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## APPENDICES

### Appendix A Lattice Parameter and Crystal Size Calculation

The lattice parameter of unit cell  $\text{TiO}_2$  were calculated as follow; the equation

Bragg's law 
$$n\lambda = 2d \sin \theta$$

(A1)

$$\lambda = 2d \sin \theta \quad (n=1)$$

(A2)

Tetragonal: 
$$\frac{1}{d^2} = \frac{(h^2 + k^2)}{a^2} + \frac{l^2}{c^2} \quad (\text{A3})$$

From equation (A2), we can write that

$$d^2 = \frac{\lambda^2}{4 \sin^2 \theta} \quad (\text{A4})$$

Substitution of equation (A4) in equation (A3), one obtains

Tetragonal: 
$$\sin^2 \theta = \frac{\lambda^2 (h^2 + k^2)}{4a^2} + \frac{\lambda^2 l^2}{4c^2} \quad (\text{A5})$$

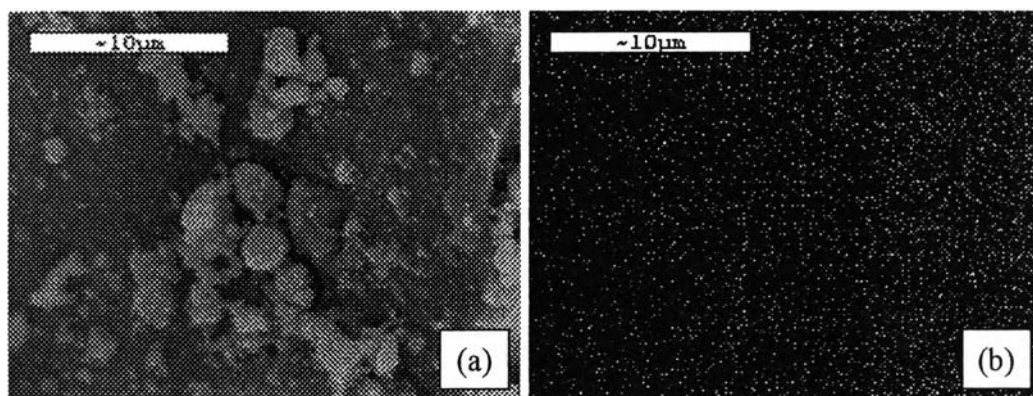
The crystal size of  $\text{TiO}_2$  were calculated as following the Scherrer equation,

$$D = \frac{K\lambda}{\beta \cos \theta}$$

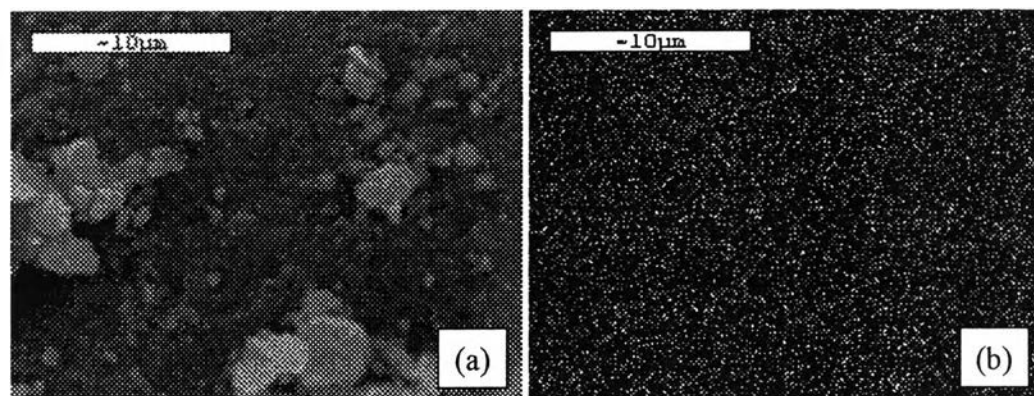
where  $\theta$  is the Bragg angle of diffraction lines,  $K$  the shape factor ( $K = 0.9$  in this work),  $\lambda$  the wavelength of incident X-rays, and  $\beta$  is the corrected half-width given by:  $\beta^2 = \beta_m^2 - \beta_s^2$ , where  $\beta_m$  is the measured half-width and  $\beta_s$  the half-width of a standard sample.

**Table A1** Summary of Physical Properties of TiO<sub>2</sub> and doped TiO<sub>2</sub> samples

Samples	Crystal size, $D$ (nm)	$d_{(hkl)}$	Lattice parameter		Experimental $2\theta$ position of 1 0 1 peak
			$a$ (°A)	$c$ (°A)	
TiO <sub>2</sub>	15.0425	3.5146	3.78	9.51	25.32
3 wt%Sb-TiO <sub>2</sub>	10.1721	3.5173	3.79	9.51	25.30
3 wt%Nb-TiO <sub>2</sub>	14.4030	3.5173	3.79	9.50	25.30
3 wt%Nb-1 wt%Sb-TiO <sub>2</sub>	15.0377	3.5173	3.79	9.50	25.30
3 wt%Nb-2 wt%Sb-TiO <sub>2</sub>	13.8385	3.5228	3.79	9.52	25.26
3 wt%Nb-3 wt%Sb-TiO <sub>2</sub>	13.2964	3.5201	3.79	9.50	25.28

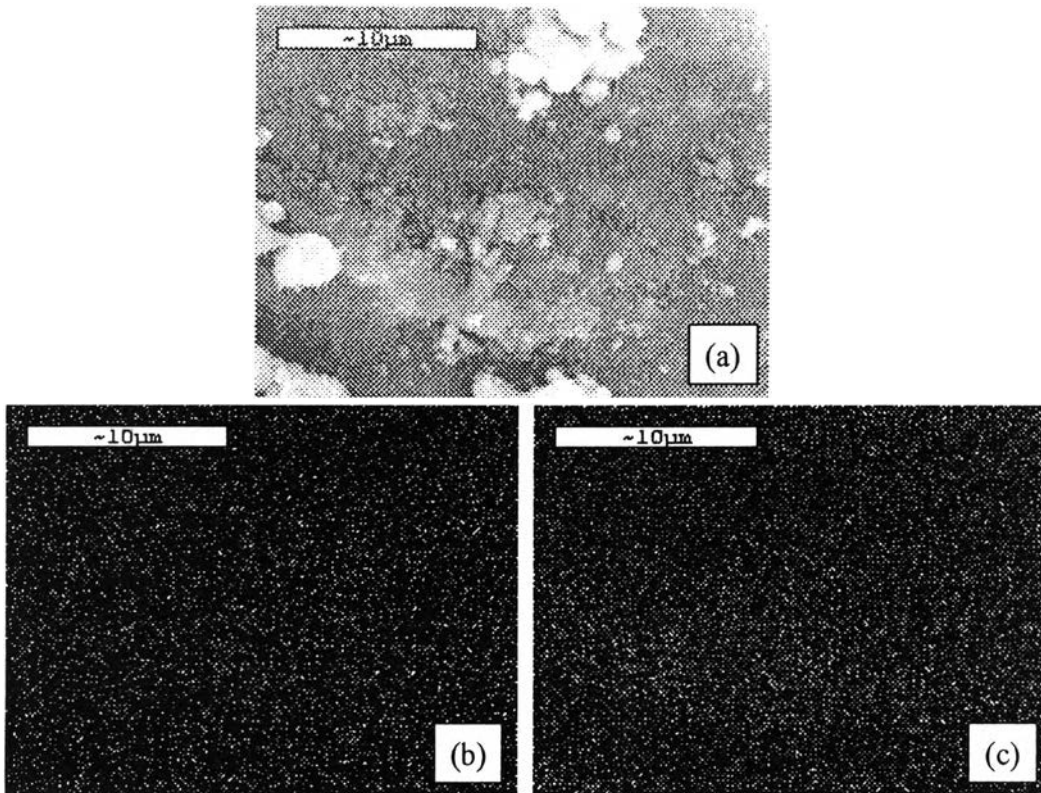
**Appendix B SEM/EDX Micrographs of Sol-Gel TiO<sub>2</sub> and doped TiO<sub>2</sub> Powders**

**Figure B1** (a) SEM image (scale bar = 10 µm), (b) EDX Sb-mapping photograph of 3wt%Sb -TiO<sub>2</sub> particles

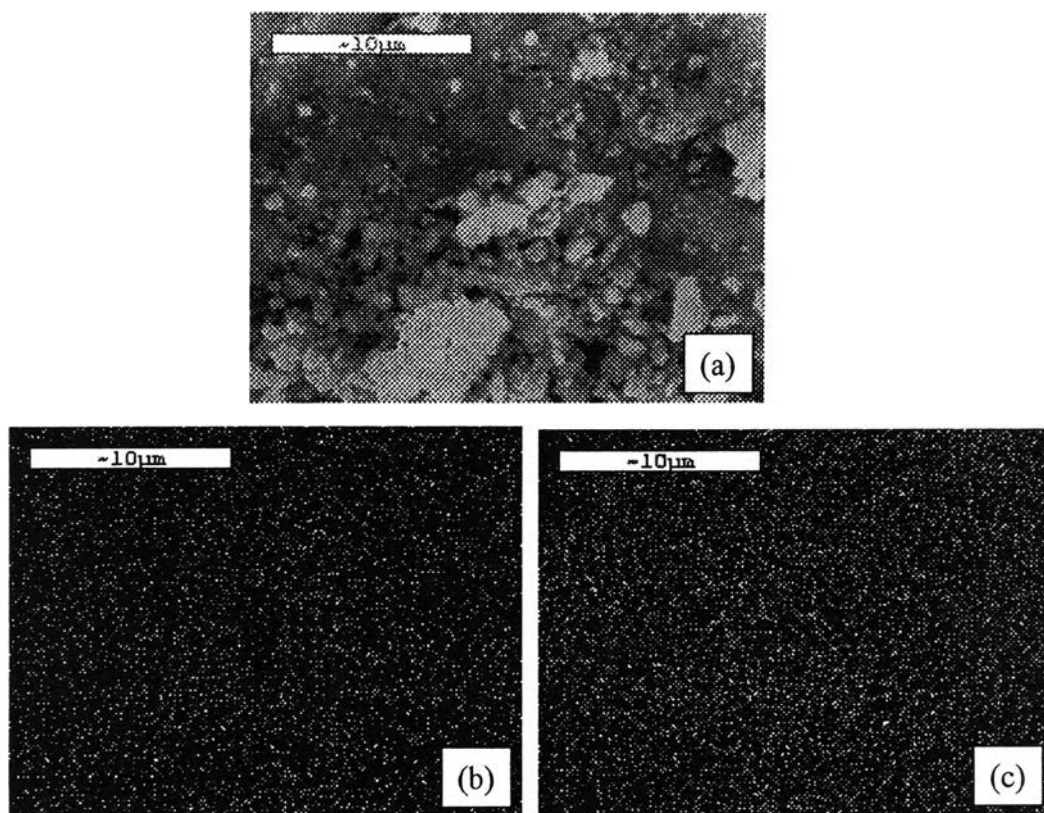


**Figure B2** (a) SEM image (scale bar = 10 µm), (b) EDX Nb-mapping photograph of 3wt%Nb -TiO<sub>2</sub> particles





**Figure B3** (a) SEM image (scale bar = 10  $\mu\text{m}$ ), (b) EDX Sb-mapping photograph, (c) EDX Nb-mapping photograph of 3wt%Nb-1wt%Sb-TiO<sub>2</sub> particles



**Figure B4** (a) SEM image (scale bar = 10  $\mu\text{m}$ ), (b) EDX Sb-mapping photograph, (c) EDX Nb-mapping photograph of 3wt%Nb-2wt%Sb-TiO<sub>2</sub> particles

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1. T. Kuanchaitrakul, S. Chirachanchai and H. Manuspiya, (2008, April 22-25) Niobium and Antimony-modified Titanium Dioxide/Epoxy thin film for Proton Exchange Membrane Fuel Cell. Proceeding of International Conference on Smart Materials/Intelligent Materials and Nanotechnology and 2<sup>nd</sup> International Workshop on Functional Materiala and Nanomaterials, Chiangmai, Thailand.
2. T. Kuanchaitrakul, S. Chirachanchai and H. Manuspiya, (2008, April 23) Inorganic Mesoporous Membrane for Potentially Used in Proton Exchange Membrane. Proceeding of the 14<sup>th</sup> PPC Symposium on Petroleum, Petrochems and Polymers, Sasa Patasala Building, Chulalongkorn University, Bangkok, Thailand.

**Presentations:**

1. T. Kuanchaitrakul, S. Chirachanchai and H. Manuspiya, (2008, April 22-25) Niobium and Antimony-modified Titanium Dioxide/Epoxy thin film for Proton Exchange Membrane Fuel Cell. Poster presented at International Conference on Smart Materials/Intelligent Materials and Nanotechnology and 2<sup>nd</sup> International Workshop on Functional Materiala and Nanomaterials, Chiangmai, Thailand.

2. T. Kuanchaitrakul, S. Chirachanchai and H. Manuspiya, (2008, April 23) Inorganic Mesoporous Membrane for Potentially Used in Proton Exchange Membrane. Poster presented at the 14<sup>th</sup> PPC Symposium on Petroleum, Petrochems and Polymers, Sasa Patasala Building, Chulalongkorn University, Bangkok, Thailand.