References

1. Kirk-Othmer. Encyclopedia of Chemical Technology. 3rd ed. United States of Americapublished by wiley interscience. 1978.
2. Encyclopedia of Science and Technology. United States of America: McGraw-Hill. 1962.
3. J. A. Toledo, M. A. Valenzuela, H. Armendariz, Oxidative dehydrogenation of 1-butene to butadiene on -$Fe_2O_3/ZnAl_2O_4$ and $ZnFe_xAl_{2-x}O_4$ catalysts, Cat. Lett. 30(1995): 279-288.
4. M. Zawadzki, J. Wrzyszcz, Hydrothermal synthesis of nanoporous zinc aluminate with high surface area, Mater. Res. Bull. 35 (2000): 109-114.
5. Kai-Hung Hsu, Mu-Rong Yang, Ko-shao Chen, A study of $ZnGa_2O_4$ phosphor prepared by the solid method, J. Mater. Sci:Materials in Electronics 9 (1998): 283-288.
6. Y. Okimura, H.Yokoi, K.Ohbayashi, Selective catalytic reduction of nitrogen oxides with hydrocarbons over Zn-Al-Ga complex oxides, Catal. Lett. 52 (1998):157-161.
7. T. Sei, Y. Nomura, T. Tsuchiya, Prepartion of $ZnGa_2O_4$ thin film by sol-gel process and effect of reduction on its electric conductivity, J. Non-Crystal. Solids 218 (1997): 135-138.
8. Z. Yan, M. Koike, H. Takei, Preparation of spinel $ZnGa_2O_4$ films on MgO substrates by the solvent evaporation epitaxy method, J. Crystal Growth 165 (1996) 183-186.
9. M. A. Valenzuela, J. p. Jacobs, P. Bosch, The influence of the preparation method on the surface structure of $ZnAl_2O_4$, Appl. Catal. A: Genral 148 (1997) 315-324.
10. T. Ohtake, N. Sonoyama, T. Sakata, Electrochemical luminescence of $ZnGa_2O_4$ and $ZnGa_2O_4$:Mn electrodes, Chem. Phys. Lett. 298 (1998) 395-399.
11. A. J. Faneli, J.V. Burlew, Preparation of alumina powder in alcohol, J. Mater. Sci. 23 (1998) 2897-2904.
12. Y. Oguri, R. E. Riman, Processing of anatase prepared from hydrothermally

13. M. Kondo, K. Shinozaki, Crystallization behavior and microstructure of hydrothermal treated monodispersed titanium dioxide particles, J. Cerm. Soc. Japan 102 (1994) 740-744.

14. M. Inoue, Y. Kondo, An ethylene glycol derivative of boehmite, Inorg. Chem. 27 (2)(1998) 215-221.

15. M. Inoue, H. Tanino, Formation of microcrystalline -alumina by glycothermal treatment of gibbsite, J. Am. Cerm. Soc. 72 (2) (1998) 352-353.

16. M. Inoue, H. Kominami, Thermal transformation of -alumina formed by thermal decomposition of aluminum alkoxide in organic media, J. Am. Cerm. Soc. 75 (9) (1992) 2597-2598.

17. M. Inoue, H. Kominami, Novel synthesis method for the catalytic use of thermally stable zirconia : Thermal decomposition of zirconia alkoxide in organic media, Appl. Catal. A97 (1993) L25-L30.

18. M. Inoue, H. Kominami, Novel synthesis method for thermally stable monoclinic zirconia : Hydrolysis of zirconia alkoxides at high temperature with a limited amount of water dissolved in inert organic solvent form the gas phase, Appl. Catal. A 121 (1995) L1-L5.

19. M. Inoue, H. Otsu, Synthesis of submicron sperical crystals of gadolinium gallium garmets by the glycothermal method, J. Mater. Sci. Lett. 14 (1995) 1303-1305.

20. M. Inoue, H. Otsu, Glycothermal synthesis of rare earth aluminium garnets, J. Alloys Comp. 226 (1995) 146-151.

21. L. Lietti, J. L. Alemany, Reactivity of V_2O_5 -WO_2 /TiO_2 catalysis in the selective catalytic reduction of nitric oxide by ammonia, Catal. Today 29 (1996) 143-148.

22. M. Inoue, T. Nishikawa, Reaction of rare earth acetates with aluminum isopropoxide in ethylene glycol : Synthesis of the garnet and monoclinic phases of rare earth aluminate, J. Mater. Sci. 33 (1998) 5835-5841.

22. M. Inoue, T. Inui, Glycothermal synthesis of metastable phases, 9th Cimtec-World Ceramics Congress, Ceramics : Getting into the 2,000's-Part B, 41-48.

24. M. Inoue, H. Kominami, H. Otsu, T. Inui, Synthesis of microcrystalline titania in organic media, Nippon Kagaku Kaishi, (1991): 1364.

25. H. Kominami, J. Kato, Y. Doushi, B. Ohtani, S. Nishimoto, M. Inoue, T. Inui and Y. Kera, Novel synthesis ofmicrocrystalline titanium (IV) oxide having high thermal stability and ultra-high photocatalytic activity : Thermal decomposition of titanium (IV) alkoxide in organic solvents, Catal. Lett. 46 (1997): 235-240.

26. H. Kominami, Y. Takada, H. Yamagiwa and Y. Kera, Synthesis of thermal stable nanocrystalline anatase bt high-temperature hydrolysis of titanium alkoxide with water water dissolved in orgainc solvent from gas phase, J. Mater. Sci. Lett. 15 (1996): 197-199.

27. H. Kominami, M. Kohno, Y. Takada, M. Inoue, T. Inui and Y. Kera, Hydrolysis of titanium alkoxide in organic solvent at high temperatures: A new synthetic method for nanosized, thermal stable titanium (IV) oxide, Ind. Eng. Chem. Res. 38 (1999): 3925-3931.

28. H. Kominami, J. Kato, M. Kohno, Y. Kera and B. Ohtani, Photocatalytic mineralization of acetic acid in acid in aerated aqoues susprnsion of ultra-highly active titanium (IV) oxide prepared by hydrothermal crystallization in toluene, Chem. Lett. (1996): 1051-1052.

29. H. Kominami, T. Matsuura, K. Imai, B. Ohtani, S. Nishimoto and Y. Kera, Ultra-high active titanium (IV) oxide photocatalyst prepared by hydrothermal crystallization from titanium (IV) alkoxide in organic solvent, Chem. Lett. (1995): 693-694.

30. H. Kominami, S. Murakami, Y. Kera and B. Ohtani, Titanium (IV) oxide photocatalyst of ultra-high activity: A new preparation process allowing compatibility, Catal. Lett. 56 (1998): 125-129.

31. M. Ionue and T. Nishikawa and T. Inui, Reaction of rare earth acetates with aluminum isopropoxide in ethylene glycol: Synthesis of the garnet and monoclinic phase of rare earth aluminate, J. Mater. Sci. 33 1998: 5835-5841.

32. M. Inoue and T. Inui, Glycothermal synthesis of metastable phases, 9th Cimtec-World Ceramics Congress, Ceramics: Getting into the 2,000's-Part B: 41-48.

33. B. M. Reddy, S. Mehdi and E. P. Reddy, Synthesis of alkoxyalumoxanes by oxidation of aluminum metal in alcohols, 9th Cimtec-World Ceramics Congress, Ceramics: Getting into the 2,000's-Part D: 593-598.

APPENDICES

APPENDIX A
CALCULATION OF CATALYST PREPARATION

Calculation of the preparation of the zinc gallate and zinc aluminate.

In this study, zinc gallate and zinc aluminate were prepared in each organic solvent have 3 different charged Zn/Ga or Zn/Al atomic ratios, Zn/Ga or Zn/Al = 0.33, 0.50 and 1.00.

Zinc acetate and gallium acetylacetonate are used as the reactants.
For the preparing of zinc gallate powder.

1. Gallium acetylacetonate ($Ga(acac)_3$, $[CH_3COCH=C(O-)CH_3]_3Ga$) has molecular weight (M.W.) of 367.05 g/mol.
   Gallium (Ga) has M.W. of 69.72 g/mol.
2. Zinc acetate ($(CH_3COO)_2Zn$) has M.W. of 183.46 g/mol.
   Zinc (Zn) has M.W. of 65.37 g/mol.

Example A1: Calculation of preparation of zinc gallate with Zn/Ga= 0.5 is shown as follow:

Gallium acetylacetonate 5 g were used for preparation of all Zn/Ga atomic ratios.

The reagent 5 g were consisted of gallium equal to:

Gallium = (69.72 / 367.05) x 5 g = 0.9497 g = 0.0136 mole

zinc equal to :

Zinc = 0.5 x 0.0136 = 0.0068 mole = 0.4452 g.

From zinc = 0.4452 g, zinc acetate is used equal to :

So, weight of zinc acetate = (183.46 / 65.37) x 0.4452 g. = 1.2460 g.

The results of calculation of all Zn/Ga atomic ratios are shown in Table A1.

Table A1. Reagents used for the synthesis of zinc gallate.

Zn/Ga atomic ratio	Gallium acetylacetonate	Zinc acetate
0.33	5 g	0.8330 g
0.50	5 g	1.2496 g
1.00	5 g	2.4991 g

Similarly, the calculation of the preparation of the zinc aluminate is shown as follow:

Zinc acetate and aluminium isopropoxide (AIP) are used as the reactants for the preparing zinc aluminate powder.

1. Aluminium isopropoxide (AIP, $[(CH_3)_2CHO]_3Al$) has M.W. of 204.25 g/mol. And purity >98%.

   Aluminium has M.W. of 26.98 g/mol
2. Zinc acetate ($(CH_3COO)_2Zn$) has M.W. of 183.46 g/mol.

   Zinc (Zn) has M.W. of 65.37 g/mol.

Example A2: Calculation of preparation of zinc aluminate with Zn/Al = 0.5 is shown as follow:

Aluminium isopropoxide 15 g were used for preparation of all Zn/Al atomic ratio.

The reagent 15 g were consisted of aluminum isopropoxide more than :

Aluminium isopropoxide = (98/100) x 15 = 14.70 g.

So, aluminium isopropoxide 14.70 g were consisted of aluminium equal to:

Aluminium = (26.98/ 204.25) x 14.7 g = 1.9418 g = 0.0720 mole

So, Zn/Al = 0.5 has zinc equal to :

Zinc = 0.5 x 0.0720 = 0.0360 mole = 2.3524 g.

From zinc = 2.3524 g., zinc acetate is used equal to :

So, weight of zinc acetate = (183.46/65.37) x 2.3524 = 6.0619 g.

The results of calculation of all Zn/Al atomic ratios are shown in Table A2.

Table A2. Reagent used for the synthesis of zinc aluminate.

Zn/Al atomic ratio	Aluminium isopropoxide	Zinc acetate
0.33	15 g	4.4012 g
0.50	15 g	6.6019 g
1.00	15 g	8.9821 g

APPENDIX B

CALCULATION OF CRYSTALLITE SIZE

Calculation of crystallite size by Scherer equation

Crystallite size was calculated from the half-height width of the diffraction peak of zinc gallate and diffraction peak of zinc aluminate using the Scherer equation. The value of the shape factor, K was taken to be 0.9 and KCl was used to be internal standard.

From Scherer equation :

$$t = \frac{0.9\lambda}{B\,Cos\,\theta_B} \qquad \text{(B.1)}$$

where t = crystallite size

K = shape factor = 0.9

λ = X-ray wave length, Cu K : = 1.5418 A°

B = the Bragg angle

$B^2 = B_M^2 - B_S^2$

B_M = the measured peak width in radians at half peak height.

B_S = the corresponding width of a standard material.

ExampleB1: The crystallite size of pure zinc gallate prepared in 1,4-butanediol is calculated as follow:

From $B^2 = B_M^2 - B_S^2$

$= 0.00902^2 - 0.00402^2$

$= 0.0000652$

$B = 0.008076$ rad

$\theta_B = 18.06°$

ต้นฉบับ หน้าขาดหาย

APPENDIX C
CALCULATION OF CHEMICAL COMPOSITION

Calculation of Zn/Ga and Zn/Al atomic ratio of as-synthesized zinc gallate and zinc aluminate

M.W. of Zn	=	65.39
M.W. of Ga	=	69.72
M.W. of Al	=	26.98

Example C1: The calculation of the as-synthesized sample at starting Zn/Al atomic ratio equals to 0.50 in 1,4-butanediol.

The data of the product at Zn/Al = 0.50 in 1,4-butanediol obtained by XRF analysis:

Percent by weight of Zn	=	53.3 %
Percent by weight of Al	=	44.9 %

Then, the mole of Zn is equal to:

mole of Zn = 53.3 / (100 x 65.39)

and the mole of Al is equal to:

mole of Al = 44.9 / (100 x 26.98)

So, the Zn/Al atomic ratio of the as-synthesized product is

Zn/Al = [53.3 / (100 x 65.39)]/[44.9 / (100 x 26.98)]

= 0.489

Example C2: The calculation of Zn/Ga of the as-synthesized products at starting Zn/Ga atomic ratio equals to 0.50 in 1,4-butanediol.

The data of the product at starting Zn/Ga = 0.50 obtained in by XRF analysis.

Percent by weight of Zn	=	35.9 %
Percent by weight of Ga	=	63.1 %

Then, the mole of Zn is equal to:

mole of Zn = 31.1 / (100 x 65.39)

And the mole of Ga is equal to:

mole of Ga = 64.1 / (100 x 65.37)

So, the Zn/Ga atomic ratio of the as-synthesized product is

Zn/Ga = [31.1 / (100 x 65.39)]/[64.1 / (100 x 65.37)]

= 0.489

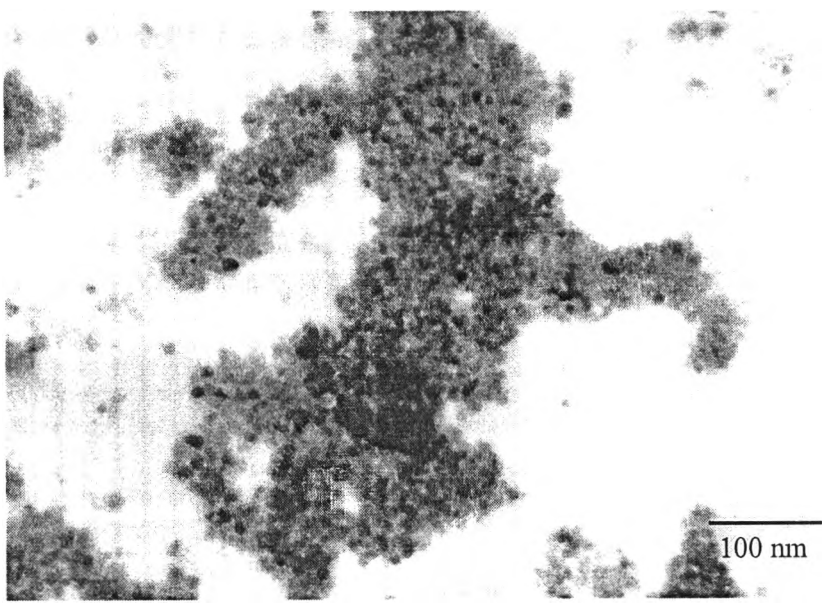
APPENDIX D

CALCULATION OF CRYSTALLITE SIZE FROM TEM PHOTOGRAPH

Calculation of crystallite size from TEM photograph

Crystallite sizes measured from TEM photograph of the as-synthesized product and calcined product of zinc gallate and zinc aluminate (d^c) (as shown in Table 5.1 to 5.7) were calculated as follows:

Example D1: The measurement of as-synthesized crystallite size of zinc gallate at starting Zn/Ga = 0.50 synthesized in 2-propanol.



At X150, 000 magnification, the scale is

150 mm = 1μm

= 1000 nm

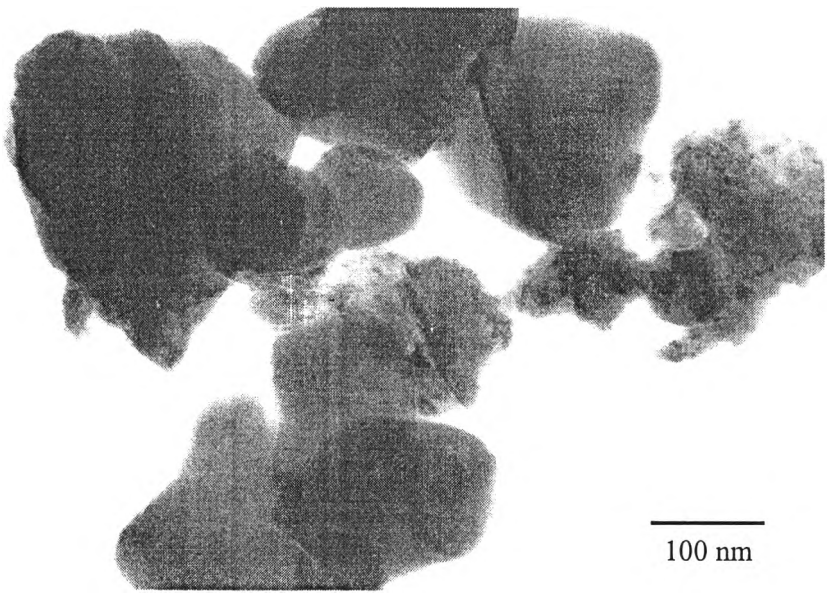
From TEM photograph, it was found that the crystallite size closed to each other and that was 1.2 mm.

So, the true crystallite size is equaled to

true crystallite size = (1000 nm / 150 mm) x 1.2 mm

= 8.00 nm

Example D2: The measurement of as-synthesized crystallite size of zinc gallate at starting Zn/Ga = 0.50 synthesized in 1,4-butanediol calcined at 1100°C.



At x150, 000 magnification, the scale is

150 mm = 1 μm

= 1000 nm

From TEM photograph, it was found that the distribution of crystallite size of the calcined product was broad so the true crystallite size was averaged.

The measured crystallite sizes in TEM photograph were 28, 25, 24, 21, 20,19, 18 15, 13, and 10 mm. So, the average measured crystallite size was equaled to:

$$\text{Average measured crystallite size} = \frac{28 + 25 + 24 + 21 + 20 + 19 + 18 + 15 + 13 + 10}{10}$$

= 19.3 mm

Thus the true crystallite size was:

true crystallite size = (1000 nm / 150 mm) x 19.3 mm

= 128.67 nm

VITA

Miss Paveena Sangthonganothai was born on February 23, 1978in Bangkok, Thailand. She received the Bachelor Degree of Chemical Engineering from Faculty of Engineering, King's Mongkut Institute of Ladkrabang Technology in 1999. She continued her Master's Study at Chulalongkorn University in June, 1999.