rpm)	Concentration (wt %)	Rotating time (sec) q/m value (-μC/g) (Ave./SD)							
		15	**30**	**60**	**90**	**120**	**240**	**360**	**720**
800	5	21.34	26.47	28.45	29.22	29.43	30.73	30.11	28.72
		0.49	1.13	0.95	0.74	2.37	2.63	1.47	0.98
1000	5	22.87	27.88	29.85	31.05	31.61	30.87	29.93	30.87
		1.48	0.38	1.18	1.32	0.95	1.39	1.15	0.78
1200	5	28.64	32.48	33.16	33.53	33.45	31.46	30.05	32.52
		0.73	0.37	0.98	0.77	1.04	2.25	1.35	3.66
1400	5	32.69	37.44	40.49	40.81	41.99	42.70	41.82	43.80
		0.75	1.60	0.50	1.01	1.65	0.59	1.22	2.22

Table A-7 : q/m values of developer, CT-01c toner and TSV-200 carrier

by MS1 Minishaker, at ±5 5% RH and ±22°C 3

Rotation speed (rpm)	Concentration (wt %)	Rotating time (sec) q/m value (-μC/g) (Ave./SD)							
		15	**30**	**60**	**90**	**120**	**240**	**360**	**720**
800	5	25.58	28.03	28.80	29.24	29.65	30.13	30.19	29.15
		2.71	1.11	1.31	1.33	1.89	1.84	0.81	0.88
1000	5	25.08	30.69	32.96	34.25	35.07	37.13	37.44	38.78
		1.36	0.58	1.46	0.99	0.96	0.97	2.22	1.51
1200	5	23.16	27.40	27.73	27.80	28.69	28.93	27.55	29.71
		1.33	0.58	0.93	0.30	0.87	0.98	0.69	1.77
1400	5	30.99	33.08	36.57	35.94	36.62	36.13	35.65	39.04
		2.07	0.77	2.98	0.37	0.83	1.60	0.59	1.10

Table A-8: q/m values of developer, CT-01d toner and TSV-200 carrier

by MS1 Minishaker, at ±5 5% RH an ±22 °C 3

Rotation speed (rpm)	Concentration (wt %)	Rotating time (sec) q/m value (-μC/g) (Ave./SD)							
		15	30	60	90	120	240	360	720
800	5	25.81	28.10	31.06	29.81	28.85	30.30	29.99	30.98
		1.08	0.29	1.62	0.59	1.97	2.76	0.20	0.95
1000	5	27.13	28.83	28.79	28.70	28.29	28.38	28.17	29.83
		1.58	1.38	0.71	1.12	0.68	2.01	0.65	0.70
1200	5	27.51	29.59	30.31	31.45	31.21	30.15	28.30	27.67
		1.10	2.06	3.10	1.53	0.68	0.78	1.48	1.71
1400	5	32.36	31.74	33.78	34.18	35.34	35.41	35.19	36.92
		3.81	0.66	1.76	0.57	0.60	0.92	0.62	1.43

Table A-9 : q/m values of developer, CT-01b toner and TSV-200 carrier

by Horizontal rotator and hand shaking, ± 35 5% RH ± d °C 3

Rotation types	Concentration (wt %)	Rotating time (sec) q/m value (-μC/g) (Ave./SD)							
		15	30	60	90	120	240	360	720
Horizontal rotating	3	21.40	30.79	38.09	37.50	41.16	40.89	40.63	43.46
		1.05	2.58	1.44	0.05	1.53	1.84	2.28	1.79
	5	13.08	24.36	29.55	31.79	31.95	34.94	35.16	37.36
		0.34	1.41	1.18	1.78	0.22	1.74	0.92	0.92
	7	12.43	17.65	22.30	22.82	25.71	27.72	28.53	28.60
		2.19	3.29	3.32	0.83	1.89	3.71	4.17	1.78
hand shaking	3	46.48	49.28	48.49	52.04	48.37	51.02	48.16	48.91
		3.48	2.70	6.13	3.42	0.76	4.92	1.51	4.39
	5	39.99	44.51	41.82	42.77	44.29	41.30	42.96	41.47
		1.15	2.98	0.68	0.24	0.63	0.35	1.66	1.03
	7	30.05	30.77	34.58	33.06	35.22	33.29	33.37	30.04
		3.04	1.89	1.32	1.46	1.90	2.24	3.41	1.50

APPENDIX B

THE Q/M VALUES OF VARIOUS DEVELOPERS

EVALUATERD BY E-SPART ANALYZER

CT-01b-1 toner+TSV-200 carrier

date		:	00.10.12
data file name		:	CCTi
sampie name		:	CT-01b-1
measuring time	(sec)	=	1409.25
field voltage applied	(V)	=	100
particle density	(g/cm3)	=	1.1

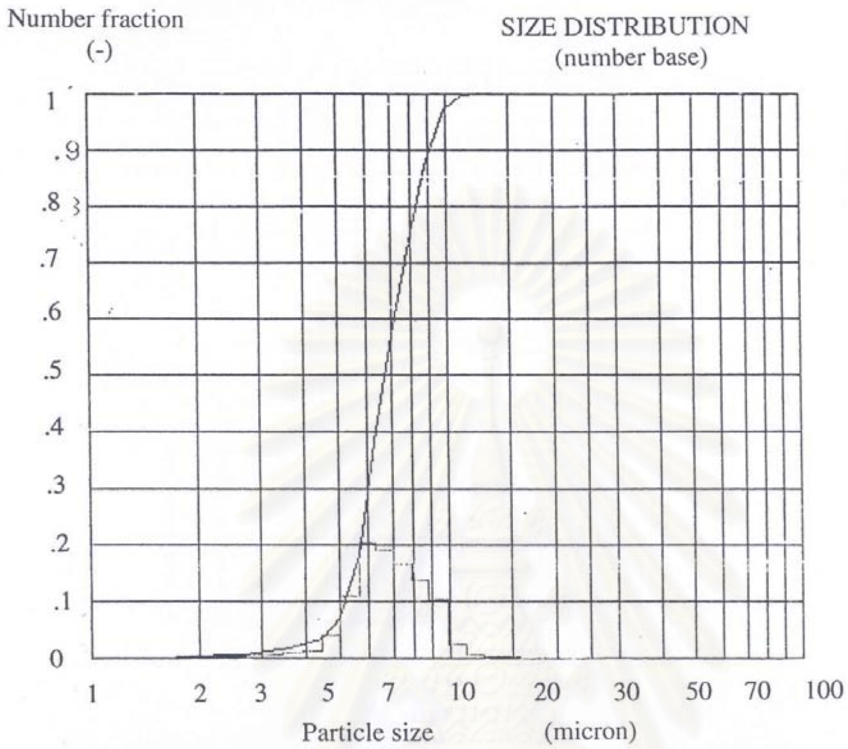
max charge range (femt C)		=	+- 42.6613
max particle charge (neg)	(femt C)	=	-31.0574
max particle charge (pos)	(femt C)	=	10.6008

No.	ave.dia. (μm)	negative (-)	negative (femt C)	positive (-)	positive (femt C)	total (-)	total (femt C)
1	1.9	7	-4.19(0.961)	1	0.17(0.039)	8	-4.02
2	2.2	1	-0.95(0.635)	1	0.55(0.365)	2	-0.40
3	2.5	6	-3.96(1.000)	0	0.00(0.000)	6	-3.96
4	2.9	9	-6.23(0.706)	3	2.59(0.294)	12	-3.64
5	3.3	7	-9.18(0.929)	6	0.70(0.071)	13	-8.48
6	3.7	14	-31.84(0.954)	5	1.55(0.046)	19	-30.29
7	4.2	23	-49.27(0.882)	12	6.61(0.118)	35	-42.66
8	4.7	85	-225.52(0.933)	25	16.08(0.067)	110	-209.44
9	5.3	282	-872.43(0.979)	27	18.64(0.021)	309	-853.79
10	6.0	519	-2215.55(0.988)	53	26.54(0.012)	572	-2189.00
11	6.7	497	-2586.10(0.982)	41	46.92(0.018)	538	-2539.18
12	7.5	432	-2733.40(0.989)	37	29.14(0.011)	469	-2704.25
13	8.4	361	-2686.00(0.994)	20	16.73(0.006)	381	-2669.27
14	9.3	280	-2403.07(0.994)	12	14.58(0.006)	292	-2388.49
15	10.5	58	-589.30(0.998)	2	1.47(0.002)	60	-587.83
16	11.8	12	-119.53(1.000)	0	0.00(0.000)	12	-119.53
17	13.3	1	-19.91(1.000)	0	0.00(0.000)	1	-19.91
18	14.9	1	-19.07(1.000)	0	0.00(0.000)	1	-19.07
19	16.7	0	0.00(0.000)	0	0.00(0.000)	0	0.00
20	18.8	0	0.00(0.000)	0	0.00(0.000)	0	0.00
21	21.3	0	0.00(0.000)	0	0.00(0.000)	0	0.00
22	24.2	0	0.00(0.000)	0	0.00(0.000)	0	0.00

average diameter : d50 (count) = 6.76(μm) d50 (volume) = 7.96(μm)

	negative		positive		total
count (-)	2595	(0.914)	245	(0.086)	2840
mass (nano gram)	588.2	(0.935)	40.6	(0.065)	628.8
charge (femt C)	-14575.50	(0.988)	182.27	(0.012)	-14393.20
q/m (micro C/g)	-24.78		4.49		-22.89

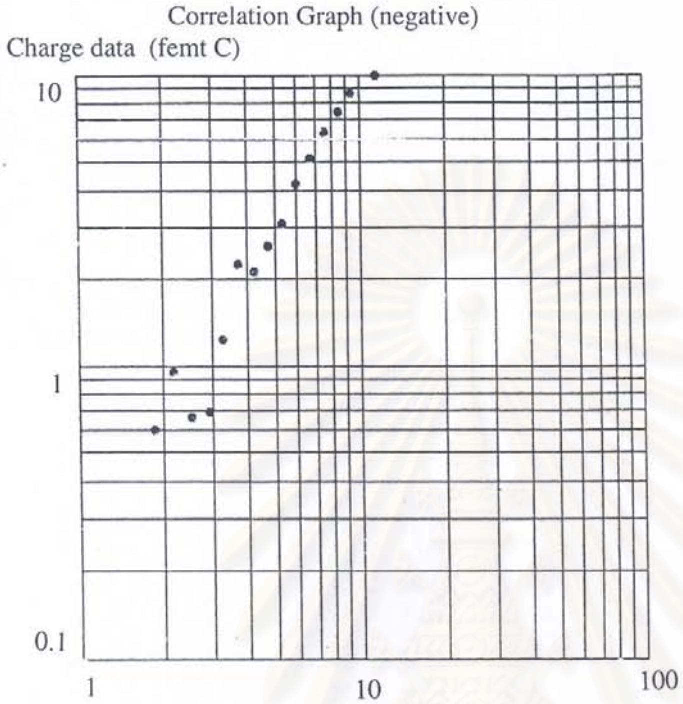
CT-01b-1 toner+TSV-200 carrier



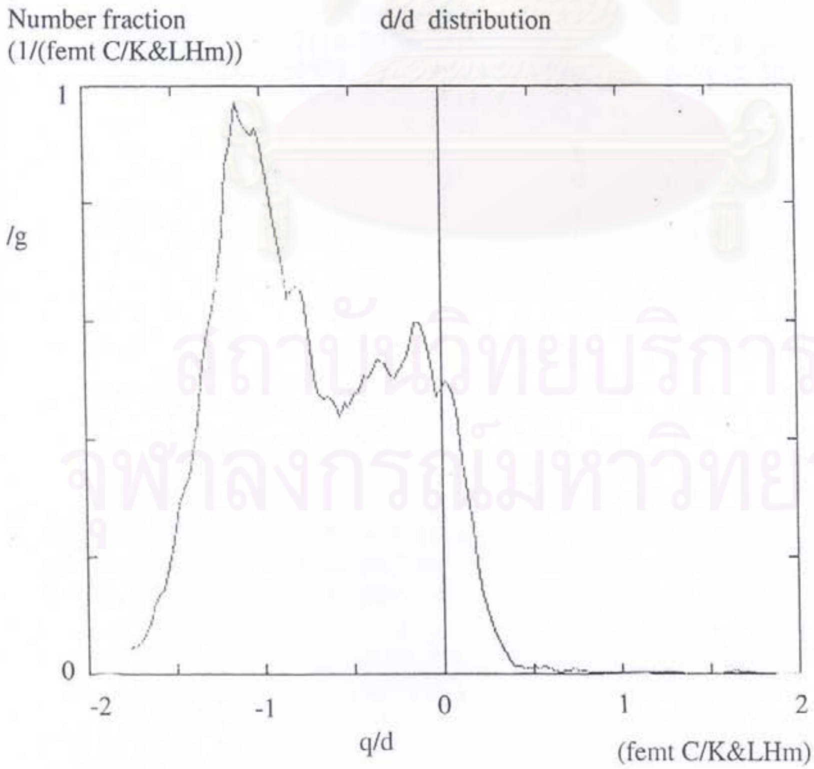
No. : SCT1
Sample: CT-01b-01

Average size
d50c = 6.8 micron
d50v = 8.0 micron

CT-01b-1 toner+TSV-200 carrier



sample : CT-01b-1
MAX or JOKEN :
size : SCT1
charge : CCT1



No. : CCT1
sample : CT-01b-1
field : 100 v
q/m : -22.89 K&LHm

CT-01b-2 toner+TSV-200 carrier

date		:	00.10.18
data file name		:	CCT2
sample name		:	CT-01b-2
measuring time	(sec)	=	1685.25
field voltage applied	(V)	=	100
particle density	(g/cm3)	=	1.1

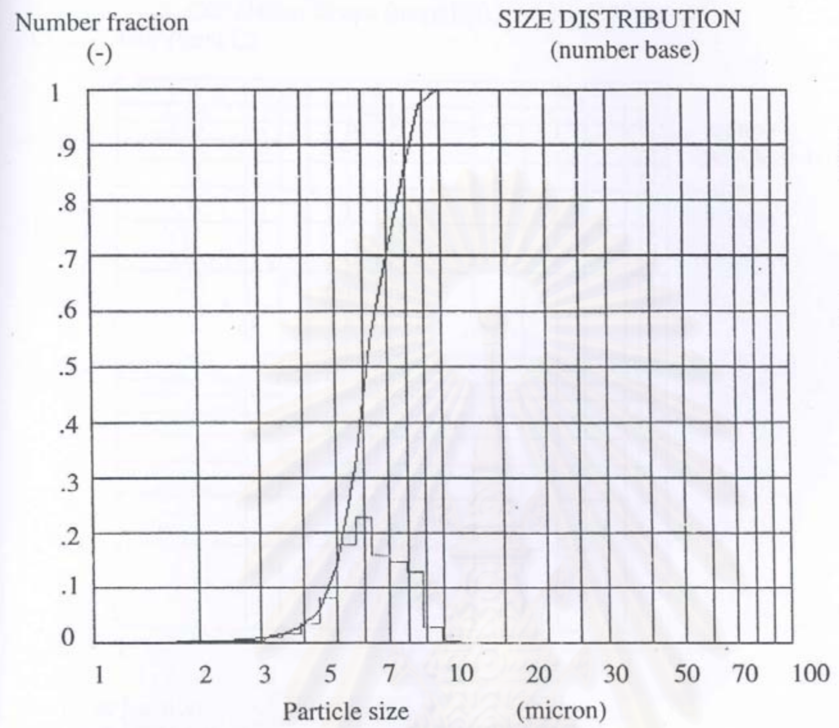
max charge range (femt C) = +- 42.6613
max particle charge (neg) (femt C) = -27.6445
max particle charge (pos) (femt C) = 4.5168

No.	ave. dia. (μm)	negative (-)	negative (femt C)	positive (-)	positive (femt C)	total (-)	total (femt C)
1	1.9	1	-0.96(0.796)	2	0.25(0.204)	3	-0.71
2	2.2	2	-0.64(0.667)	3	0.32(0.333)	5	-0.32
3	2.5	5	-8.03(0.996)	1	0.03(0.004)	6	-8.00
4	2.9	8	-10.52(1.000)	0	0.00(0.000)	8	-10.52
5	3.3	15	-20.16(0.962)	4	0.79(0.038)	19	-19.37
6	3.7	29	-60.72(0.961)	9	2.45(0.039)	38	-58.27
7	4.2	82	-157.08(0.971)	13	4.61(0.029)	95	-152.47
8	4.7	208	-663.59(0.983)	21	11.69(0.017)	229	-651.89
9	5.3	463	-1822.28(0.990)	41	18.49(0.010)	504	-1803.79
10	6.0	606	-2901.20(0.993)	42	20.54(0.007)	648	-2880.65
11	6.7	424	-2414.00(0.991)	27	20.92(0.009)	451	-2393.08
12	7.5	405	-2678.53(0.998)	15	5.70(0.002)	420	-2672.82
13	8.4	339	-2570.99(0.994)	17	15.45(0.006)	356	-2555.54
14	9.3	77	-692.23(0.996)	4	2.60(0.004)	81	-689.62
15	10.5	3	-20.96(1.000)	0	0.00(0.000)	3	-20.96
16	11.8	0	0.00(0.000)	0	0.00(0.000)	0	0.00
17	13.3	0	0.00(0.000)	0	0.00(0.000)	0	0.00
18	14.9	0	0.00(0.000)	0	0.00(0.000)	0	0.00
19	16.7	0	0.00(0.000)	0	0.00(0.000)	0	0.00
20	18.8	0	0.00(0.000)	0	0.00(0.000)	0	0.00
21	21.3	0	0.00(0.000)	0	0.00(0.000)	0	0.00
22	24.2	0	0.00(0.000)	0	0.00(0.000)	0	0.00

average diameter : d50 (count) = 6.16(μm) d50 (volume) = 7.23(μm)

	negative		positive		total
count (-)	2667	(0.931)	199	(0.069)	2866
mass (nano gram)	452.1	(0.944)	26.6	(0.056)	478.7
charge (femt C)	-14021.90	(0.993)	103.86	(0.007)	-13918.00
q/m (micro C/g)	-31.02		3.90		-29.08

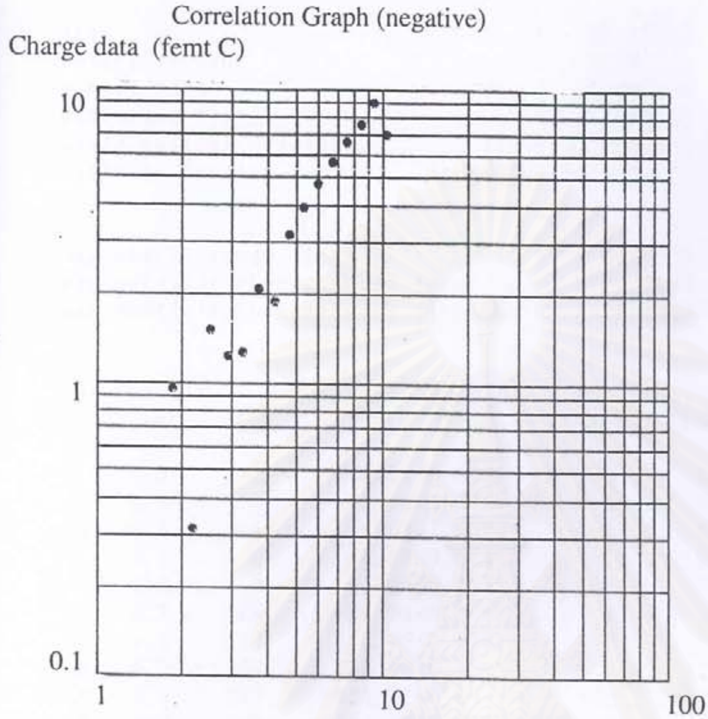
CT-01b-2 toner+TSV-200 carrier



No. : SCT2
Sample: CT-01b-2

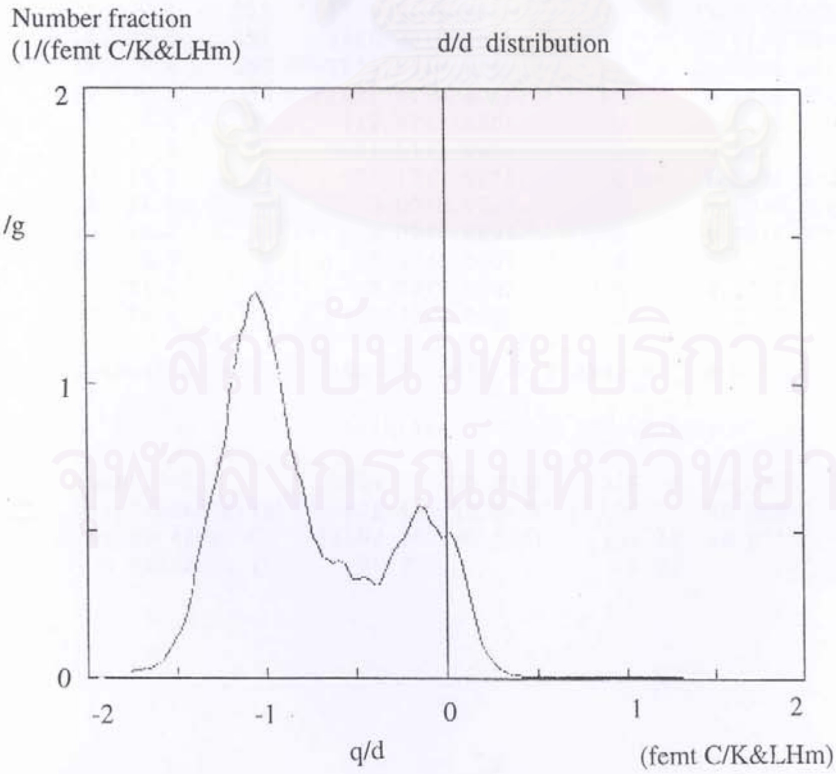
Average size
d50c = 6.2 micron
d50v = 7.2 micron

CT-01b-2 toner+TSV-200 carrier



sample : CT-01b-2
MAX or JOKEN :
size : SCT2
charge : CCT2

X : Particle size (K&LHm)



No. : CCT2
sample : CT-01b-2
field : 100 v
q/m : -29.08 K&LHm

CT-01b-3 toner+TSV-200 carrier

date	:	00.10.19
data file name	:	CCT3
sample name	:	CT-01b-3
measuring time (sec)	=	1622.25
field voltage applied (V)	=	100
particle density (g/cm3)	=	1.1

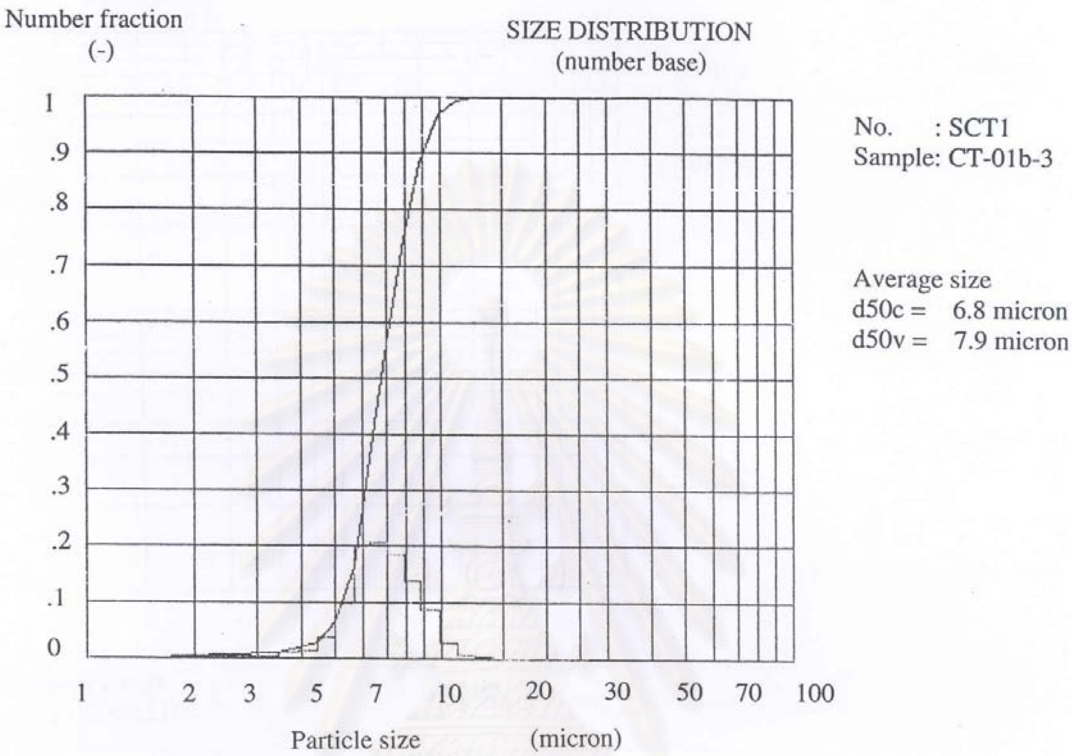
max charge range (femt C)	=	+- 42.6613
max particle charge (neg) (femt C)	=	-26.2794
max particle charge (pos) (femt C)	=	22.1838

No.	ave. dia. (μm)	negative (-)	negative (femt C)	positive (-)	positive (femt C)	total (-)	total (femt C)
1	1.9	2	-0.74(0.909)	1	0.07(0.091)	3	-0.66
2	2.2	7	-6.28(1.000)	0	0.00(0.000)	7	-6.28
3	2.5	4	-4.03(1.000)	0	0.00(0.000)	4	-4.03
4	2.9	6	-4.18(0.864)	1	0.66(0.136)	7	-3.52
5	3.3	3	-5.58(0.934)	1	0.40(0.066)	4	-5.18
6	3.7	16	-31.94(0.988)	2	0.40(0.012)	18	-31.54
7	4.2	24	-46.82(0.928)	6	3.64(0.072)	30	-43.17
8	4.7	94	-235.28(0.990)	14	2.45(0.010)	108	-232.82
9	5.3	247	-821.77(0.971)	28	24.41(0.029)	275	-797.36
10	6.0	509	-2224.09(0.983)	52	37.47(0.017)	561	-2186.62
11	6.7	532	-2744.19(0.988)	50	33.92(0.012)	582	-2710.27
12	7.5	497	-3086.38(0.993)	22	22.61(0.007)	519	-3063.77
13	8.4	359	-2608.63(0.992)	25	20.79(0.008)	384	-2587.83
14	9.3	237	-1941.54(0.992)	14	15.88(0.008)	251	-1925.66
15	10.5	79	-712.87(1.000)	0	0.00(0.000)	79	-712.87
16	11.8	16	-181.61(1.000)	0	0.00(0.000)	16	-181.61
17	13.3	2	-27.17(1.000)	0	0.00(0.000)	2	-27.17
18	14.9	0	0.00(0.000)	0	0.00(0.000)	0	0.00
19	16.7	0	0.00(0.000)	0	0.00(0.000)	0	0.00
20	18.8	0	0.00(0.000)	0	0.00(0.000)	0	0.00
21	21.3	0	0.00(0.000)	0	0.00(0.000)	0	0.00
22	24.2	0	0.00(0.000)	0	0.00(0.000)	0	0.00

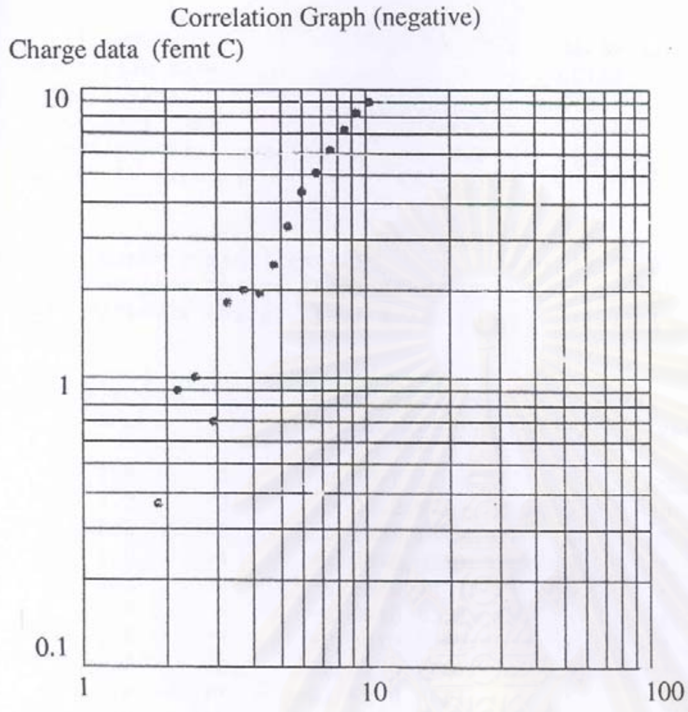
average diameter : d50 (count) = 6.82(μm) d50 (volume) = 7.88(μm)

	negative		positive		total
count (-)	2634	(0.924)	216	(0.076)	2850
mass (nano gram)	602.4	(0.940)	38.7	(0.060)	641.1
charge (femt C)	-14683.10	(0.989)	162.72	(0.011)	-14520.40
q/m (micro C/g)	-24.37		4.21		-22.65

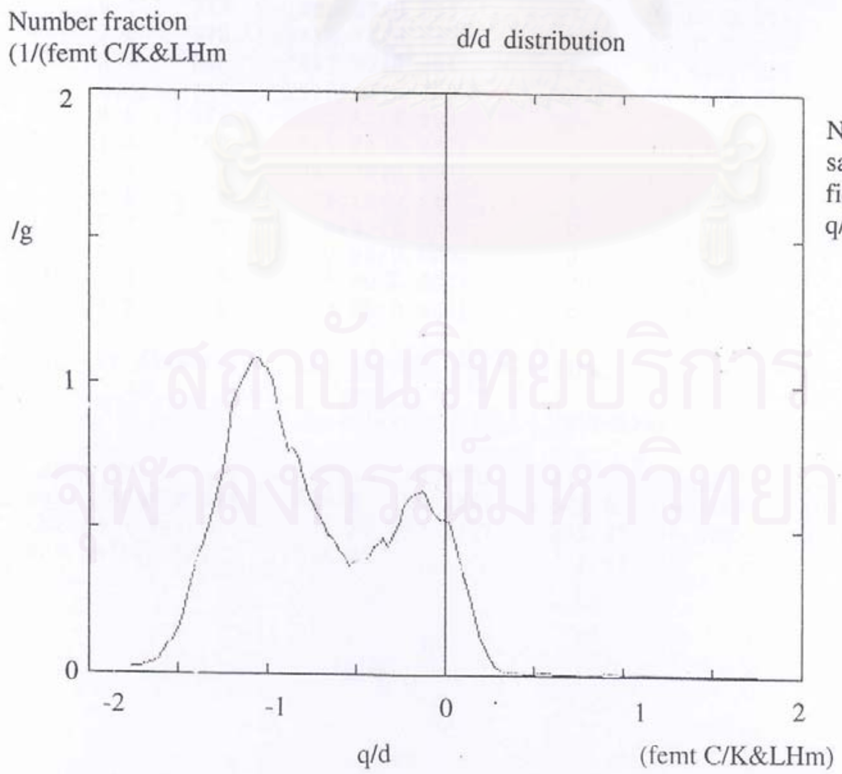
CT-01b-3 toner+TSV-200 carrier



CT-01b-3 toner+TSV-200 carrier



sample : CT-01b-3
MAX or JOKEN :
size : SCT3
charge : CCT3



No. : CCT01
sample : CT-01
field : 100 v
q/m : -12.33 K&LHm

CT-01 toner+TSV-200 carrier

date		:	00.04.12
data file name		:	CCT01
sample name		:	CT01
measuring time	(sec)	=	3096
field voltage applied	(V)	=	100
particle density	(g/cm3)	=	1.1

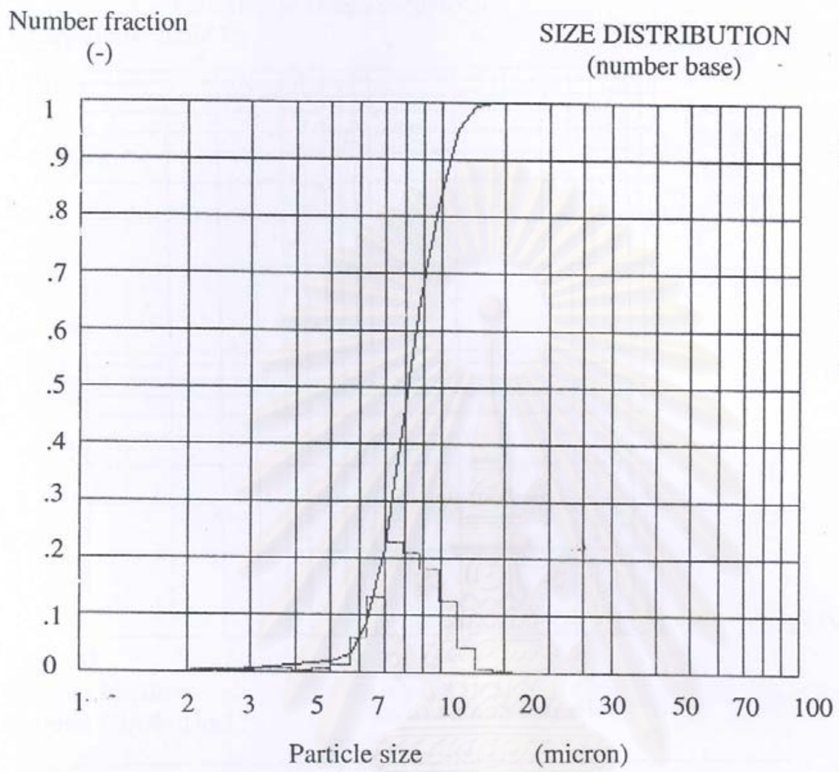
max charge range (femt C)	= +- 42.6613
max particle charge (neg) (femt C)	= -15.6843
max particle charge (pos) (femt C)	= 11.7211

No.	ave. dia. (μm)	negative (-)	negative (femt C)	positive (-)	positive (femt C)	total (-)	total (femt C)
1	1.9	0	0.00 (0.000)	0	0.00 (0.000)	0	0.00
2	2.2	0	0.00 (0.000)	2	0.40 (1.000)	2	0.40
3	2.5	0	0.00 (0.000)	0	0.00 (0.000)	0	0.00
4	2.9	4	-1.08 (0.483)	4	1.16 (0.517)	8	0.08
5	3.3	8	-8.26 (0.817)	4	1.84 (0.183)	12	-6.41
6	3.7	5	-4.96 (0.739)	5	1.75 (0.261)	10	-3.20
7	4.2	3	-2.56 (0.549)	5	2.11 (0.451)	8	-0.46
8	4.7	6	-8.01 (0.605)	7	5.23 (0.395)	13	-2.78
9	5.3	27	-67.62 (0.982)	5	1.24 (0.018)	32	-66.38
10	6.0	145	-474.11 (0.940)	23	30.00 (0.060)	168	-444.11
11	6.7	342	-1326.27 (0.975)	37	33.64 (0.025)	379	-1292.63
12	7.5	579	-2718.14 (0.972)	73	77.27 (0.028)	652	-2640.87
13	8.4	528	-2847.35 (0.981)	65	55.41 (0.019)	593	-2791.94
14	9.3	468	-2910.29 (0.980)	54	58.84 (0.020)	522	-2851.44
15	10.5	324	-2200.02 (0.987)	35	29.17 (0.013)	359	-2170.85
16	11.8	109	-904.24 (0.987)	12	12.22 (0.013)	121	-892.02
17	13.3	9	-56.75 (0.831)	8	11.54 (0.169)	17	-45.22
18	14.9	2	-12.15 (0.921)	1	1.05 (0.079)	3	-11.10
19	16.7	0	0.00 (0.000)	0	0.00 (0.000)	0	0.00
20	18.8	0	0.00 (0.000)	0	0.00 (0.000)	0	0.00
21	21.3	0	0.00 (0.000)	0	0.00 (0.000)	0	0.00
22	24.2	0	0.00 (0.000)	0	0.00 (0.000)	0	0.00

average diameter : d50 (count) = 8.15 (μm) d50 (volume) = 9.18 (μm)

	negative		positive		total
count (-)	2559	(0.883)	340	(0.117)	2899
mass (nano gram)	949.6	(0.886)	122.5	(0.114)	1072.0
charge (femt C)	-13541.80	(0.977)	322.87	(0.023)	-13218.90
q/m (micro C/g)	-14.26		2.64		-12.33

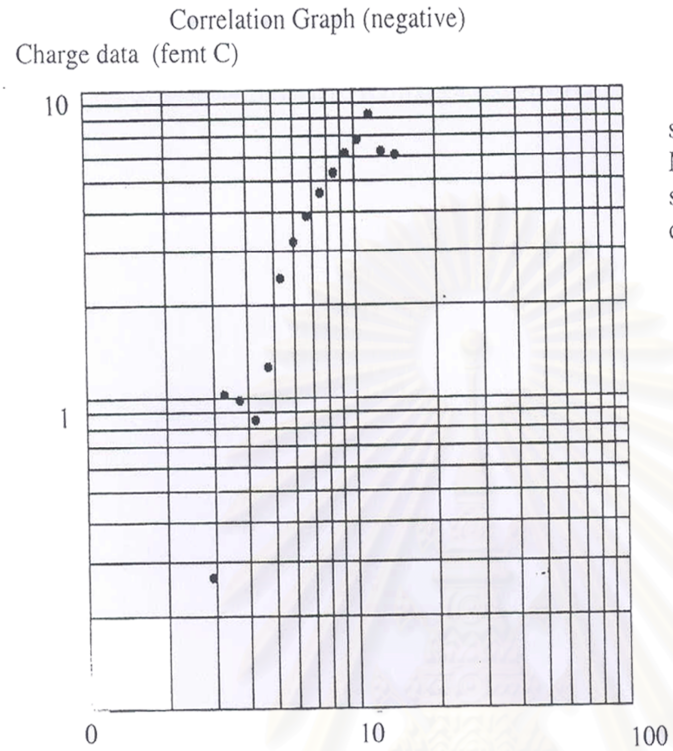
CT-01 toner+TSV-200 carrier



No. : SCT1
Sample: CT-01

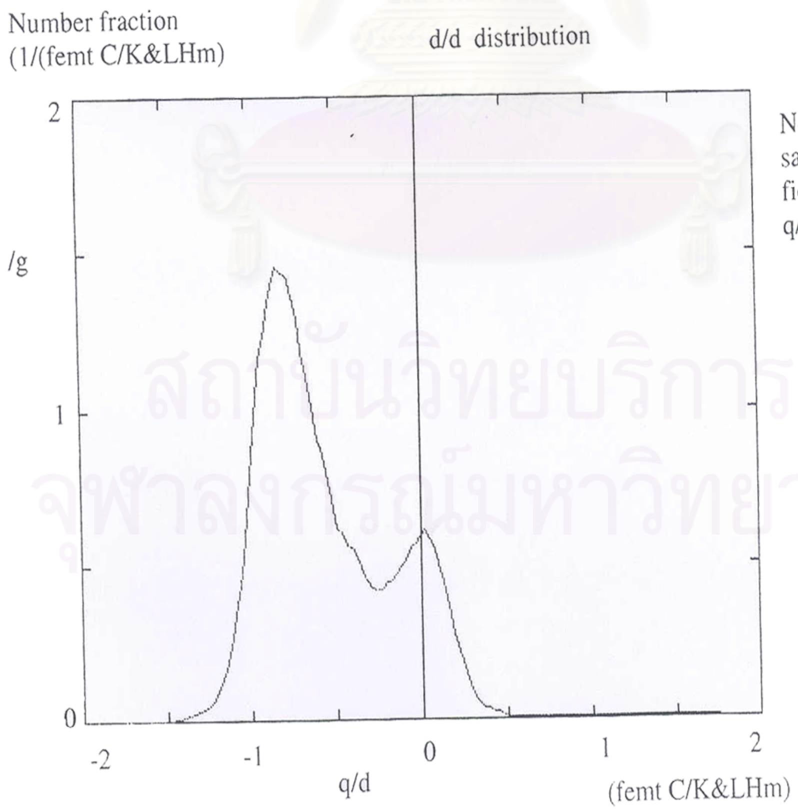
Average size
d50c = 8.2 micron
d50v = 9.2 micron

CT-01 toner+TSV-200 carrier



sample : CT-01
MAX or JOKEN :
size : SCT
charge : CCT

X : Particle size (K&LHm)



No. : CCT01
sample : CT-01
field : 100 v
q/m : -12.33 K&LHm

APPENDIX C

MEASUREMENT ON PRINT QUALITY

Table C-1 : The solid density values of the CT-01b toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	1.52	1.54	1.53	1.54	1.53	1.54	1.53	1.52	1.52	1.52
2	1.53	1.53	1.52	1.54	1.53	1.54	1.53	1.52	1.52	1.52
3	1.52	1.52	1.52	1.54	1.53	1.54	1.53	1.52	1.52	1.52
4	1.54	1.53	1.53	1.53	1.53	1.54	1.54	1.53	1.53	1.53
5	1.53	1.54	1.53	1.54	1.54	1.53	1.53	1.53	1.53	1.53
6	1.53	1.53	1.53	1.54	1.54	1.53	1.53	1.53	1.53	1.52
7	1.54	1.53	1.54	1.53	1.53	1.53	1.52	1.52	1.52	1.53
8	1.54	1.53	1.53	1.53	1.54	1.53	1.54	1.52	1.52	1.53
9	1.54	1.52	1.53	1.52	1.53	1.52	1.53	1.52	1.54	1.53
10	1.53	1.51	1.53	1.52	1.52	1.52	1.53	1.53	1.54	1.54
11	1.54	1.50	1.54	1.53	1.52	1.53	1.53	1.54	1.53	1.54
12	1.52	1.50	1.55	1.54	1.56	1.55	1.56	1.53	1.54	1.54
13	1.52	1.53	1.56	1.56	1.54	1.53	1.54	1.53	1.54	1.53
14	1.52	1.53	1.56	1.57	1.54	1.53	1.54	1.54	1.54	1.54
15	1.52	1.52	1.57	1.58	1.54	1.54	1.53	1.54	1.54	1.54
16	1.51	1.50	1.57	1.57	1.54	1.54	1.53	1.53	1.54	1.53
17	1.50	1.52	1.53	1.54	1.55	1.56	1.54	1.56	1.54	1.53
18	1.51	1.52	1.53	1.54	1.55	1.54	1.54	1.55	1.53	1.54
19	1.52	1.52	1.52	1.53	1.54	1.55	1.55	1.55	1.55	1.54
20	1.51	1.54	1.52	1.54	1.54	1.54	1.55	1.54	1.54	1.53
21	1.51	1.50	1.50	1.54	1.54	1.54	1.54	1.54	1.55	1.54
22	1.52	1.53	1.51	1.53	1.54	1.55	1.54	1.54	1.54	1.53
23	1.53	1.52	1.50	1.54	1.53	1.54	1.53	1.53	1.53	1.53
24	1.52	1.52	1.51	1.51	1.52	1.52	1.52	1.54	1.53	1.52
Ave.	1.52	1.52	1.53	1.54	1.54	1.54	1.54	1.53	1.53	1.53
SD	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01

Table C-2 : The solid density values of the CT-01b-1 toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	1.47	1.50	1.49	1.49	1.50	1.49	1.49	1.50	1.50	1.49
2	1.48	1.49	1.50	1.49	1.51	1.50	1.51	1.51	1.50	1.50
3	1.50	1.50	1.49	1.49	1.51	1.50	1.50	1.51	1.50	1.50
4	1.49	1.49	1.49	1.48	1.51	1.49	1.50	1.51	1.49	1.50
5	1.50	1.50	1.49	1.49	1.51	1.50	1.50	1.51	1.49	1.50
6	1.50	1.51	1.49	1.48	1.50	1.50	1.51	1.51	1.49	1.49
7	1.48	1.51	1.50	1.49	1.51	1.51	1.51	1.50	1.50	1.49
8	1.49	1.51	1.49	1.48	1.50	1.51	1.51	1.51	1.50	1.50
9	1.50	1.51	1.51	1.48	1.50	1.51	1.51	1.52	1.49	1.50
10	1.51	1.52	1.50	1.50	1.51	1.51	1.51	1.52	1.51	1.49
11	1.51	1.52	1.51	1.51	1.51	1.52	1.51	1.51	1.51	1.49
12	1.52	1.53	1.51	1.51	1.52	1.52	1.52	1.52	1.51	1.51
13	1.53	1.53	1.51	1.52	1.52	1.53	1.53	1.53	1.51	1.51
14	1.53	1.53	1.53	1.52	1.52	1.53	1.54	1.54	1.51	1.53
15	1.54	1.54	1.52	1.51	1.53	1.53	1.54	1.54	1.52	1.53
16	1.54	1.54	1.53	1.52	1.54	1.53	1.54	1.53	1.52	1.53
17	1.53	1.53	1.51	1.50	1.52	1.53	1.53	1.52	1.51	1.52
18	1.53	1.54	1.50	1.51	1.53	1.53	1.54	1.53	1.50	1.52
19	1.52	1.54	1.50	1.51	1.52	1.53	1.53	1.51	1.52	1.52
20	1.52	1.52	1.50	1.50	1.51	1.52	1.52	1.51	1.50	1.52
21	1.52	1.53	1.50	1.51	1.52	1.53	1.53	1.52	1.52	1.51
22	1.54	1.53	1.50	1.50	1.52	1.53	1.52	1.52	1.51	1.51
23	1.53	1.53	1.50	1.51	1.52	1.52	1.52	1.52	1.51	1.51
24	1.54	1.52	1.50	1.51	1.53	1.52	1.52	1.52	1.50	1.51
Ave.	1.51	1.52	1.50	1.50	1.52	1.52	1.52	1.52	1.51	1.51
SD	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table C-3 : The solid density values of the CT-01b-2 toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	1.49	1.48	1.47	1.50	1.45	1.48	1.49	1.48	1.48	1.47
2	1.49	1.48	1.46	1.49	1.46	1.49	1.50	1.49	1.48	1.46
3	1.49	1.47	1.46	1.49	1.45	1.49	1.49	1.49	1.47	1.46
4	1.49	1.47	1.46	1.51	1.44	1.49	1.50	1.49	1.47	1.46
5	1.49	1.48	1.47	1.51	1.45	1.49	1.50	1.49	1.48	1.47
6	1.48	1.48	1.47	1.51	1.45	1.48	1.50	1.48	1.48	1.47
7	1.48	1.47	1.47	1.47	1.45	1.47	1.49	1.47	1.47	1.47
8	1.49	1.48	1.48	1.49	1.44	1.49	1.49	1.49	1.48	1.48
9	1.50	1.48	1.48	1.50	1.45	1.50	1.51	1.50	1.48	1.48
10	1.50	1.48	1.48	1.50	1.46	1.50	1.51	1.50	1.48	1.48
11	1.49	1.47	1.46	1.49	1.45	1.49	1.49	1.49	1.47	1.46
12	1.48	1.48	1.46	1.48	1.45	1.48	1.50	1.48	1.48	1.46
13	1.47	1.47	1.47	1.47	1.45	1.47	1.50	1.47	1.47	1.47
14	1.50	1.49	1.50	1.50	1.44	1.50	1.50	1.50	1.49	1.46
15	1.50	1.48	1.50	1.50	1.45	1.50	1.50	1.50	1.48	1.45
16	1.49	1.49	1.47	1.50	1.45	1.49	1.49	1.49	1.49	1.47
17	1.50	1.47	1.49	1.51	1.45	1.50	1.50	1.50	1.47	1.47
18	1.49	1.47	1.48	1.51	1.45	1.49	1.50	1.49	1.47	1.47
19	1.49	1.47	1.51	1.50	1.45	1.49	1.51	1.49	1.47	1.47
20	1.48	1.48	1.48	1.50	1.48	1.48	1.51	1.48	1.48	1.48
21	1.49	1.46	1.49	1.51	1.45	1.49	1.49	1.49	1.46	1.45
22	1.48	1.46	1.46	1.51	1.45	1.49	1.49	1.48	1.46	1.46
23	1.48	1.48	1.48	1.50	1.48	1.49	1.48	1.48	1.48	1.48
24	1.49	1.47	1.49	1.49	1.46	1.48	1.48	1.47	1.47	1.47
Ave.	1.49	1.48	1.48	1.50	1.45	1.49	1.50	1.49	1.48	1.47
SD	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table C-4 : The solid density values of the CT-01b-3 toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	1.40	1.40	1.41	1.41	1.39	1.41	1.40	1.42	1.42	1.42
2	1.40	1.40	1.40	1.40	1.39	1.42	1.42	1.44	1.42	1.43
3	1.40	1.41	1.40	1.40	1.40	1.43	1.41	1.43	1.43	1.43
4	1.40	1.40	1.40	1.40	1.40	1.42	1.42	1.43	1.41	1.42
5	1.41	1.40	1.41	1.39	1.40	1.42	1.41	1.44	1.40	1.42
6	1.41	1.42	1.41	1.41	1.41	1.43	1.40	1.44	1.42	1.44
7	1.42	1.42	1.41	1.43	1.41	1.43	1.42	1.44	1.42	1.44
8	1.42	1.42	1.42	1.42	1.40	1.42	1.42	1.44	1.40	1.44
9	1.43	1.44	1.42	1.40	1.41	1.41	1.42	1.43	1.40	1.44
10	1.42	1.41	1.42	1.42	1.42	1.42	1.41	1.42	1.41	1.43
11	1.42	1.41	1.42	1.40	1.40	1.42	1.40	1.41	1.40	1.42
12	1.41	1.41	1.40	1.40	1.39	1.40	1.40	1.41	1.40	1.41
13	1.41	1.42	1.42	1.41	1.40	1.41	1.42	1.43	1.41	1.42
14	1.43	1.43	1.44	1.42	1.40	1.41	1.42	1.41	1.42	1.43
15	1.45	1.44	1.42	1.41	1.40	1.41	1.41	1.41	1.41	1.43
16	1.44	1.43	1.41	1.41	1.39	1.41	1.40	1.41	1.40	1.42
17	1.40	1.41	1.40	1.39	1.39	1.40	1.40	1.42	1.39	1.42
18	1.40	1.40	1.39	1.39	1.37	1.40	1.40	1.41	1.39	1.41
19	1.40	1.40	1.40	1.38	1.37	1.40	1.39	1.41	1.40	1.40
20	1.41	1.38	1.39	1.38	1.37	1.40	1.40	1.40	1.39	1.41
21	1.40	1.38	1.39	1.39	1.37	1.40	1.40	1.41	1.40	1.41
22	1.40	1.39	1.39	1.39	1.38	1.40	1.40	1.42	1.42	1.41
23	1.40	1.39	1.39	1.40	1.37	1.41	1.41	1.41	1.42	1.42
24	1.40	1.39	1.39	1.40	1.39	1.42	1.41	1.42	1.42	1.43
Ave.	1.41	1.41	1.41	1.40	1.39	1.41	1.41	1.42	1.41	1.42
SD	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table C-5 : The solid density values of the CT-01 toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	1.40	1.42	1.38	1.38	1.35	1.38	1.38	1.37	1.40	1.40
2	1.38	1.36	1.36	1.38	1.35	1.37	1.36	1.36	1.36	1.35
3	1.38	1.38	1.39	1.37	1.36	1.36	1.34	1.36	1.35	1.34
4	1.36	1.38	1.38	1.37	1.37	1.36	1.34	1.35	1.35	1.36
5	1.33	1.36	1.38	1.36	1.36	1.35	1.35	1.35	1.36	1.37
6	1.32	1.37	1.38	1.35	1.35	1.35	1.37	1.36	1.34	1.36
7	1.34	1.38	1.38	1.34	1.35	1.34	1.36	1.36	1.37	1.36
8	1.33	1.39	1.35	1.34	1.36	1.36	1.36	1.35	1.36	1.37
9	1.36	1.38	1.36	1.35	1.35	1.35	1.38	1.38	1.37	1.37
10	1.36	1.39	1.35	1.36	1.36	1.35	1.38	1.36	1.36	1.37
11	1.34	1.38	1.36	1.35	1.37	1.35	1.38	1.38	1.37	1.36
12	1.35	1.37	1.38	1.34	1.39	1.37	1.36	1.37	1.37	1.35
13	1.34	1.36	1.37	1.36	1.37	1.36	1.36	1.38	1.35	1.38
14	1.35	1.38	1.40	1.35	1.39	1.35	1.38	1.35	1.36	1.40
15	1.34	1.39	1.39	1.38	1.37	1.37	1.37	1.36	1.36	1.41
16	1.38	1.37	1.39	1.37	1.38	1.37	1.36	1.37	1.35	1.39
17	1.37	1.38	1.36	1.37	1.36	1.37	1.35	1.37	1.37	1.36
18	1.38	1.39	1.38	1.35	1.37	1.36	1.36	1.35	1.38	1.37
19	1.36	1.39	1.36	1.38	1.36	1.38	1.36	1.36	1.38	1.37
20	1.35	1.36	1.37	1.39	1.37	1.37	1.34	1.37	1.37	1.37
21	1.34	1.39	1.38	1.35	1.38	1.36	1.35	1.37	1.35	1.36
22	1.38	1.36	1.37	1.37	1.38	1.36	1.36	1.35	1.37	1.35
23	1.39	1.37	1.40	1.40	1.36	1.39	1.37	1.38	1.38	1.37
24	1.40	1.40	1.39	1.41	1.37	1.40	1.40	1.38	1.39	1.40
Ave.	1.36	1.38	1.38	1.37	1.37	1.36	1.36	1.36	1.37	1.37
SD	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02

Table C-6 : The solid density values of the CT-01a toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	1.45	1.45	1.44	1.44	1.46	1.44	1.44	1.44	1.44	1.44
2	1.45	1.44	1.45	1.43	1.45	1.44	1.44	1.43	1.45	1.45
3	1.46	1.44	1.44	1.45	1.46	1.46	1.44	1.44	1.46	1.46
4	1.74	1.45	1.44	1.45	1.46	1.44	1.44	1.45	1.46	1.45
5	1.46	1.45	1.45	1.45	1.47	1.45	1.45	1.44	1.47	1.46
6	1.47	1.46	1.44	1.46	1.46	1.46	1.46	1.45	1.47	1.47
7	1.47	1.46	1.44	1.46	1.46	1.46	1.47	1.45	1.48	1.46
8	1.47	1.47	1.45	1.47	1.47	1.46	1.47	1.45	1.47	1.46
9	1.47	1.46	1.46	1.48	1.46	1.46	1.47	1.46	1.47	1.47
10	1.46	1.46	1.46	1.48	1.47	1.46	1.47	1.46	1.48	1.47
11	1.47	1.46	1.46	1.48	1.48	1.47	1.48	1.46	1.47	1.47
12	1.46	1.46	1.47	1.48	1.47	1.47	1.49	1.46	1.48	1.47
13	1.47	1.47	1.47	1.48	1.46	1.47	1.49	1.47	1.48	1.47
14	1.47	1.47	1.47	1.48	1.47	1.48	1.48	1.47	1.49	1.47
15	1.47	1.47	1.48	1.50	1.48	1.49	1.47	1.49	1.49	1.49
16	1.48	1.48	1.48	1.49	1.49	1.50	1.49	1.49	1.50	1.49
17	1.47	1.48	1.49	1.49	1.49	1.48	1.49	1.50	1.49	1.49
18	1.47	1.49	1.48	1.49	1.48	1.48	1.49	1.49	1.49	1.50
19	1.47	1.48	1.48	1.49	1.48	1.49	1.49	1.49	1.49	1.51
20	1.47	1.49	1.47	1.48	1.48	1.48	1.48	1.48	1.50	1.49
21	1.47	1.49	1.46	1.47	1.48	1.48	1.49	1.48	1.49	1.48
22	1.48	1.48	1.48	1.47	1.48	1.47	1.48	1.48	1.49	1.49
23	1.47	1.48	1.46	1.46	1.47	1.48	1.49	1.47	1.48	1.48
24	1.46	1.47	1.45	1.46	1.47	1.47	1.48	1.46	1.46	1.46
Ave.	1.48	1.47	1.46	1.47	1.47	1.47	1.47	1.47	1.48	1.47
SD	0.06	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02

Table C-7 : The solid density values of the CT-01c toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	1.45	1.43	1.44	1.44	1.44	1.44	1.44	1.43	1.46	1.45
2	1.46	1.44	1.45	1.45	1.44	1.45	1.46	1.43	1.47	1.45
3	1.46	1.44	1.45	1.45	1.46	1.46	1.46	1.44	1.48	1.45
4	1.46	1.44	1.45	1.45	1.45	1.47	1.47	1.44	1.47	1.45
5	1.46	1.45	1.46	1.45	1.46	1.47	1.46	1.44	1.47	1.46
6	1.46	1.45	1.46	1.45	1.45	1.46	1.46	1.46	1.46	1.46
7	1.46	1.46	1.46	1.46	1.45	1.46	1.45	1.46	1.46	1.47
8	1.46	1.45	1.45	1.46	1.45	1.46	1.46	1.46	1.46	1.46
9	1.47	1.46	1.45	1.46	1.46	1.46	1.46	1.46	1.46	1.47
10	1.46	1.45	1.44	1.45	1.45	1.47	1.47	1.46	1.46	1.46
11	1.46	1.45	1.44	1.45	1.45	1.46	1.47	1.46	1.47	1.46
12	1.47	1.45	1.44	1.45	1.45	1.47	1.47	1.46	1.47	1.46
13	1.46	1.46	1.45	1.45	1.45	1.46	1.46	1.45	1.46	1.46
14	1.47	1.46	1.45	1.46	1.45	1.45	1.46	1.46	1.47	1.46
15	1.47	1.45	1.46	1.45	1.46	1.46	1.45	1.46	1.47	1.45
16	1.46	1.46	1.45	1.47	1.46	1.45	1.46	1.45	1.46	1.46
17	1.46	1.45	1.45	1.46	1.45	1.44	1.45	1.45	1.47	1.46
18	1.45	1.45	1.45	1.46	1.44	1.45	1.45	1.45	1.46	1.46
19	1.45	1.44	1.45	1.46	1.44	1.45	1.46	1.45	1.46	1.45
20	1.44	1.44	1.44	1.45	1.44	1.45	1.45	1.45	1.45	1.45
21	1.43	1.44	1.45	1.45	1.46	1.45	1.45	1.45	1.45	1.44
22	1.43	1.43	1.45	1.45	1.43	1.44	1.44	1.45	1.45	1.44
23	1.43	1.43	1.44	1.45	1.45	1.44	1.44	1.44	1.45	1.45
24	1.43	1.43	1.44	1.45	1.44	1.44	1.44	1.44	1.44	1.44
Ave.	1.45	1.45	1.45	1.45	1.45	1.45	1.46	1.45	1.46	1.46
SD	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table C-8 : The solid density values of the CT-01d toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	1.48	1.50	1.49	1.48	1.47	1.48	1.46	1.47	1.47	1.48
2	1.49	1.49	1.50	1.48	1.46	1.49	1.47	1.47	1.49	1.50
3	1.50	1.50	1.51	1.49	1.47	1.51	1.47	1.48	1.50	1.51
4	1.48	1.51	1.51	1.49	1.48	1.50	1.47	1.49	1.49	1.51
5	1.48	1.51	1.51	1.50	1.49	1.49	1.47	1.49	1.49	1.52
6	1.50	1.50	1.51	1.51	1.49	1.50	1.49	1.50	1.49	1.51
7	1.49	1.51	1.51	1.50	1.50	1.51	1.49	1.51	1.51	1.52
8	1.50	1.51	1.51	1.50	1.51	1.51	1.51	1.51	1.51	1.52
9	1.50	1.51	1.51	1.51	1.51	1.52	1.50	1.52	1.53	1.52
10	1.51	1.51	1.52	1.51	1.51	1.52	1.51	1.52	1.52	1.52
11	1.52	1.51	1.52	1.51	1.52	1.52	1.50	1.52	1.54	1.52
12	1.52	1.52	1.52	1.52	1.53	1.52	1.52	1.52	1.54	1.52
13	1.52	1.51	1.52	1.52	1.53	1.52	1.52	1.53	1.53	1.54
14	1.52	1.52	1.52	1.52	1.52	1.53	1.52	1.53	1.52	1.54
15	1.51	1.52	1.52	1.52	1.51	1.52	1.52	1.52	1.54	1.54
16	1.52	1.51	1.52	1.51	1.51	1.52	1.53	1.54	1.54	1.54
17	1.51	1.50	1.51	1.50	1.51	1.52	1.51	1.52	1.53	1.54
18	1.51	1.50	1.51	1.51	1.52	1.51	1.52	1.52	1.53	1.53
19	1.50	1.51	1.51	1.51	1.51	1.51	1.52	1.52	1.53	1.54
20	1.50	1.51	1.51	1.50	1.51	1.53	1.52	1.53	1.52	1.53
21	1.50	1.50	1.50	1.50	1.52	1.51	1.51	1.52	1.52	1.53
22	1.50	1.50	1.49	1.50	1.51	1.52	1.51	1.53	1.52	1.52
23	1.51	1.49	1.49	1.50	1.50	1.50	1.51	1.52	1.51	1.52
24	1.50	1.47	1.49	1.50	1.49	1.51	1.50	1.51	1.51	1.50
Ave.	1.50	1.51	1.51	1.50	1.50	1.51	1.50	1.51	1.52	1.52
SD	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02

Table C-9 : The background density values of the CT-01b toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
2	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
3	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
4	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
5	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
6	0.01	0.02	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
7	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
8	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
9	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
10	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
11	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
13	0.01	0.02	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.02	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02
15	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02
16	0.02	0.02	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02
17	0.02	0.02	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02
18	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
19	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.02
20	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.02
21	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.02
22	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.02
23	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.02
24	0.01	0.02	0.00	0.00	0.02	0.01	0.01	0.02	0.02	0.02
Ave.	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.01
SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

Table C-10 : The background density values of the CT-01b-1 toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
14	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
15	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
16	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
18	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01
19	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01
20	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01
21	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01
22	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02
23	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
24	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Ave.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SD	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00

Table C-11 : The background density values of the CT-01b-2 toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
12	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.00
13	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.00
14	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.00
15	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01
16	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
17	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
18	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
19	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
20	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
21	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
22	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
23	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
24	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.01
Ave.	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01
SD	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00

Table C-12 : The background density values of the CT-01b-3 toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
2	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
3	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01
4	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01
5	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01
6	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01
7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
12	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
13	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01
14	0.01	0.01	0.02	0.01	0.00	0.00	0.01	0.01	0.01	0.01
15	0.00	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.01
16	0.00	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.02
17	0.01	0.01	0.02	0.02	0.00	0.01	0.00	0.01	0.01	0.02
18	0.00	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02
19	0.00	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02
20	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.02
21	0.00	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.01
22	0.00	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.02
23	0.00	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.02
24	0.00	0.01	0.02	0.02	0.01	0.00	0.00	0.01	0.02	0.02
Ave.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SD	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00

Table C-13 : The background density values of the CT-01 toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02
2	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
3	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
4	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
5	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
6	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
7	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02
8	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
9	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
10	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
11	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02
12	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02
13	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
14	0.01	0.01	0.01	0.01	0.03	0.02	0.02	0.02	0.03	0.03
15	0.02	0.01	0.01	0.01	0.03	0.03	0.02	0.02	0.03	0.03
16	0.02	0.01	0.01	0.02	0.03	0.03	0.02	0.02	0.03	0.03
17	0.01	0.01	0.01	0.02	0.03	0.03	0.02	0.02	0.02	0.03
18	0.02	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.03	0.03
19	0.02	0.01	0.01	0.02	0.03	0.03	0.03	0.02	0.03	0.03
20	0.02	0.01	0.01	0.02	0.03	0.03	0.02	0.02	0.03	0.03
21	0.02	0.01	0.01	0.01	0.03	0.03	0.02	0.02	0.03	0.03
22	0.02	0.01	0.01	0.01	0.03	0.02	0.02	0.02	0.03	0.03
23	0.02	0.01	0.01	0.02	0.03	0.03	0.02	0.02	0.03	0.03
24	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.02
Ave.	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
SD	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01

Table C-14 : The background density values of CT-01a toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02
2	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02
3	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02
4	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02
5	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
6	0.03	0.02	0.02	0.01	0.02	0.02	0.03	0.02	0.02	0.02
7	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
8	0.03	0.02	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.02
9	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03
10	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.03
11	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.02
12	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.02
13	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
14	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.02
15	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02
16	0.04	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.02	0.03
17	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
18	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.02	0.02
19	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.02	0.02
20	0.04	0.05	0.05	0.04	0.05	0.04	0.04	0.05	0.02	0.03
21	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.02	0.03
22	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.02	0.03
23	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.03	0.03
24	0.03	0.03	0.04	0.02	0.03	0.03	0.03	0.03	0.03	0.02
Ave.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
SD	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00

Table C-15 : The background density values of the CT-01c toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
2	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
3	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03
4	0.02	0.01	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.03
5	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.03
6	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.02	0.02	0.03
7	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.02	0.03
8	0.01	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.02	0.04
9	0.01	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03
10	0.01	0.01	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03
11	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.03
12	0.01	0.01	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03
13	0.01	0.01	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02
14	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02
15	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02
16	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01
17	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01
18	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01
19	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
20	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01
21	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01
22	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
23	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
24	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Ave.	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02
SD	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01

Table C-16 : The background density values of the CT-01d toner

Position \ Copy number	1	2	3	4	5	6	7	8	9	10
1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.03
3	0.02	0.02	0.01	0.02	0.02	0.03	0.02	0.02	0.02	0.02
4	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.02
5	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
7	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
8	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
9	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.02
10	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.03
11	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.03
12	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.02
13	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.03
14	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.02	0.02	0.02
15	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.03	0.02	0.02
16	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
17	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.03	0.02	0.02
18	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03
19	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
20	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
21	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02
22	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.03
23	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.03
24	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.03
Ave.	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02
SD	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00

Table **C-17 :** Dot gain percentage of various the toners at 50% screen rulling by printing with Oki printer

Toners	**% Halftone**	**Copy number**										**Ave.**	**SD**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
CT-01a	20	6.42	8.08	6.00	6.04	7.08	6.42	6.63	5.04	6.00	6.58	6.43	0.79
	40	13.54	13.96	13.00	11.92	13.75	13.21	12.33	10.83	15.33	11.17	12.90	1.37
	60	18.67	16.96	18.04	19.17	15.08	17.58	15.67	17.71	20.08	17.71	17.67	1.51
	80	13.75	14.54	14.21	12.92	14.46	13.63	13.79	14.13	13.79	14.21	13.94	0.48
CT-01b	20	0.88	0.96	0.08	-0.33	-0.29	0.21	-0.83	0.04	-0.79	0.25	0.02	0.61
	40	8.71	8.04	8.58	5.38	7.50	3.92	6.75	4.17	6.00	5.71	6.48	1.73
	60	17.25	15.92	15.79	17.13	16.54	16.25	14.33	15.46	16.00	15.13	15.98	0.88
	80	14.75	14.79	15.46	14.58	15.25	15.33	16.96	14.33	14.63	14.00	15.01	0.82
CT-01c	20	6.50	5.96	5.58	4.21	5.79	5.58	6.17	6.04	7.04	7.04	5.99	0.82
	40	14.13	14.25	13.92	15.79	13.92	14.71	13.67	14.38	14.71	15.07	14.46	0.65
	60	19.88	16.50	17.58	19.71	16.50	16.96	18.46	20.00	18.42	19.67	18.37	1.41
	80	15.25	15.33	15.21	14.63	15.42	14.96	15.50	15.21	13.79	13.75	14.90	0.65
CT-01d	20	5.71	4.92	5.00	3.54	5.96	5.25	5.58	6.00	5.88	3.96	5.18	0.85
	40	14.50	13.46	14.25	14.13	13.79	14.63	13.33	14.58	12.75	15.46	14.09	0.78
	60	18.63	19.38	17.04	16.50	18.63	17.08	18.13	19.33	19.58	19.13	18.34	1.11
	80	15.58	14.29	15.83	15.71	15.92	15.67	16.33	16.38	16.13	15.96	15.78	0.59
CT-01b-1	20	3.00	1.83	0.58	1.42	2.83	0.83	2.04	2.29	3.00	2.13	2.00	0.85
	40	5.79	8.46	8.71	7.67	7.13	7.71	6.04	7.96	6.17	7.25	7.29	3.24
	60	14.54	14.42	14.75	14.58	14.25	13.83	13.25	13.29	12.46	15.50	14.09	0.89
	80	12.25	12.71	15.50	14.33	12.71	12.00	11.50	12.71	12.38	11.54	12.76	1.25
CT-01b-2	20	0.67	0.92	-0.13	0.67	1.08	0.04	0.04	0.67	1.00	0.17	0.51	0.44
	40	5.04	6.54	4.25	4.71	3.83	8.50	6.75	6.67	5.04	3.92	5.53	1.52
	60	16.04	14.00	12.04	12.74	12.71	13.92	13.83	12.54	13.33	12.63	13.38	1.15
	80	12.42	10.88	11.25	12.83	12.63	13.63	11.13	12.08	13.67	9.83	12.03	1.25
CT-01b-3	20	-2.58	-1.75	-1.71	-1.92	-2.67	-1.54	-2.67	-4.42	-4.08	-4.00	-2.77	1.07
	40	-0.33	2.75	1.54	0.63	0.25	-0.96	-2.13	1.58	-0.33	1.29	0.43	1.42
	60	8.79	12.33	9.46	10.17	9.54	10.04	10.96	10.21	10.54	9.58	10.16	0.98
	80	9.92	8.67	9.67	7.96	8.92	9.54	9.96	8.29	7.67	6.83	8.74	1.05
CT-01	20	-3.33	-1.04	-1.54	-0.21	-2.08	-1.42	-2.29	-0.21	-1.00	-2.04	-1.52	0.97
	40	-0.29	0.58	2.17	-0.71	-1.29	-1.33	-2.33	-1.88	1.13	-0.58	-0.45	1.40
	60	6.21	6.79	2.67	3.54	3.54	2.63	4.67	5.29	4.33	3.46	4.31	1.43
	80	6.88	5.92	3.83	4.42	5.21	3.25	0.58	3.88	3.83	3.50	4.13	1.70

VITA

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