

## CHAPTER II

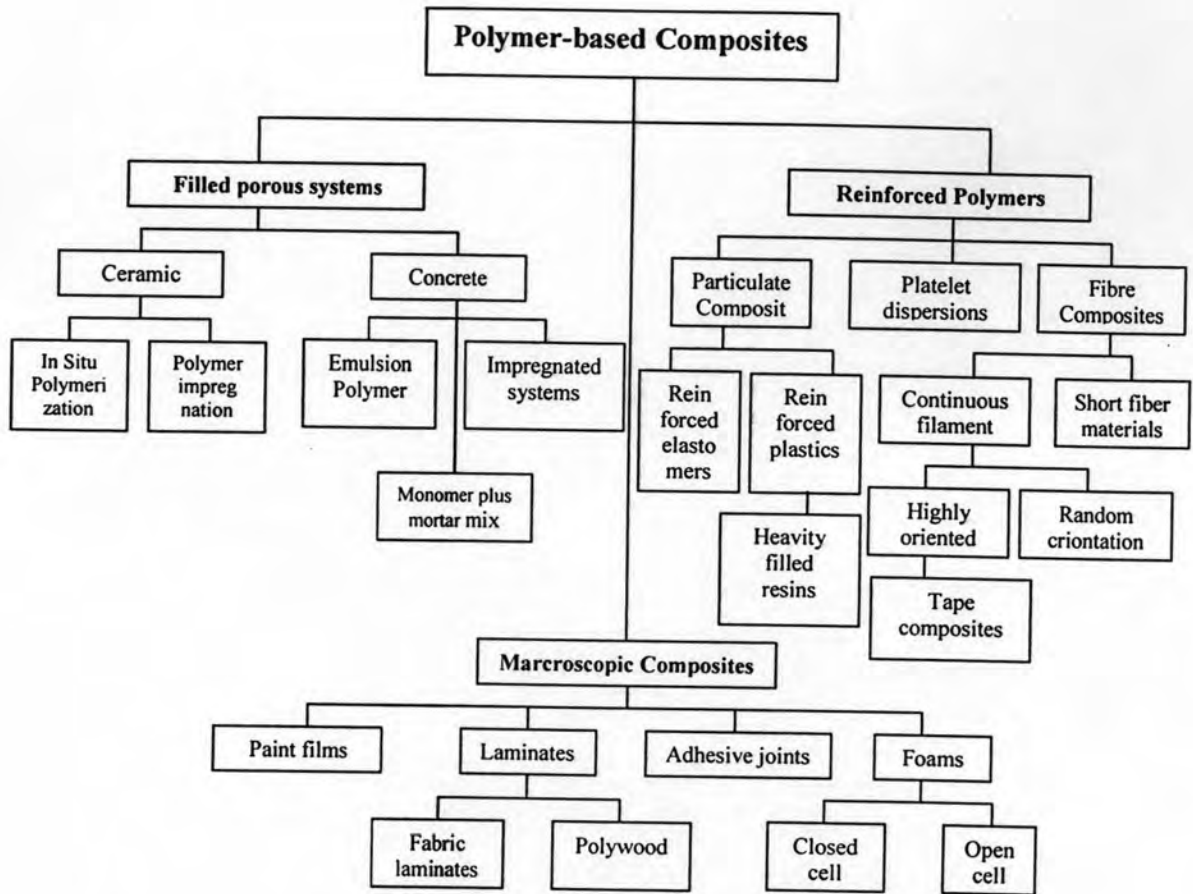
### THEORY

#### 2.1 Composites

Composite material can be defined as a macroscopic combination of two or more distinct materials, having a recognizable interface between them. However, because composites are usually used for their structural properties, the definition can be restricted to include only those materials that contain reinforcement (such as fibers or particles) supported by a binder (matrix) material. The constituents can be organic, inorganic or metallic (synthetic and naturally occurring) in the form of the particles, rods, fibers, plates, foams, etc. Compared with homogeneous materials, these additional variables often provide greater latitude in optimizing, for a given application, such physically uncorrelated parameters as strength, density, electrical properties, and cost. Further, the composite may be the only effective vehicle for exploiting the unique properties of certain special material (Reinhart, et al., 1989; Hillig et al., 1981).

##### 2.1.1 Classification of Composite Materials

Most polymer-based composites do not have a formal nomenclature at this time, although it could well be argued that one is solely needed. Scheme 2.1 provides a polymer composite classification. There are three major types of polymer composites: those where the matrix is non-polymeric (although wood, clearly polymeric, plays a matrix role here); those with the polymer as the matrix, usually being reinforced or filled with another material, such as fibers, plates, or particulates; and those where some degree of dual-phase continuity prevails, as in laminates foams. More importantly, they may suggest to the reader yet new combinations of matter.



**Scheme 2.1:** Classifications of polymer-based composites (Birley et al., 1988).

### 2.1.2 Theory of the Action of Filler and Reinforcements

The action of active filler can be attributed to several mechanisms (Gachter and Muller, 1987). Some fillers form chemical bond with the material to be reinforced, such as carbon black produces crosslink in elastomers by means of radical reaction.

Other fillers act mainly through the volume they take up. The chain molecules of the polymer to be reinforced cannot assume all the conformational positions that are basically possible. Moreover, it can be assumed that in certain zones around the filler particles the polymeric phase differs in structure and properties from the polymer matrix. The polymer segments attached to filler surfaces by primary or

secondary valence bonds in turn caused a certain immobilization of adjacent segment and circumstances permitting an orientation of the polymer matrix. The increase in glass transition temperatures observed in filled polymers, resulting from the limitations of mobility in the filler/polymer boundary zone, can be regarded as confirmation of this theoretical concept.

The zone direct to filler surface, whose structure would appear to be ordered, causes a stiffening of the material as a whole. Lower deformability and higher strength are also due to this composite nature. Uniform distribution of fillers is especially important, so that as many polymer chains as possible can be bound to the free filler surface. The free surface energy and the polarity of the bond between the filler and the matrix are important factors in this regard.

Another mode of action of active fillers is from the fact that when the polymer molecules are subjected to mechanical stress, they can slider off the filler surface. The impact energy can; therefore, be more uniformly distributed and impact strength increases as, for example, in the unplasticized PVC/calciumcarbonate system. In some cases, microcraze formation that destroys the impact energy at the filler/polymer interface is also facilitated.

### **2.1.3 Mechanical Properties of Particulate Filled Polymer**

An important attribute of polymers is ability to modify their inherent physical properties by the addition of certain fillers, while retaining their characteristic processing ease. Addition of filler in varying degree also affects the basic mechanical properties of the polymer. In many cases the changes in the mechanical properties of the filled polymer can be predicted by some theoretical and empirical models.

#### **2.1.3.1 Tensile Modulus**

In principle, the modulus of composite materials depends on the geometry, particle size distribution, concentration of filler, and etc. It has been represented by a large number of equations as seen in scheme 2.2.

Model	Equation
Einstein	$E_R = 1 + 2.5\phi$
Guth	$E_R = 1 + 2.5\phi + B\phi^2$ ; $B$ usually 14.1
Mooney	$E_R = \exp\left[\frac{K\phi}{1 - \phi/\phi_m}\right]$ ; $K$ usually 2.5
Kerner	$E_R = \frac{G_f\phi/[(7-5\nu)G_p + (8-10\nu)G_f] + \phi/[15(1-\nu)]}{G_p\phi/[(7-5\nu)G_p + (8-10\nu)G_f] + \phi/[15(1-\nu)]}$
Thomas	$E_R = 1 + 2.5\phi + 10.05\phi^2 + 0.00273\exp[16.6\phi]$
Frankle-Acrivos	$E_R = 1 + \frac{9}{8}\left[\frac{(\phi/\phi_m)^{1/3}}{1 - (\phi/\phi_m)^{1/3}}\right]$
Quemada	$E_R = \frac{1}{(1 - 0.5K\phi)^2}$ ; $K$ usually 2.5
Nielsen	$E_R = \frac{1 + A\phi}{1 - \psi\phi}$ ; $\psi = 1 - \left(\frac{1 - \phi_m}{\phi_m^2}\right)$ ; $A = f(\text{geometry})$

**Scheme 2.2:** Important models for predicting modulus value of filled polymer (Bigg et al., 1987).

**Note:**  $E_R$  = relative modulus,  $\phi$  = volume fraction of filler,  $G_f$  = shear modulus of filler,  $G_p$  = shear modulus of polymer,  $\nu$  = Poisson ratio of polymer,  $\phi_m$  = maximum packing fraction of filler.

Einstein's equation is applicable only for materials filled with low concentrations of non-interactive spheres. Whereas, Guth's equation is an expansion of Einstein's to account for inter-particle interactions at higher filler concentrations. Thomas's equation is an empirical relationship based on data generated with monodisperse spherical particles. Quemada introduces a variable coefficient to account for interparticle interactions and differences in particle geometry. Mooney and Frankle-Acrivos introduce the concept of maximum packing fraction to account

for differences in particle geometry. Nielsen's modification of Kerner's equation takes into account both the maximum packing fraction of the filler, interparticle interactions, and the relative modulus of the two constituents. The maximum packing fractions and shape factors according to those models are shown in Table 2.1 and 2.2.

**Table 2.1:** Maximum packing fraction of several fillers types (Bigg et al., 1987).

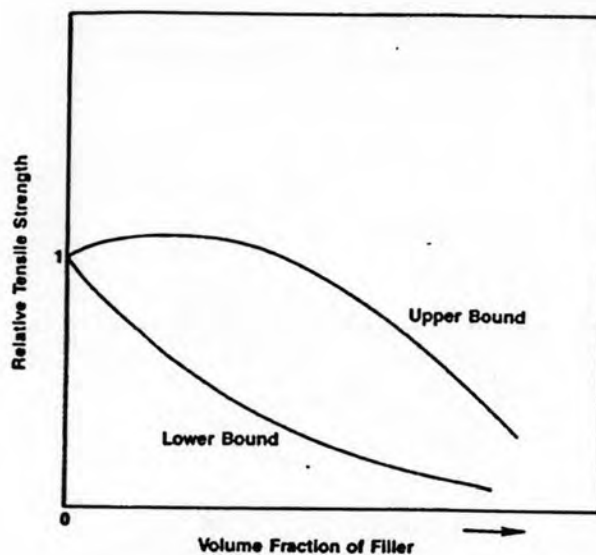
Filler types	Packing Geometry	$\phi_m$
Spheres	Hexagonal	0.74
Spheres	Face centered cubic	0.74
Spheres	Body centered cubic	0.60
Spheres	Simple cubic	0.52
Spheres	Random	0.637
Irregular	Random (L/D = 5:1)	0.637
Fibers	Random (L/D = 20:1)	0.52
Fibers	Random	0.20
Fibers	Unidirectional random	0.637
Flakes	Random (L/t = 56:1)	0.33

**Table 2.2:** Sharp factor for several filler types (Bigg et al., 1987).

Filler types	Aspect Ratio	A
Spheres	1	1.5
cubes	1	2.0
Flakes	?	2.0
Random fibers	2	1.58
Random fibers	5	2.45
Random fibers	10	4.93

### 2.1.3.2 Tensile Strength

The tensile strength of a filled polymer is more difficult to predict because it depends strongly on local polymer-filler interactions, as well as the above factors. Two general tensile strength-filler concentration responses are possible. These responses are typified by the curves drawn in Figure 2.1.



**Figure 2.1:** Typical tensile strength-concentration curves for filled polymers showing upper and lower bound responses (Bigg et al., 1987).

The upper bound response assumes strong adhesion between the polymer and filler, while the lower bound response assumes weak, or no, adhesion between the two materials. Most particulate filled polymers fall somewhere between these two responses. The upper bound and lower bound responses for the tensile strength of a filled polymer are often represented by the following equation 2.1 and 2.2.

- For lower bound response

$$\sigma_c = \sigma_p(1 - a\phi^b) \quad (2.1)$$



**Where:**

$\sigma_c$  is the tensile strength of the filled composition.

$\sigma_p$  is the tensile strength of the polymer.

$a$  is a constant related to stress concentrations.

$b$  is a constant related to the geometry of the filler.

$\phi$  is the volume fraction of the filler.

**Note:** For spherical filler particles having no adhesion to the polymer matrix “a” has been found equal to 1.21. When there is some adhesion between the polymer and filler, there is less stress induced in the polymer by the filler and “a” smaller than 1.21. “b” has been found to equal 2/3 when the sample fails by random fracture, while it equal 1 when the sample fails by planar fracture.

- For upper bound response

$$\sigma_c = \sigma_p (1 - a\phi^b + c\phi^d) \quad (2.2)$$

**Where:**

$c$  and  $d$  should be strong indicators of polymer-filler adhesion.

**2.1.3.3 Aspect Ratio**

Aspect ratio is the relationship of the horizontal dimension (the width of the screen) to the vertical dimension (the height). Reinforcing occurs if filler has an aspect ratio greater than some critical value. The critical aspect ratio is expressed as:

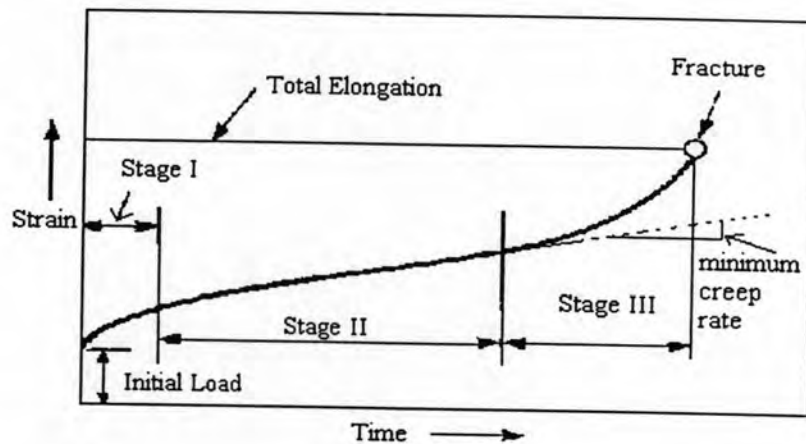
$$\left(\frac{L}{D}\right)_c = \frac{\sigma_f}{2\tau_i} \quad (2.3)$$

**Where:**  $\sigma_f$  is the tensile strength of the filler particle.

$\tau_i$  is the interfacial adhesion between the polymer and filler.

### 2.1.3.4 Creep

Creep is one of the principal properties which needs to be addressed when developing and using polymer composites because most materials respond differently depending on the time required to complete the mechanical test (Bodig and Jayne, 1982). The deflection of materials under short-term and long-term loading is sometimes critical to their performance (Lee et al., 2004). Creep causes failures in three distinct stages of deformation; primary, secondary, and tertiary, as shown in Figure 2.2.



**Figure 2.2:** Regions of creep behavior strain vs. time.

(<http://www.materialsengineer.com>)

- **Stage I:** where the strain rate stabilizes and hence decreases (primary or transient creep),
- **Stage II:** where the curve is linear, i.e. the strain rate (slope of the curve) is constant and minimum (secondary or steady state creep),
- **Stage III:** where the strain rate starts to increase gradually until the sample fractures (tertiary creep).



## 2.2 Matrix

Matrix is an essentially homogeneous resin or polymer material in which the fiber system of composite is embedded. The purpose of composite matrix is to bind the fiber together by virtue of its cohesive and adhesive characteristics, to transfer stresses between the fibers, to provide a barrier against an adverse environment, and to protect the surface of the fibers from mechanical abrasion.

Polypropylene (PP) is a thermoplastic polymer that is attractive thanks to its wide industrial applications. It is synthesized by placing propylene monomer under controlled conditions of heat and pressure in the presence of organometallic, stereospecific catalysts (Ziegler-Natta type). Polypropylene has low specific gravity, excellent chemical resistant, good mechanical properties, low moisture absorption, highest melting point (in the family of olefin fibers), and easy to process at moderate cost (especially per unit volume). Table 2.3 shows the properties of Polypropylene compared with high density polyethylene (HDPE) and low density polyethylene (LDPE).

**Table 2.3:** Properties of polypropylene and other polyolefin (Fried et al., 1995).

Properties	ASTM	PP	LDPE	HDPE
Specific gravity	D792	0.90-0.91	0.91-0.93	0.94-0.97
Crystallinity (%)	-	82	50-70	80-95
Melting temperature (°C)	-	165-171	98-120	127-135
Tensile strength (Mpa)	D638	31-41	4.1-16	21-38
Tensile modulus (Gpa)	D638	1.10-1.55	0.1-0.26	0.41-1.24
Elongation-to-break (%)	D638	100-600	90-800	20-130
Impact strength Notched Izod (J/m)	D256	21-53	No break	27-1068
Heat deflection temperature at 455 Kpa (°C)	D648	115-125	38-49	60-88

### 2.3 Filler (Woodflour)

In recent year, significant efforts have been made to manufacture thermoplastic composites using natural fibers as woodflour, wheat straw, nut shell fiber, and jute fiber. The quality of filler depends upon factors such as distribution and average size of the particles, their sharp and porosity, chemical nature of the surface and content of impurities (Albano et al., 2002). The use of woodflour as a filler is a choice offering an economic solution for the increasing costs of wood sawdust and to reduce the environmental pollution. The woodflour has offers several benefits, including low cost, high specific properties, renewable nature, and biodegradability (Wu et al., 1999). Table 2.4 shows the components of natural woods to consist of cellulose, hemicellulose, lignin, pectin, wax and water-soluble substances. The cellulose, hemicellulose and lignin as the key components controlling to physical properties of the woods (Bci. et. al, 1999).

Cellulose, the major wood constituent, comprises approximately 43% by weight of wood substance. It is a high molecular weight linear polymer consisting of chains of bonded glucose monomers. During the growth of tree, cellulose molecules are arranged into ordered stands called fibrils, which in turn are organized into the large structural elements comprising the cell wall of wood fibers.

The hemicelluloses are associated with cellulose and are polymers built from several different kinds of sugar monomers. The relative amounts of these sugars vary markedly with species. Hemicellulose plays an important role in fiber-to-fiber bonding in the papermaking process.

Lignin comprises 23-33% of soft wood, and 16-25% of hard wood. It occurs in the wood throughout the cell wall, but is concentrated toward the outside of the cells and between cells. Lignin is a three-dimensional phenylpropane polymer.

The extractives may range from roughly 5-8%, depending on such factors as species, growth conditions, and time of year the tree is cut. The extraneous materials are both organic and inorganic. The organic component contributes to such properties of wood as color, order, taste, decay resistance, density, hygroscopicity, and flammability. Extractives include tannins, polyphenolics, coloring matters, essential oils, and fats. The inorganic component of the extraneous material generally

comprises 0.2-1.0% of the wood substance, although higher values are occasionally reported. Calcium, potassium, and magnesium are the more abundant elemental constituent.

The woodflour from rubber wood (*Hevea brasiliensis*) is used as filler in this research because of its availability and this wood is widely grown in Thailand. The properties of rubber wood are shown in Table 2.5.

**Table 2.4:** Chemical constituents of natural wood (Bci. et al., 1999).

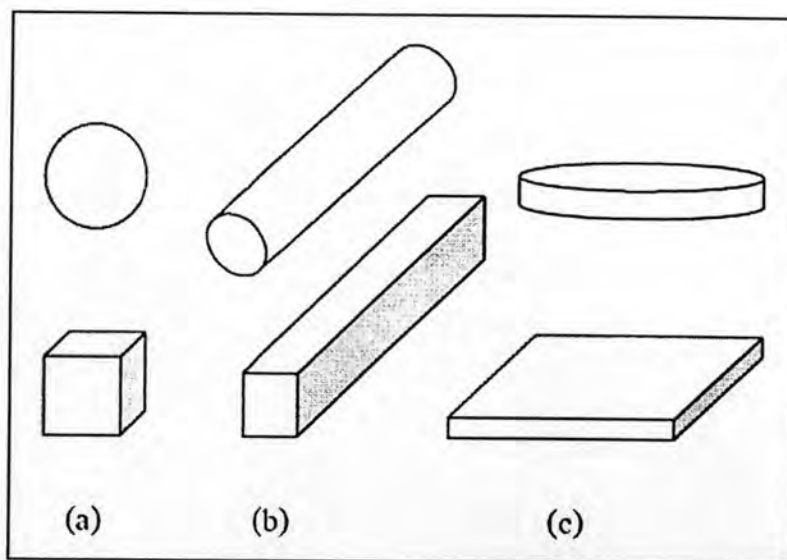
Components	Percentage composition	
	Softwood (coniferous)	Hardwood (deciduous)
Cellulose	43	43
Hemicellulose	~28	~38
Lignin	23-33	16-25
Extractives	5-8	2-4
Ash	~1	~1

**Table 2.5:** Properties of rubber wood (<http://www.mnflooring.com>).

Properties	Value
Density (g/cm <sup>3</sup> )	0.56-0.64
Tangential Shrinkage Coefficient (%)	1.2
Radical Shrinkage Coefficient (%)	0.8
Hardness (N)	4350
Static Bending, N/mm at 12% MC	66
Modulus of elasticity, N/mm at 12% MC	9700

## 2.4 Compatibilizer

The reinforcement in filled polymer composites depends on many factors, including the properties of the polymer and filler, the size and shape of filler as seen in Figure 2.3, the phase state of the polymer (crystalline, rubbery, etc.), the process by which the filled polymer composite is manufactured, and the nature of the interphase between the polymer matrix and the filler. While all these factors, and more, have an effect on the final composite properties, it is typically the properties of the interphase that determine the extent to which stress in the matrix is transferred to the filler. This is especially relevant for wood filled polymer composites, where poor wettability and lack of adhesion often provide weak interphases and consequently less than maximal composite properties. Improvements of mechanical properties of a wood plastic composite by a compatibilizer are believed to result from enhanced interfacial adhesion. Strong interactions across interfaces of wood and thermoplastic are essential for high strength properties of a wood plastic composite.



**Figure 2.3:** Shapes of reinforcing fillers (a) Particle, (b) Short fiber, (c) Disk

Compatibilizers have been used as a “molecular bridge” to produce a bond between polymer and filler or reinforcement particles. Over forty compatibilizers have been used in the wood plastic composites. Compatibilizers are classified into organic, inorganic, and organic-inorganic groups. Organic agents include isocyanates, anhydrides, amides, imides, acrylates, chlorotriazines, epoxides, organic acids, monomers, polymers, and copolymers. Only a few inorganic compatibilizer, such as silicates, are used in the wood fiber plastic composites. Organic-inorganic agents include silanes and titanates.

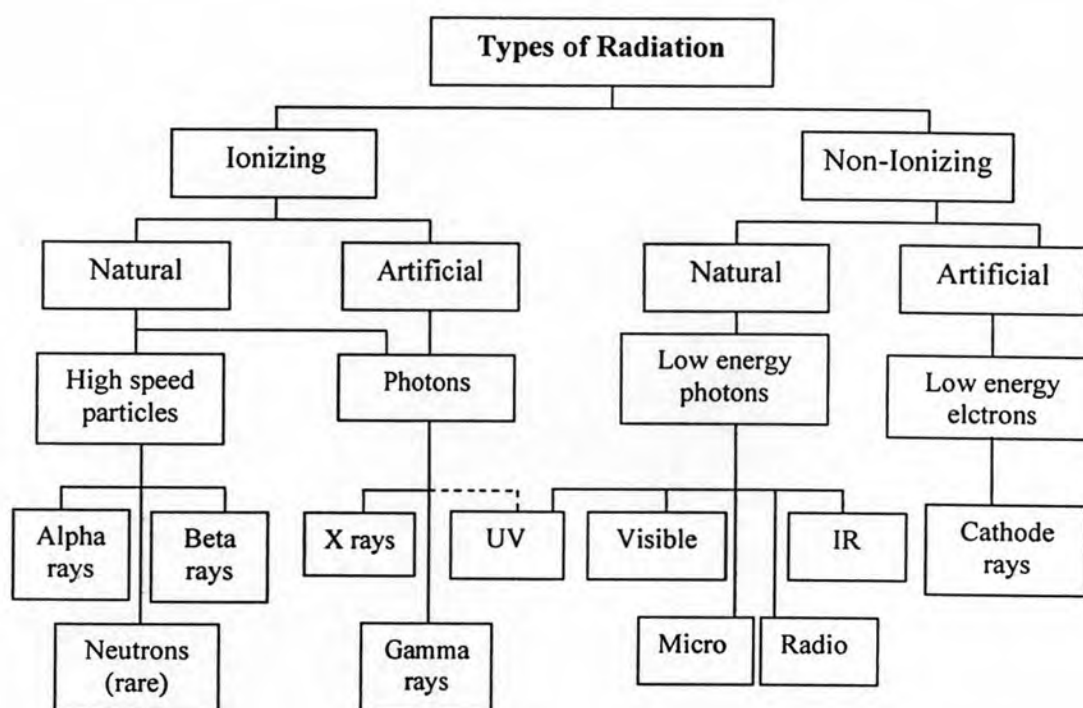
For organic agent types, anhydrides such as MA, AA, SA and PHA are popular compatibilizers in wood fiber plastic composite. MA is  $\alpha$ ,  $\beta$ -unsaturated carbonyl compound, containing one carbon-carbon double bond (C=C) and two carboxylate groups (-COO-). It is usually used to modify the polymer matrix by graft copolymerization. The formed copolymers, e.g., MAPE, MAPP, SEBS-MA and SMA, are used as compatibilizers. In this study, MAPP (maleic anhydride graft polypropylene) is used to modify the surface as a compatibilizer for polypropylene wood composites (Lu et al., 2003).

## 2.5 Radiation

Radiation is the energy that lights or disperses into the waveform or electron such as heat radiation, cosmic radiation, and nuclear radiation, etc.

Most of radiations can be classified as 2 major groups as follows:

1. Natural radiation is the rays in the nature
2. Artificial radiation is the rays that are synthetic.



**Scheme 2.3:** Classifications of radiations (<http://www.quark.physics.uwo.ca>).

### 2.5.1 Radiological Units

The International Commission on Radiological Units made the following recommendations which were approved at the Copenhagen Meeting in 1953:



1. Intensity of radiation is defined as the energy flowing through unit area perpendicular to the beam per unit time. It is expressed in ergs per square centimeter-second or in watts per square centimeter.
2. Quantity of radiation is the time integral of intensity. It is the total energy which has passed through unit area perpendicular to the radiation beam and is expressed in ergs per square centimeter.
3. Absorbed dose of any ionizing radiation is the amount of energy imparted to matter at the place of interest. It is expressed in rads or Gy.
4. Rad is the traditional unit of absorbed dose and is 100 ergs per gram or  $6.25 \times 10^{13}$  electron-volts per gram.
5. Gray (Gy) is the SI unit of absorbed dose and is  $1 \text{ J kg}^{-1}$  or 100 rads.
6. Integral absorbed dose is the integral of the energy absorbed throughout a given region of interest. It is expressed in gram-rads. (1 gram-rad = 100 ergs)
7. Absorbed dose-rate is the absorbed dose per unit time. It is expressed in rads per unit time.

In 1956 the International Commission on Radiological Units made some additional recommendations at the Geneva meeting.

8. Exposure dose of X- or  $\gamma$ -radiation in a certain region is a measure of the radiation based upon its ability to produce ionization. The unit of an exposure dose is the roentgen. One roentgen is an exposure dose of X- or  $\gamma$ -radiation such that the associated corpuscular emission per 0.001293 g of air produces in air ions carrying one electrostatic unit of quantity of electricity of either sign.
9. Exposure dose-rate is the exposure dose per unit time. It is expressed in roentgens per unit time.
10.  $W_a$  whenever ionization methods, are used for the estimation of absorbed dose, the observed ionization must be multiplied by a quantity "W" equal to an average energy dissipated by the ionizing particles in the production of one ion pair in the gas. It is

recommended that the value  $W = 34 \text{ eV}$  be used in the case of air for X- and  $\gamma$ -radiation of quantum energy greater than 20 keV.

### 2.5.2 Dosimetry of Electromagnetic Radiation

The “dose” or the amount of radiation energy imparted to the matter can be measured by “calorimetric measurement”. Energy absorbed in a calorimeter containing a material having radiation absorption characteristics similar to those of the target material irradiated with the same beam characteristics (energy and current). This method gives directly the energy absorbed from a radiation field. Calorimetry is also a primary standard used to calibrate chemical dosimeter.

### 2.5.3 Gamma Rays

The first scientist who found the phenomena of radioactivity is Henri Becquerel in March, 1896. Gamma ray is electromagnetic wave that has no mass and weight, no deviation in the magnetic field and has the power of high penetration. It is the result of nuclear process that is generated from the degradation of nucleus of atom. The most of radioisotopes or radioactive sources used is Cobalt-60 ( $^{60}\text{Co}$ ). The gamma rays have short wavelengths in the region of  $3 \times 10^{-9} \text{ cm}$  to  $3 \times 10^{-11} \text{ cm}$  or energy of approximately 40 keV to 4 MeV.

$^{60}\text{Co}$  is the radioactivity which has concentration of gamma ray of 42,814 curies. It was found by George Brandt, a Swedish Chemist, in 1735 and used in 1950 for curing the cancer. In practice, gamma radiation factory will use gamma ray from  $^{60}\text{Co}$ , because it is cheaper than other isotopes and have a half-cycle of only 5.25 years.  $^{60}\text{Co}$  is stable under the environment that has high radiation and can be used at high temperature up to  $1000^\circ\text{C}$ . It gives off two gamma rays/disintegration, one with 1.17 MeV energy and the other one with a 1.33 MeV or a total of 2.5 MeV energy/disintegration.

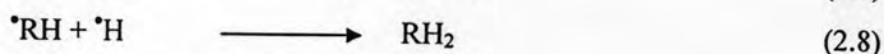
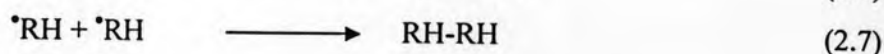
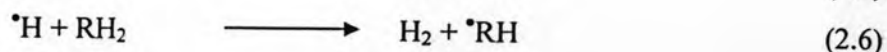
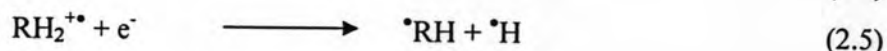
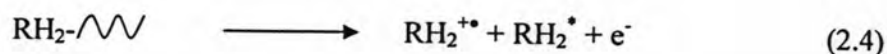
### 2.5.4 Radiation Effects on Polymers

When polymer chain is attacked by ionized radiation, there are two possible outcomes i.e. crosslinking and degradation. For crosslinking, the molecular weight may increase with the formation of a 3D networks, but in degradation, the molecule weight is decreased. Table 2.6 shows the groups of polymers classified by their response with gamma radiation (Klinkularb, 1989).

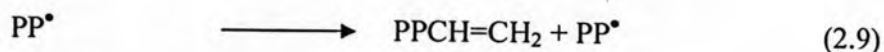
**Table 2.6:** Classification of irradiated polymers with gamma ray (Klinkularb, 1989).

<b>Group 1 Cross-linking Polymer</b>	<b>Group 2 Degradation Polymer</b>
Polyethylene Polypropylene Polystyrene Polyacrylates Polyacrylamide Polyvinyl chloride Polyamides Polyesters Polyvinylpyrrolidone Natural rubber Polysiloxanees Polyvinyl alcohol Polyacroleine	Polyisobutylene Poly-methylstyrene Polymethacrylates Polymethacrylamide Polyvinylidene chloride Cellulose and derivatives Polytetrafluoroethylene Polytrifluorochoeroethylene

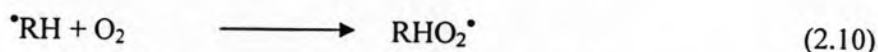
For polypropylene or other organic compound, those contain mainly carbon-carbon and carbon-hydrogen bonds. The possible reaction mechanisms that occur during irradiation are summarized below:



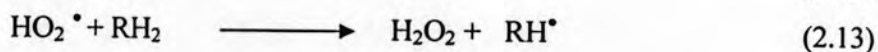
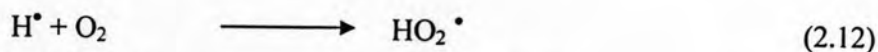
Crosslinking of polypropylene can also occur by reaction (2.9) (Paul, and Bucknall, 2000).



In the presence of oxygen during irradiation, oxygen can react with polymer and become peroxy radical such as:



Reaction (2.11) can be followed by reaction (2.10) leading to chain oxidation of the substrate. The radiolysis is also affected by the reactions of oxygen with hydrogen atoms.



In oxygen condition, oxidative degradation dominates generate the hydroxyl and carbonyl groups that lead to chain scission of polymer chain. The oxidative degradation is caused by the free radical reactions that lead to the formation of the peroxy, as well as chain scission and cause deterioration of mechanical properties. It occurs not only during radiolysis in the presence of air or oxygen, but, if oxygen is available, it can take place for months during the post-irradiation period. Several

factors affect the extent of oxidative degradation such as solubility of oxygen, dose and thickness of the sample (oxygen diffusion) (Paul, and Bucknall, 2000).

### **2.5.5 Radiation Effects on Cellulose and Wood (Punyahlek, 1989).**

#### **2.5.5.1 Radiolysis of Cellulose.**

Important reaction is the frustrating of molecule chain, at the same time; it can make crosslinking when cellulose receives gamma ray. Many chemical changing and endlinking can occur. If pure cellulose derives the rays less than 0.1 kGy, molecule chain is frustrated, but is frustration will clearly occur when derive the ray amount of 10 kGy or higher. Radioactive cellulose is hydrolyzed by acid easier than basic solvent. If radioactive is in the environment that has oxygen, series of =CO or -COOH as well as CO, CO<sub>2</sub>, H<sub>2</sub> and O<sub>2</sub>. CO is derived from series of carboxyl, whereas H<sub>2</sub> and O<sub>2</sub> are derived from frustration of series of alcohol. Radiolysis process of cellulose makes a new network depending the crosslink reaction of independent radical.

#### **2.5.5.2 Radiolysis of Wood.**

Lignin is an important component in wood's cell that its property is more resistant to destruction by gamma ray than that of cellulose due to the fact that lignin has aromatic ring in molecule structure. Aromatic ring system absorbs the ray and disperses energy to around the molecule or some of them. The impact from the ray is less than the series of atom has sensitive to the ray but alone it can't disperse the irradiated energy. Ability of energy dispersion of lignin has prevented the damage from the ray to cellulose in wood's cell wall. Pure lignin will degrade by the ray when it has the radiation dose of upl MGy. If wood receives over 10 kGy of the ray, the wood is degraded and the strength of wood is sacrificed. Generally in polymerization process, use the radiation dose of 1-10 kGy is utilized to affect the change of the structure and strength of wood. If the dose too high such as is high to 100-1000 kGy, it can damage the strength of typical hydrocarbon polymer.

### 2.5.6 Using of Gamma Radiation in Composites Technology

Technology based on the irradiation of composites at room temperature leads to chemical changes through the formation of ions and free radicals. The course of their reactions is influenced by the conditions under which the system has been radiated; for example, in the presence of oxygen, oxidative degradation can predominate. In addition, it can also be influenced by the presence of other additives. Ambient temperature processing and the ability to change the course of resulting chemical reactions by suitable additives have been reported as important factors in the attraction of this technology for the polymer industry.

The major industrial applications of gamma irradiation technology in the field of polymers are based on polymerization, crosslinking, scission, and sterilization of medical disposables. Radiation processing of polymer composite can lead to crosslinking or scission of one or more components, or even to inter-phase (inter-polymer) crosslinking.

The extent of substrate decomposition and the nature of the radiolysis products formed depend on many factors, including

- the functionality of the groups
- the presence of additives, e.g., olefinic or aromatic compounds
- temperature and pressure