REFERENCES

1. L. Zhang and R.V.Koka. A study on the oxidation and carbon diffusion of TiC in alumina-titanium carbide ceramics using XRS and Raman. Materials Chemistry and physics57(1998): 23-32.
2. Y.W.Kim and J.G.Lee. Pressureless Sintering of Alumina-Titanium carbide Composite. J.Am.Ceram.Soc.72(1989): 1333-1337.
3. S.J. Burden, J. Hong, J.W. Rue, and C.L. Stromborg. Comparison of Hot-Isostatically-Pressed and Uniaxially Hot-Pressed Alumina-Titanium Carbide Cutting Tools. Am.Ceram.Soc. Bull 67[6](1988): 1003-1006.
4. J.Subrahyam and M.Vijayakumar. Review Self-propating high-temperature synthesis. J.Mats.Sci.27(1992): 6249-6273.
5. W.H.Sutton. Microwave Processing of Ceramic Material. Ceramic Bulletin68[2](1989): 376-386.
6. M.L.Fall. Sintering Wear Parts With Microwave Sintered Sample. Available from: http://www.ceralink.com
7. H.S.Shulman. Breaking Barriers to Commercialization of High Temperature Microwave Processing. Available from http://www.ceralink.com
8. R.H.G.A.Kiminami, M.R.Morelli, D.C.Folz and D.E.Clark. Microwave synthesis of Alumina Powders. Am.Ceram.Soc. Bull 79[3](2000): 63-67.
9. E.D.Whitney, Ceramic Cutting tools: Materials, Development and Performance. U.S.A.: Noyes Publication, 1994.
10. W.W.Gruss. Ceramic Tools Improve Cutting Performance. Ceramic Bulletin67[6](1988): 993-996.
11. M.Barsoum, Fundamentals of Ceramic. International edition. Singapore: Mcgraw-Hill, 1997.
12. A.Tampieri and A.Bellosi. Oxidation Resistance of Alumina-Titanium Nitride and Alumina-Titanium carbide Composites. J.Am.Ceram.Soc.75[6](1992): 1688-1690.
13. K.F.Cai, D.S.McLachlan, N.Axen and R.Manyatsa. Preparation, Microstuctures and Properties of Al_2O_3-TiC composites. Ceramics International28(2002): 217-222.

14. R.P.Wahi and B.Ilschner. Fracture Behavior of Composites Based on Al_2O_3-TiC J. Mater. Sci.15(1980): 875-885.

15. R.Vassen and D.Stover. Processing and Properties of Nanograin Silicon Carbide. J.Am.Ceram.Soc.82[10](1999): 2585-93.

16. Y.Wan and J.Gong. Influence of TiC particle size on the load-independent hardness of Al_2O_3-TiC composites. Materials letters,4362(2003): 1-5.

17. W.D.Kingery, H.K.Bowen and D.R.Uhlmann, Introduction to Ceramics. 2^{nd} edition. Singapore: John Wiley & Sons, Inc., 1976.

18. Y.W.Kim and J.G.Lee. Pressureless Sintering of Alumina-TiC Composite . J.Am.Ceram.Soc.72[6](1989): 1333-37.

19. J.S.Choi, S.Y.Park, D.J.Kim and S.J.L.Kang. Sintering and Mechanical Properties of Y_2O_3 Added Al_2O_3-TiC Composite. J.Korean Ceram.Soc.26[3](1989): 438-444.

20. K.W.Chae and D.Y.Kim. Effect of Y_2O_3 Additions on Densification of An Al_2O_3-TiC Composite. J.Am.Ceram.Soc.76[7](1993): 1857-60.

21. J.Gong, Z.Zhao, H.Miao and Z.Guan. R-curve behavior of TiC particle reinforced Al_2O_3-TiC composites. Scrpta mater.43(2000): 27-31.

22. J.Gong, H.Miao, Z.Zhao and Z.Guan. Effect of TiC particle size on the toughness characteristics of Al_2O_3-TiC composite. Materials Letters.49(2001): 235-238.

23. M.P.Borom and M.Lee. Effect of Heating rate on Densification of Alumina-Titanium carbide Composites.Adv.Ceram.Mater.1[4](1986): 335-40.

24. M.Lee and M.P.Borom. Rapid Rate Sintering of Al_2O_3-TiC composite for Cutting-Tool Applications.Adv.Ceram.Mater.3[1](1988): 38-44.

25. G.C. and J.Walsh. Rapid Sintering Method for Producing Alumina-Titanium carbide composite.United States Patent.Patent Number 5.342.564,1994.

26. Y.Kanemitsu, T.Hagio, M.Miyahara, Y.Hara, M.Furukawa and T.Kitahara. Sintered Bodies Al_2O_3-TiC-TiO_2 Containing Yttrium(Y).United States Patent.Patent Number 4.356.272,1982.

27. K.Yamamoto. Toughness Ceramic Materials.Japan Patent. Patent Number 79.103.407,1979.

28. S.Adachi. T.Wada, T.Mihara, Y.Miyamoto and M.Koizumi. High Pressure Self-Combustion Sintering of Alumina-Titanium Carbide Ceramic Composite. J.Am.Ceram.Soc.73[5](1990): 1451-52.

29. C.R.Bowen and B.Derby. The formation of TiC/Al_2O_3 microstructures by a self-propagating high-temperature synthesis reaction. J.Mats.Sci.31(1996): 3791-3803.

30. H.G.Lee. CHEMICAL THERMODYNAMICS FOR METALS AND MATERIALS. Singapore: Imperial College Press, 1999.

31. R.W.Rice. Review: Microstructural aspects of fabricating bodies by self-propagating synthesis. J.Mats.Sci.31(1996): 3791-3803.

32. Y.Choi and S.W.Rhee. Reaction of TiO_2-Al-C in the Combustion Synthesis of TiC-Al_2O_3 Composite. J.Am.Ceram.Soc.78[4](1995): 986-92.

33. Q.Dong, Q.Tang, W.C.Li and D.Y.Wu. The effect of ZrO_2 nanaparticles on TiO_2-Al-C combustion synthesis system. Materials letters.55(2002): 259-64.

34. Y.Choi and S.W.Rhee. Effect of precursors on the combustion synthesis of TiC-Al_2O_3 composite. J.Matter.Res.9[7](1994): 1761-66.

35. J.H.Lee, S.K.Ko and C.W.Won. Combustion characteristics of TiO_2/Al/C system. Materials Research Bulletin.36(2001): 1157-67.

36. R.A.Cutler and K.M.Rigtrup.Synthesis, Sintering, Microstructure and Mechanical properties of Ceramics Made by Exothermic Reaction. J.Am.Ceram.Soc. 75[1](1992): 36-43.

37. J.H.Lee, S.K.Ko and C.W.Won. Sintering behavior of Al_2O_3-TiC composite powder prepared by SHS process. Materials Research Bulletin.36(2001): 989-996.

38. L.L. Hench and J.K. West. Principles of Electronic Ceramics. New York : John Wiley & Sons, 1990.

39. A.C. Metaxas and R.J. Meredith. Industrial Microwave Heating. London, UK: Peter Peregrinus, 1983.

40. Y.L.Tian, L.Johnson and M.E.Brodwin.Microwave sintering of Al_2O_3-TiC composite.Proceedings of First International Conference on Ceramic Powder Processing Science, Orlando, Florida, USA .November 1-4, (1987)

41. A.Goldstein and A.Singurindi. Al_2O_3/TiC Based metal Cutting Tools by Microwave Sintering Followed by Hot Isostatic Pressing. J.Am.Ceram.Soc. 83[6](2000): 1530-32.

42. American Society for Testing and Material (ASTM). Standard Test Method for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products, ASTM C373-88(Reapproved1999), New York: ASTM,1999.

43. American Society for Testing and Material (ASTM). Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance, ASTM C1198-01, New York: ASTM,2001.

44. American Society for Testing and Material (ASTM). Standard Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature, ASTM C1161-02c, New York: ASTM,2003.

45. American Society for Testing and Material (ASTM). Standard Test Method for Vickers Indentation Hardness of Advanced Ceramics, ASTM C1327-99, New York: ASTM,1999.

46. G.R.Antis, P.Chantikul, B.R.Lawn and D.B.Marshall. A Critical Evaluation of Indentation Techniques for Measuring Fracture Toughness: I, Direct Crack Measurement. J.Am.Ceram.Soc. 64[1](1981): 533-38.

47. C.P.Gazzara and D.R.Messier. Determination of Phase Content of Si_3N_4 by X-Ray Diffraction Analysis. Ceramic Bulletin. 56[9](1977): 777-80.

48. T.D.Xia, Z.A.Munir, Y.L.Tang, W.j.Zhao and T.M.Wang. Structural Formation in Combustion Synthesis of Al_2O_3-TiC Composited. J.Am.Ceram.Soc. 83[3](2000): 507-12.

49. TiO_2 type and application Available from: http://www.titanium.co.kr/english/tio2/class.asp

50. A.H.Heuer. The Role of MgO in the Sintering of Alumina. J. Am. Ceram. Soc. 62[5](1979): 317-18.

51. J.Gong, H.Miao and Z.Zhao. The influence of TiC-particle-size on the fracture toughness of Al_2O_3-30wt.%TiC composites. J. Eu. Ceram. Soc. 21(2001): 2377-81.

APPENDICES

APPENDIX A

Thermochemical data for TiC, Al_2O_3, TiO_2 Al and C*

Element	Temp range (K)	ΔH^o (KJ/mole)	ΔH_m (KJ/mole)	C_p (KJ/mole)
TiC	298 – 1800	-184.096		49.5+(3.35x10^{-3}T)-(14.98x10^{-3}T^{-2})
	1800 – 3290			34.2+(11.58x10^{-3}T)-(74.161x10^{-3}T^{-2})
Al_2O_3	298 – 1800	-1675.69	111.085	106.61+(17.78x10^{-3}T)-(28.54x10^{-3}T^{-2})
	1800 – 2327			128+(5.28x10^{-3}T)-(20.235x10^{-3}T^{-2})
	2327 – 3000			1992.464
TiO_2 (rutile)		-944.747	-	-
TiO_2 (anatase)		-938.722	-	-
Al		0	-	-
C		0	-	-

The theoretical adiabatic temperature of reaction 2.3 can be calculated using thermodynamics data in above table as follow:

$$\Delta H^o_{298} = (3\Delta H^o_{298,TiC} + 2\Delta H^o_{298,Al_2O_3}) - (3\Delta H^o_{298,TiO_2} + 4\Delta H^o_{298,Al} + 3\Delta H^o_{298,C})$$

In the case of rutile ΔH^o_{298} = -1069.431 kJ/mole

In the case of anatase ΔH^o_{298} = -1087.506 kJ/mole

---

* J.H.Lee, S.K.Ko and C.W.Won. Combustion characteristics of TiO_2/Al/C system. Materials Research Bulletin. 36(2001): 1157-67.

$$-(\Delta H^{o}_{298}) = \int_{298}^{Tad} \sum C_p(products)dT$$

Thus the calculation of rutile is follow:

$$1087506 = \int_{298}^{1800} (3C_{p,TiC(s)} + 2C_{p,Al_2O_3(s)})dT + \int_{1800}^{2327} (3C_{p.TiC(s)} + 2C_{p,Al_2O_3(s)})dT$$

$$+ \Delta H_{m,Al_2O_3} \int_{2327}^{T_{ad}} (3C_{p,TiC(s)} + 2C_{p,Al_2O_3(s)})dT$$

$\therefore T_{ad}$ = 2330.9784 K

And the calculation of anatase is follow:

$$1087506 = \int_{298}^{1800} (3C_{p,TiC(s)} + 2C_{p,Al_2O_3(s)})dT + \int_{1800}^{2327} (3C_{p.TiC(s)} + 2C_{p,Al_2O_3(s)})dT$$

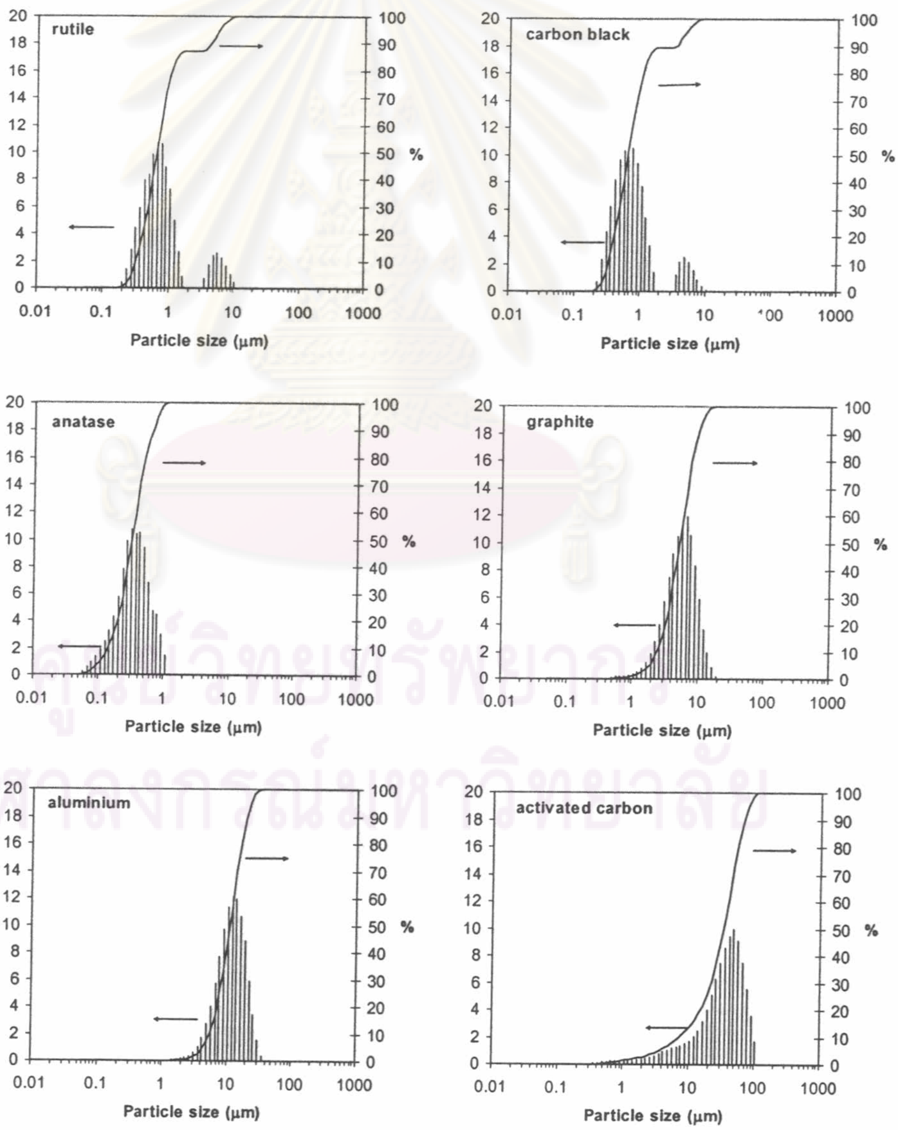
$$+ \Delta H_{m,Al_2O_3} \int_{2327}^{T_{ad}} (3C_{p,TiC(s)} + 2C_{p,Al_2O_3(s)})dT$$

$\therefore T_{ad}$ = 2331.2667 K

APPENDIX B

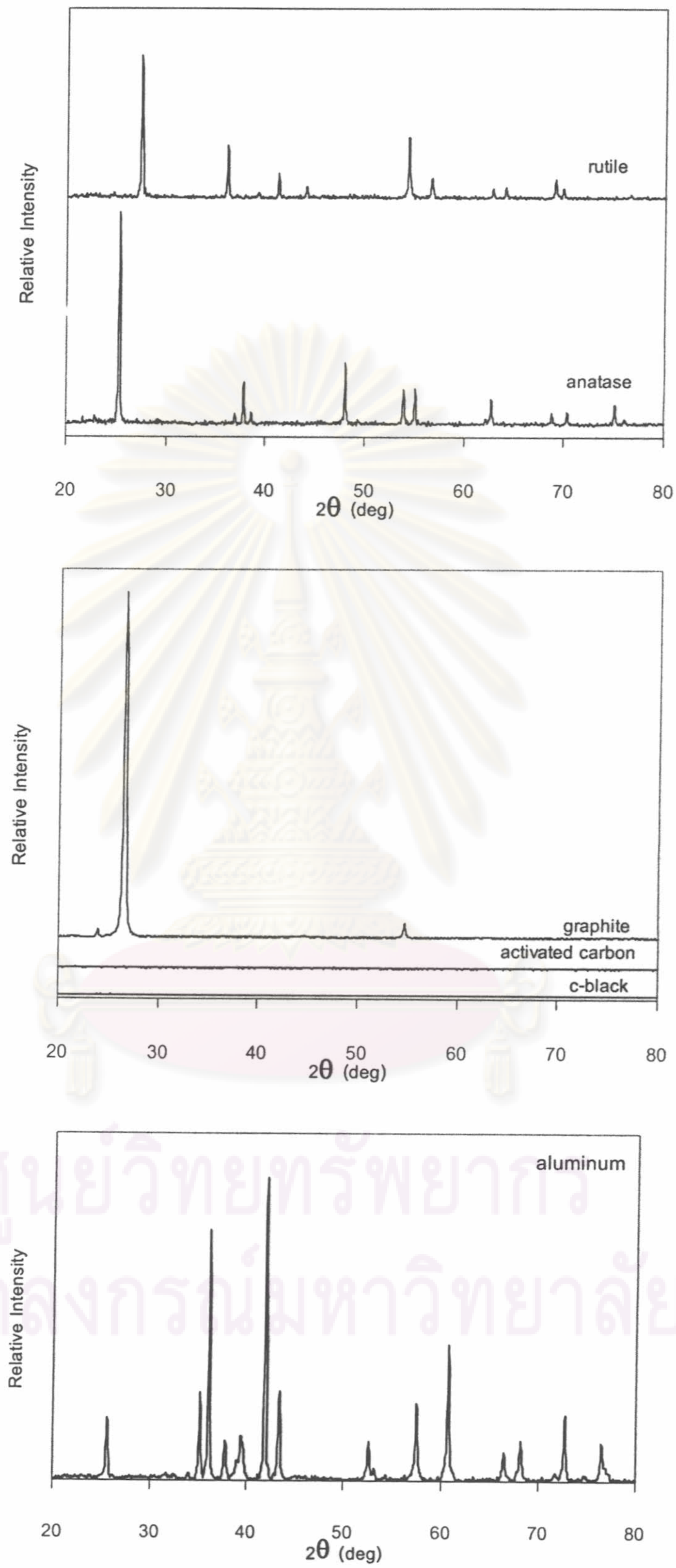
Reactant particle size at 10%, 50%, 90% and mean particle size D(4,3)

Reactants	D(0.1)	D(0.5)	D(0.9)	D(4,3)
Rutile	0.32	0.64	4.11	1.24
Anatase	0.14	0.32	0.65	0.36
Carbon black	0.34	0.66	3.47	1.13
Graphite	2.84	6.07	11.12	6.61
Activated carbon	8.28	39.18	77.81	41.75
Aluminum	5.49	11.1	19.73	11.99



Particle size distribution and cumulative particle size of various reactants.

APPENDIX C

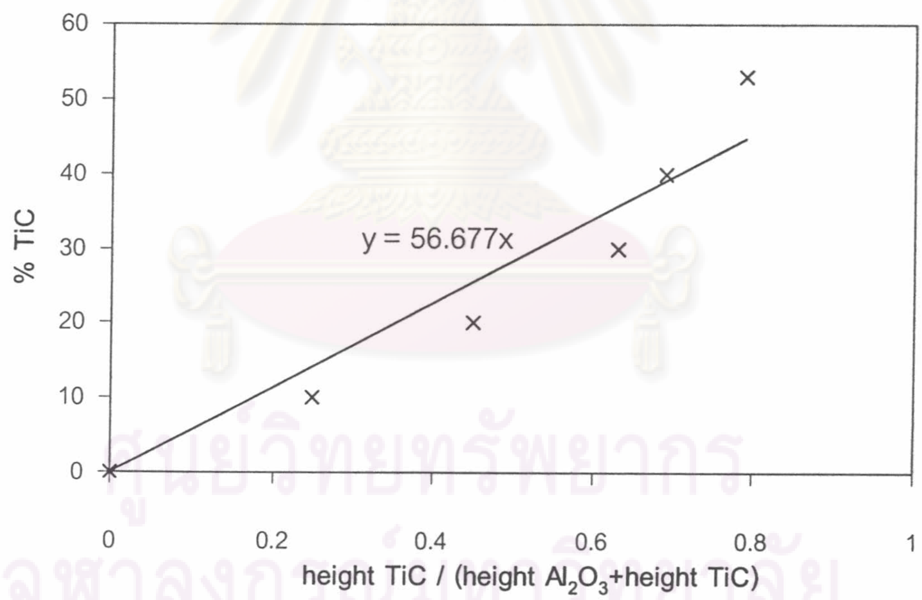


XRD pattern of various reactant in combustion synthesis.

APPENDIX D

Standard calculation made up from maximum peak intensity of commercial mixing powder (Al_2O_3 and TiC) with varying weight ratio.

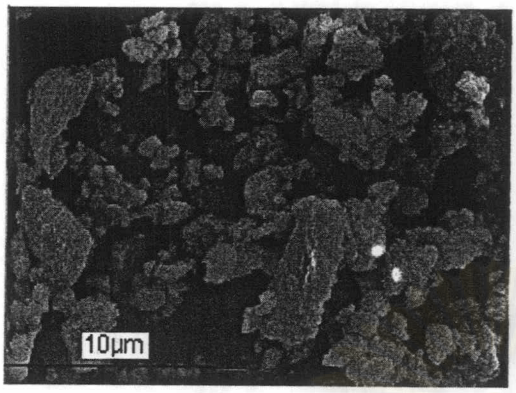
%TiC	Maximum peak height		$H_{TiC}/(H_{Al2O3}+H_{TiC})$
	Al_2O_3	TiC	
0	540	0	0
10	1360	462	0.25
20	920	749	0.45
30	219	366	0.63
40	557	1244	0.69
53	375	1394	0.79



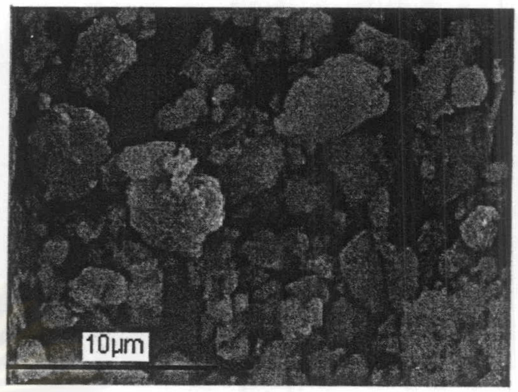
%TiC calculation of each composition received from standard graph.

Composition	Maximum peak height		$H_{TiC}/(H_{Al2O3}+H_{TiC})$	%TiC
	Al_2O_3	TiC		
C-TC1	331	1530	0.82	46.60
C-TC2	272	1126	0.81	45.65
C-TC3	231	934	0.81	45.44
C-TC4	285	1192	0.81	45.74
C-TC5	307	1194	0.80	45.08
C-TC6	238	865	0.78	44.45
M-TC1	209	1022	0.83	47.05
M-TC2	268	1177	0.81	46.17
M-TC3	238	841	0.78	44.18
M-TC4	226	1118	0.83	47.15
M-TC5	304	1129	0.79	44.65
M-TC6	241	816	0.77	43.75

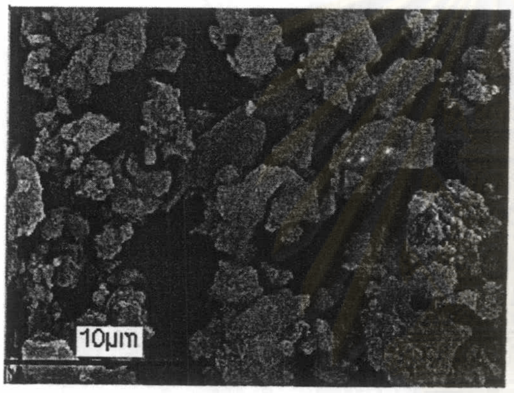
APPENDIX E



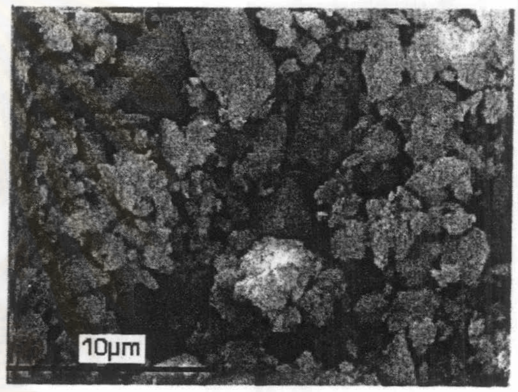
milled C-TC1



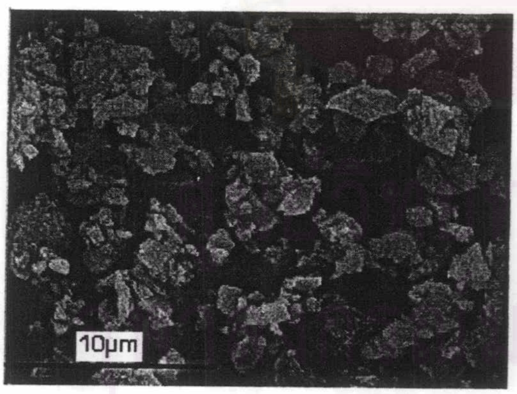
milled M-TC1



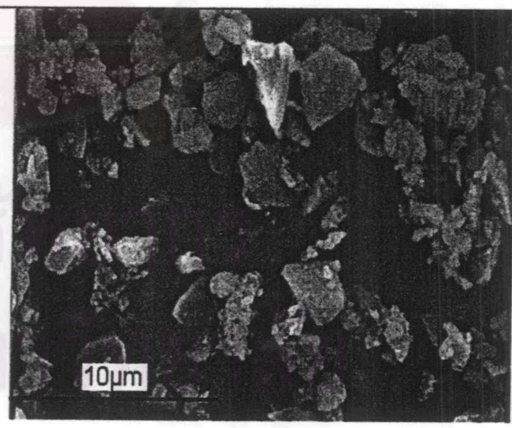
milled C-TC2



milled M-TC2

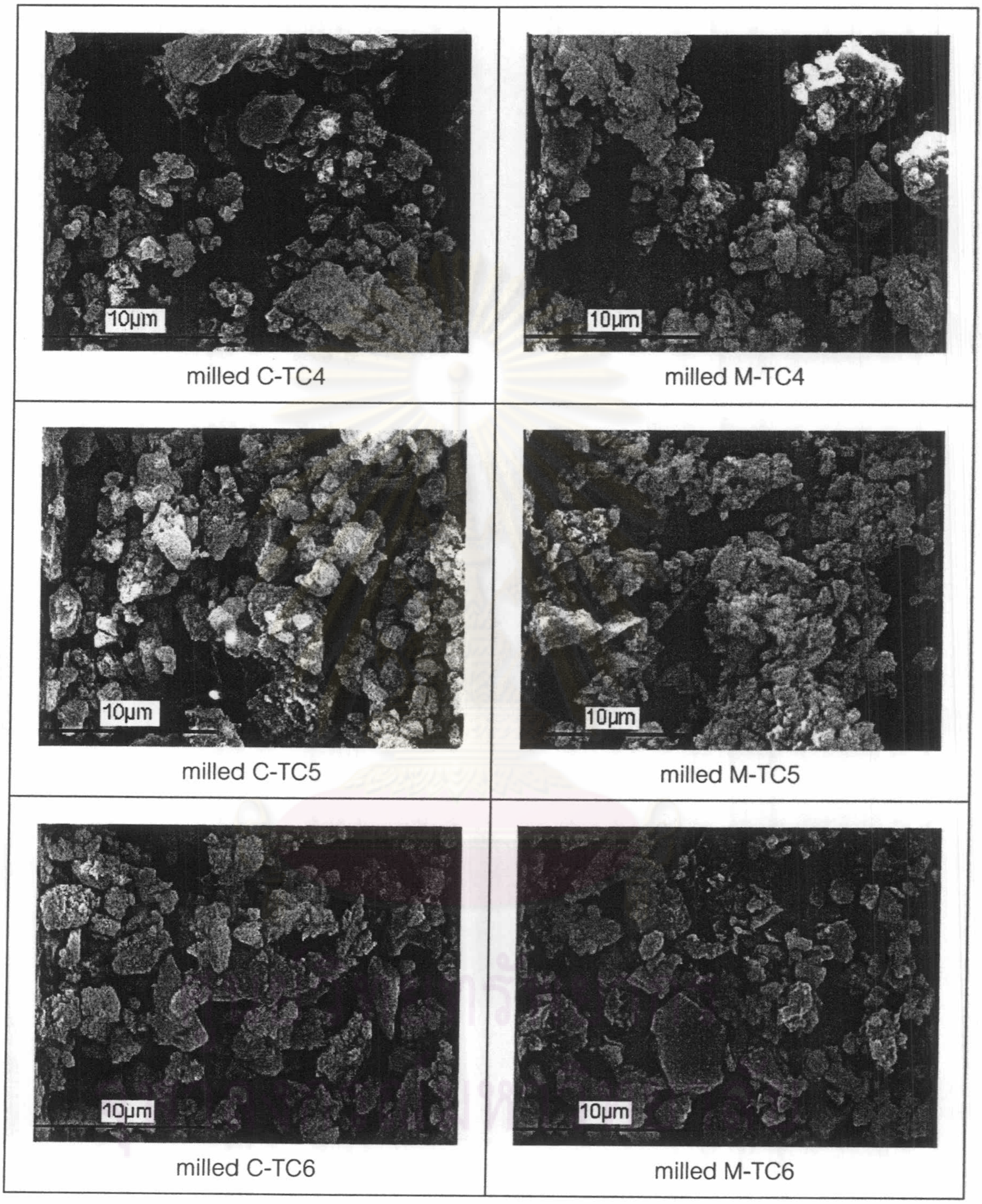


milled C-TC3

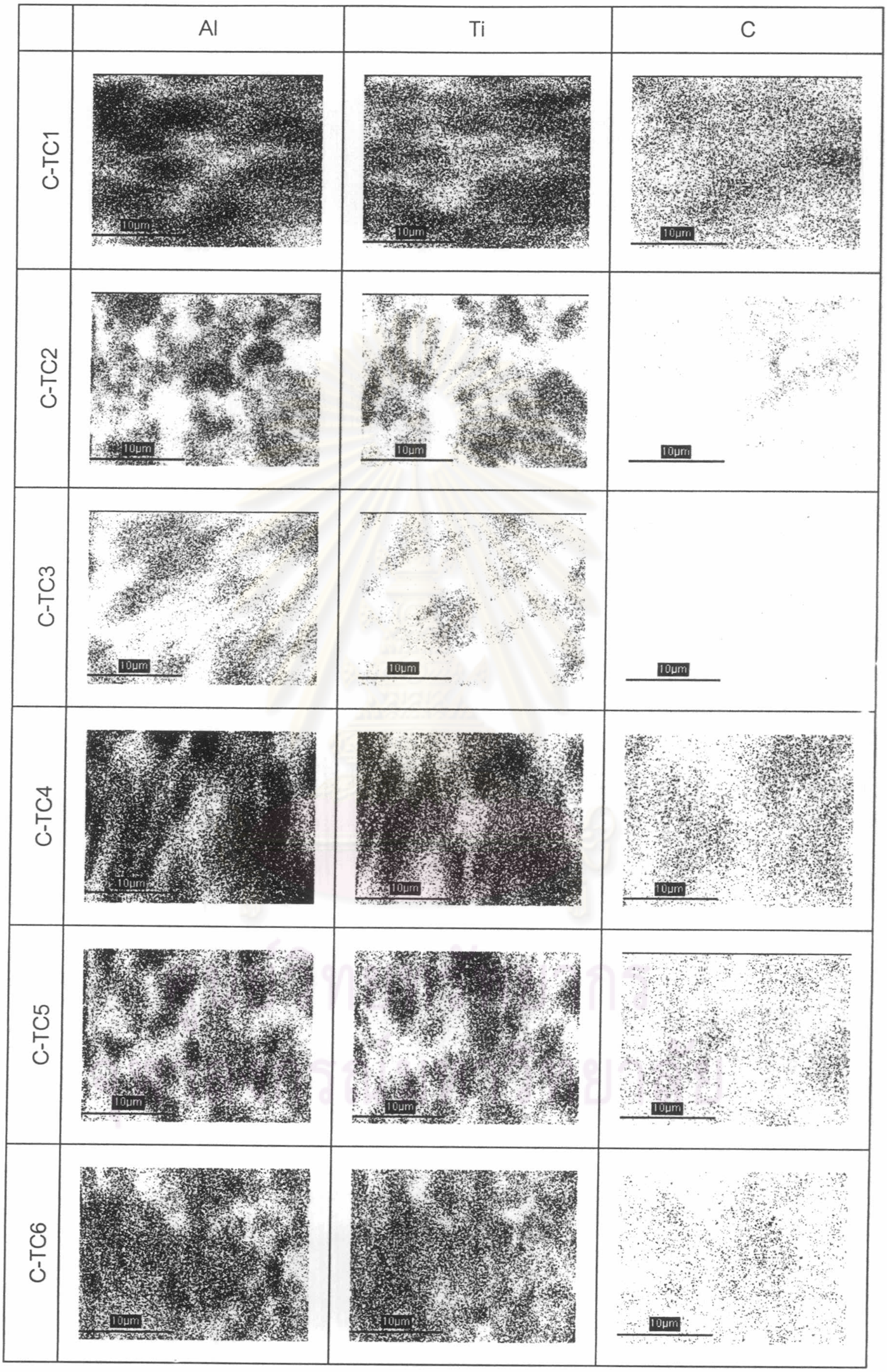


milled M-TC3

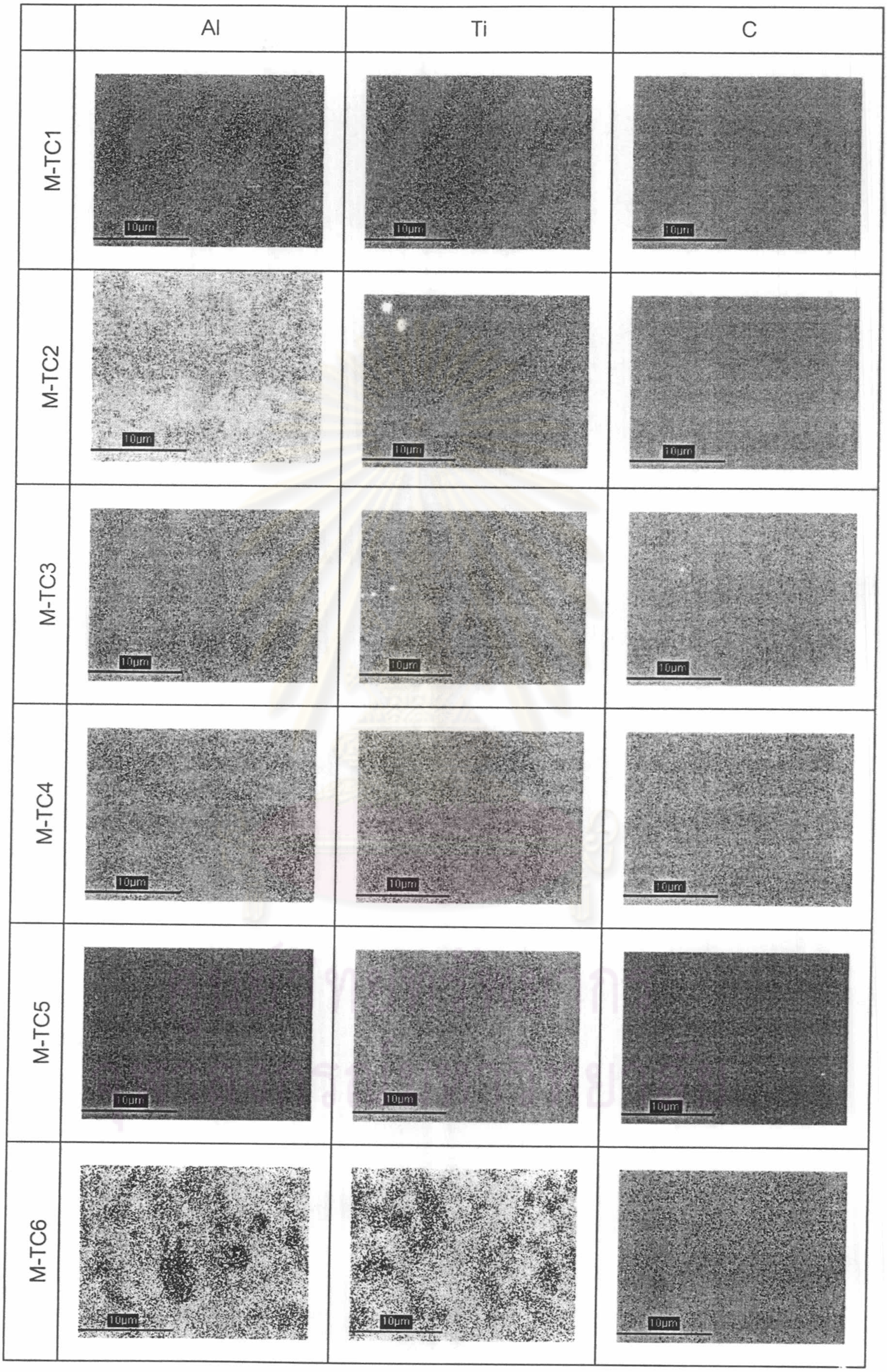
SEM micrograph of milled as-combusted powder prepared from rutile as titania source.



SEM micrograph of milled as-combusted powder prepared from anatase as titania source.



EDS mapping of milled conventional as-combusted powder.

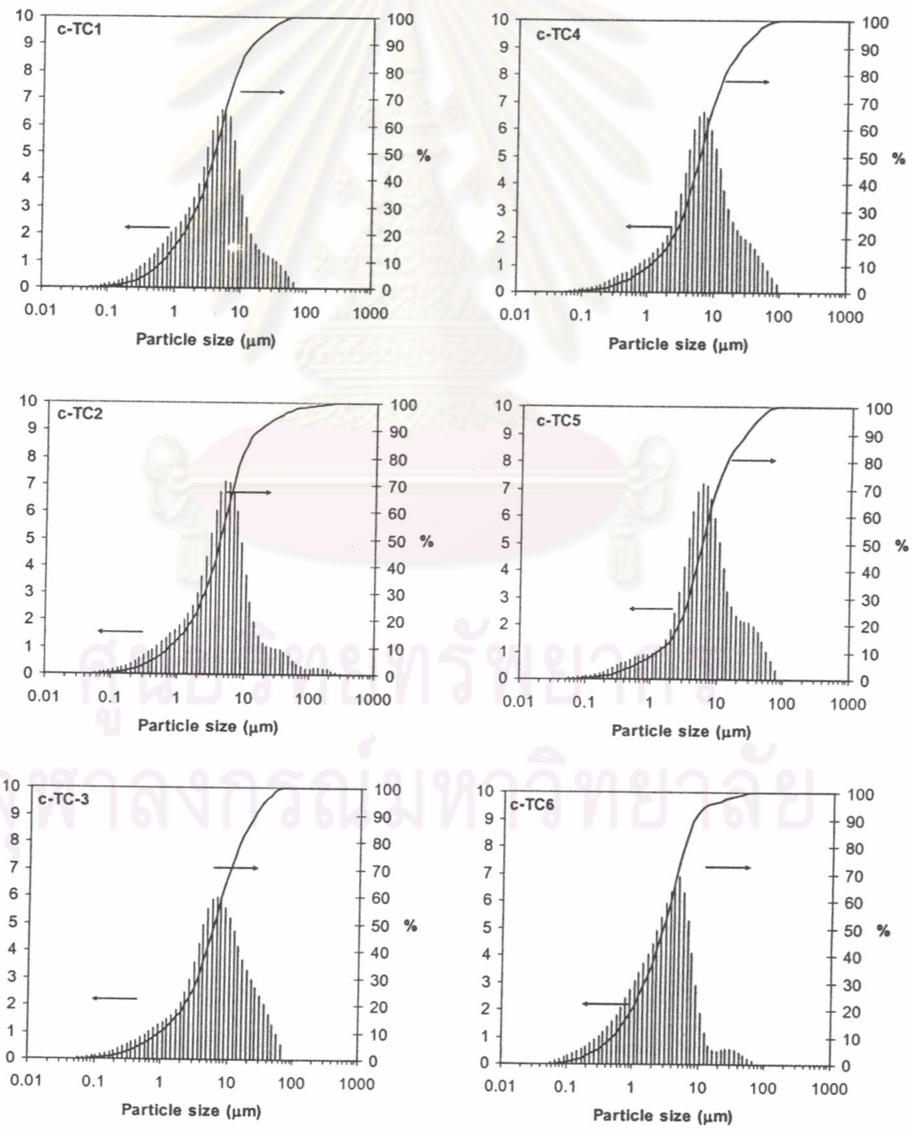


EDS mapping of milled microwave as-combusted powder.

APPENDIX F

Milled conventional as-combusted particle size at 10%, 50%, 90% and mean particle size

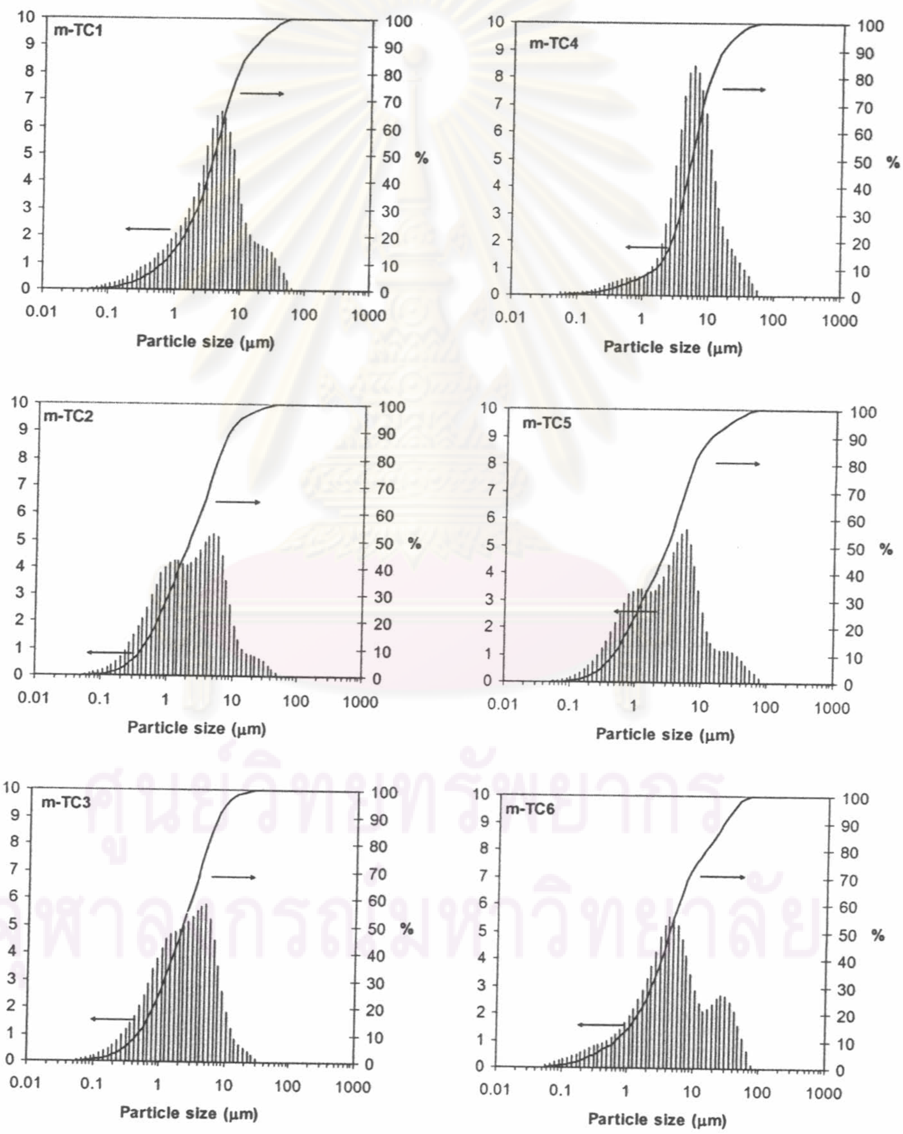
Compositions	D(0.1)	D(0.5)	D(0.9)	D(4,3)
C-TC1	0.68	3.91	13.96	6.38
C-TC2	0.77	4.26	15.28	8.90
C-TC3	0.99	6.11	24.41	9.88
C-TC4	0.94	5.14	21.75	8.80
C-TC5	1.28	5.76	24.84	9.79
C-TC6	0.51	2.82	8.01	4.36



Particle size distribution and cumulative particle size of conventional combusted powder.

Milled microwave as-combusted particle size at 10%, 50%, 90% and mean particle size

Compositions	D(0.1)	D(0.5)	D(0.9)	D(4,3)
M-TC1	0.68	3.90	15.84	6.58
M-TC2	0.43	2.15	8.19	3.84
M-TC3	0.48	2.21	7.16	3.29
M-TC4	1.62	5.36	15.53	7.50
M-TC5	0.48	2.96	13.10	5.28
M-TC6	0.68	4.27	24.16	9.22



Particle size distribution and cumulative particle size of microwave combusted powder.

APPENDIX G

Physical and mechanical properties of sintered products at 1900°C.

Composition	Relative density (%TD)		Vickers hardness (GPa)	
	C-TC	M-TC	C-TC	M-TC
TC1	93.76	91.25	13.36	11.74
TC2	95.84	88.68	18.94	11.33
TC3	92.60	-	12.10	-
TC4	93.55	84.84	16.82	8.05
TC5	92.84	95.04	16.37	6.81
TC6	94.70	96.80	14.52	15.58

BIOGRAPHY

Miss Mettaya Kitiwan was born on April12^{th,} 1979, in Chiang-Rai. She studied for primary grade at Anuban Chiang-Rai. Then she studied secondary school at Damrong-Ratsongkhor and high school at Samakkhee Vittayakhom in Science program. After graduating with a Bechelor's Degree in Material Science, Faculty of Science, Chiang-Mai University in May 2001, she continued a further study in Master's Degree in the field of Ceramic Technology at Chulalongkorn University and graduated in May 2005.