Surface modification of titania nanoparticles by capillary condensation and surface reaction

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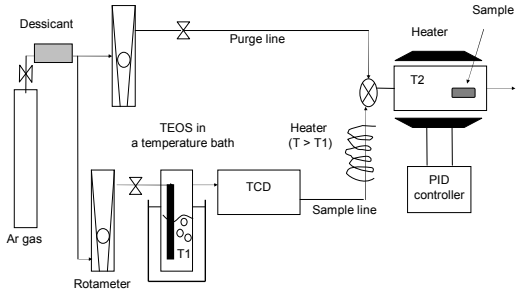
RESEARCH MOTIVATION

Surface modification process can be used to enhance the nanostructured film

- Nanostructured films are generally porous and aggregated, and are used for various applications (filters, catalysts, or sorption media)
- Traditional techniques (annealing, encapsulation, monolayer coating, and etc) are commonly utilized in order to enhance the original properties
- Proposed process is designed to coat the surface of nanoparticles selectively by capillary condensation and surface reaction
- Advantages of selective coating
  - Minimize the deterioration of surface properties
  - Increase the mechanical strength of nanostructured film

EXPERIMENTAL PROCEDURE



Schematic diagram of the experiment

THEORETICAL BACKGROUND

- Fundamental Young-Laplace equation is modified based on the geometry of meniscus on the surface of nanoparticles
- Young-Laplace equation is simple but valid for systems down to the meniscus 2-4 nm
- This relationship gives some information about the effect of various conditions such as temperature, geometry, and the amount and stability of condensed liquid on specific surfaces

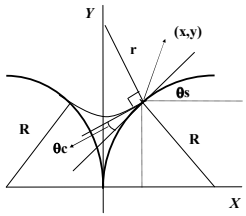


Diagram of nanoparticles in contact

$$RT \ln \frac{P}{P_s} = \frac{2\gamma V}{r}$$

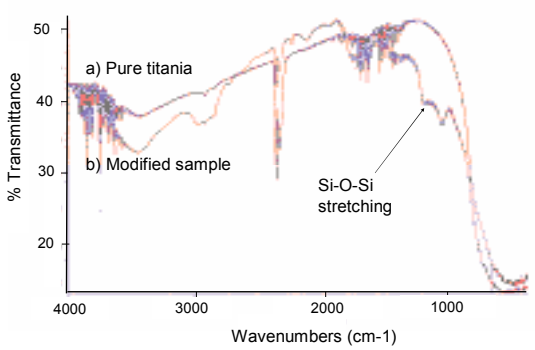
$$\Delta P = \gamma\left(\frac{1}{y} - \frac{1}{r}\right)$$

$$y = R\sin(90-\theta_s) = R\cos\theta_s$$

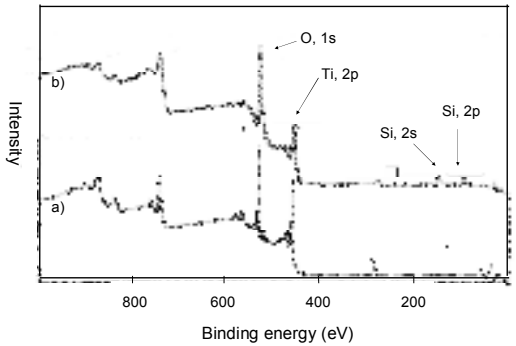
$$x = r\sin(\theta_s - \theta_c)$$

$$\frac{h}{R'} = \sin(90-\theta_s) - \frac{(1-\sin\theta_s)(1-\cos\theta_d)}{\sin\theta_d}, \quad \theta_d = \theta_s - \theta_c$$

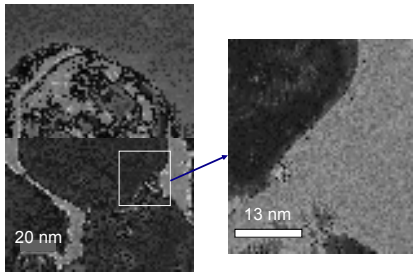
EXPERIMENTAL RESULTS



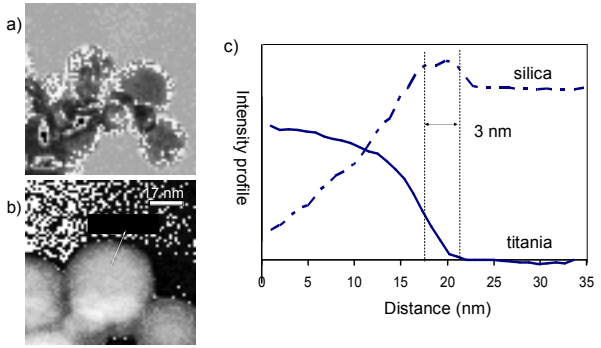
FTIR spectra of a) pure titania particle and b) modified titania particle



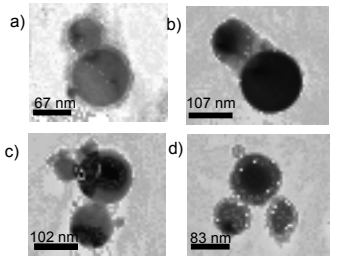
XPS results of a) pure titania and b) silica-coated titania



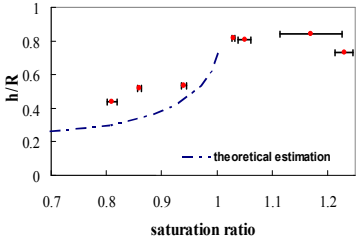
High resolution TEM image of selectively silica-coated titania nanoparticles



Electron energy loss spectroscopy analysis results: a) High resolution TEM image, b) High angle annular dark field image of selectively-coated titania particle, in which a white arrow represents the path of the line spectrum (36 spectrum separated by 1 nm), c) Intensity profiles of the Si-L2,3 and Ti-L2,3 extracted from the line spectrum depicted in b).



TEM images at the various saturation ratios



Comparison of experimental results and theoretical analysis based on Y-L equation

CONCLUSIONS AND FUTURE WORK

- Surface modification process by capillary condensation and surface reaction was performed at nanoscale length in a flow chamber.
- Modified nanoparticle samples have the bridge-shaped layer between the particles and the presence of silica layer is verified by various methods (TEM, HRTEM, FT-IR, XPS, and EELS).
- We investigated the qualitative dependency of silica layer amount from series of TEM images and compared it with theoretical analysis by Young-Laplace equation.
- Future work: understanding of meniscus geometric effect by molecular simulation and investigation of surface modification effect for the photo-activity of titania particles

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