Photothermal Aerosol Synthesis and Characterization of Silicon Nanoparticles

REU 2000
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University at Buffalo

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August 4, 2000

Outline

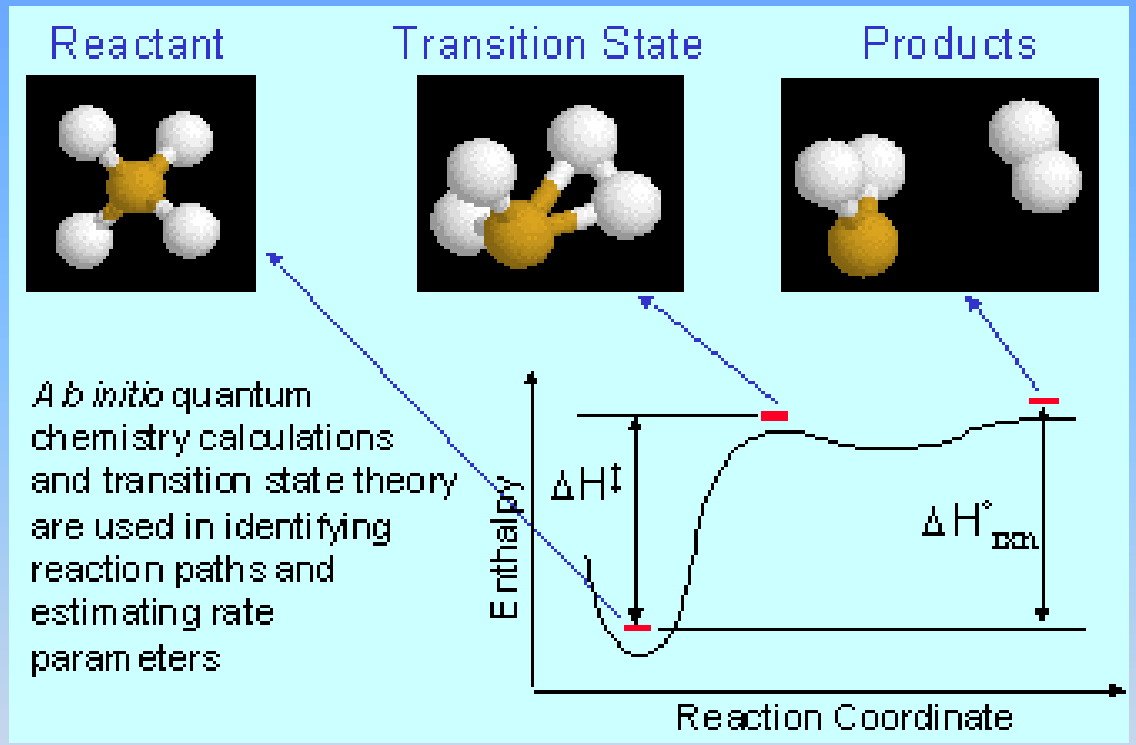
- Objectives
- Background Information
- Equipment & Methods
- Results
- Conclusion
- Future Studies

Objectives

- To understand the homogeneous particle nucleation process
- To control the homogeneous nucleation of particles while maintaining high deposition rates and reactant utilization in CVD processing
- To synthesize semiconductor nanoparticles

Background Information

- Particle nucleation:



- Overall reaction:

$$n\mathrm{SiH_4} \rightarrow \mathrm{Si}_n\mathrm{H}_{2m} + (2n\text{-}m)\mathrm{H_2}$$

Background Information (continued)

- Chemical vapor deposition (CVD):

  "A broad class of processes using controlled chemical reactions to create thin-film layers on wafers."

Equipment & Methods

- Laser-driven aerosol synthesis reactor
- Continuous-wave CO_2 laser
- Scanning mobility particle spectrometer (SMPS):
  - Aerosol neutralizer
  - Differential mobility analyzer (DMA)
  - Condensation particle counter (CPC)
  - Flow control and measurement devices

Equipment & Methods (continued)

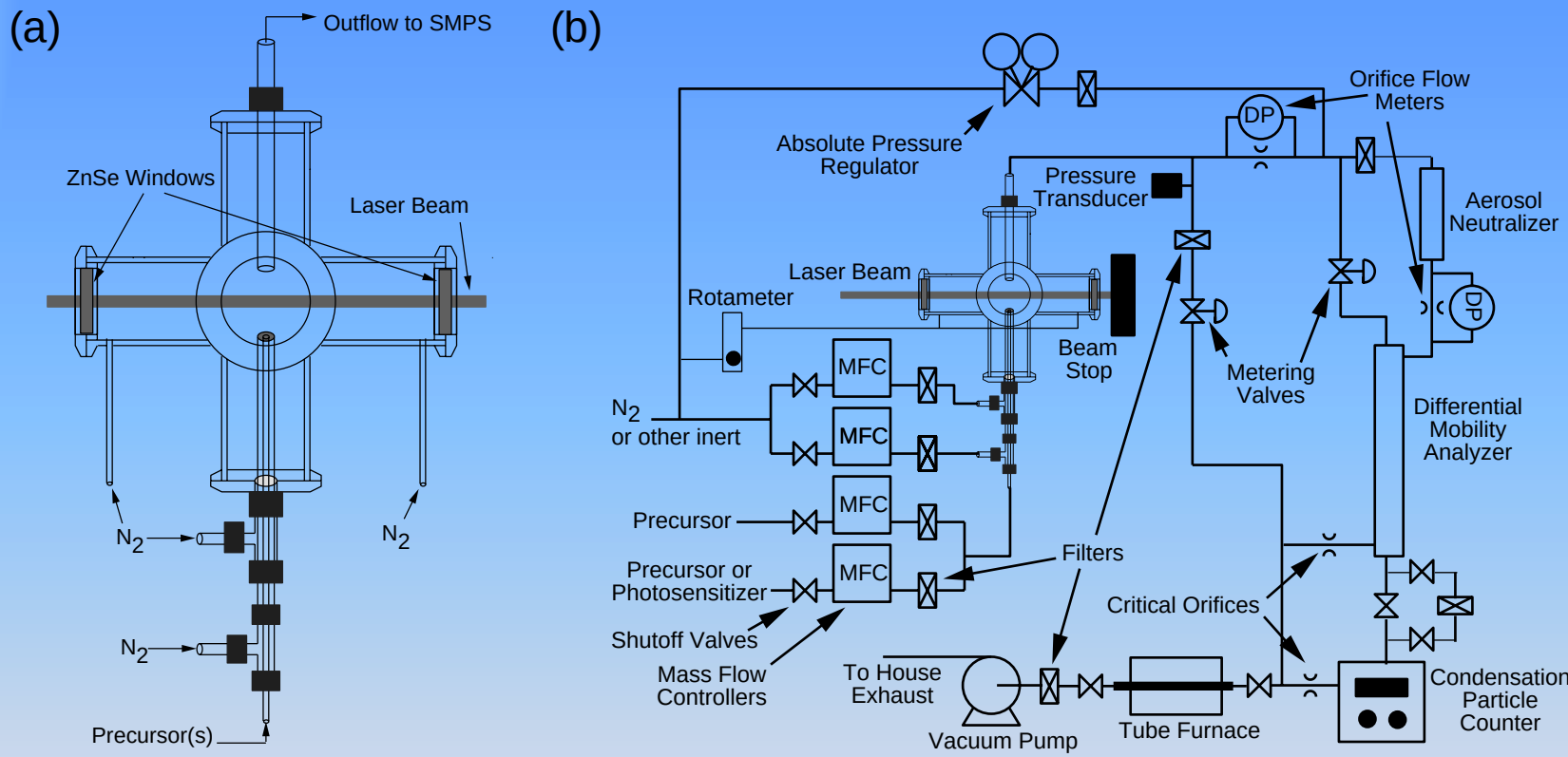


Figure 1. Schematics of (a) the photothermal aerosol synthesis reactor and (b) the overall particle synthesis and characterization system.

Reactor

Overall System

Equipment & Methods (continued)

- SiH_4 and N_2 flowed into the reactor
- Gases in the reactor heated by CO_2 laser and nucleation occurred
- Particles separated by the DMA
- Number of particle detected by the CPC

Equipment & Methods (continued)

- Particle distribution measured by varying the voltage and by the selection of particular size-to-charge ratio
- Sample particles collected for TEM analysis
- Size distribution constructed by using data inversion computer program

Results

July 22, 2000; 1st run; silane

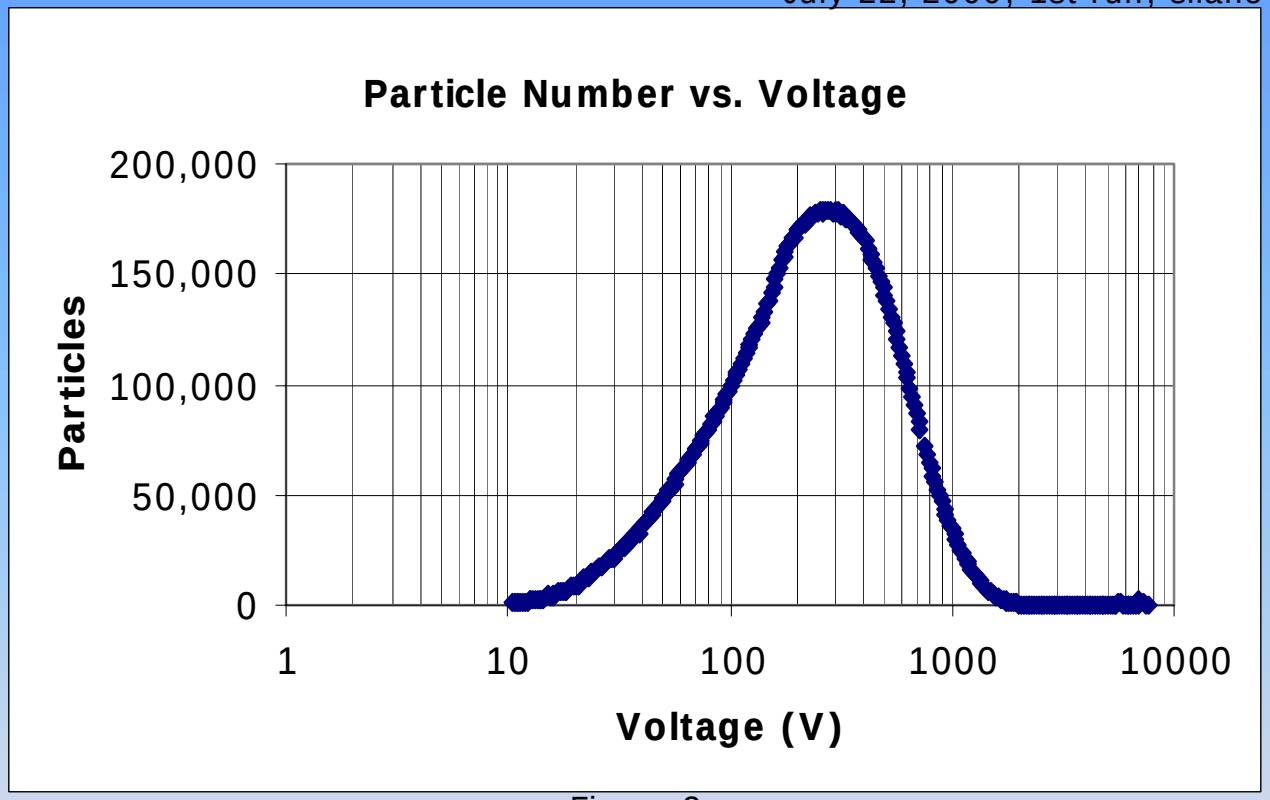


Figure 3

Particle Distribution Plot

Results (continued)

- Function:

$$q(\lambda, N) = \sum_{i=1}^{D} (KN - R)^2 + \lambda \int \left(\frac{\partial^2 N}{\partial (\ln x)^2}\right)^2 d(\ln x)$$

K = kernel function of the instrument
N = particle size distribution
R = response measured by the instrument
λ = regularization parameter

References:

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Wolfenbarger, J. K. and J. H. Seinfeld (1990). "Inversion of Aerosol Size Distribution Data." *J. Aerosol Sci*. **21**(2): 227-247.

Results (continued)

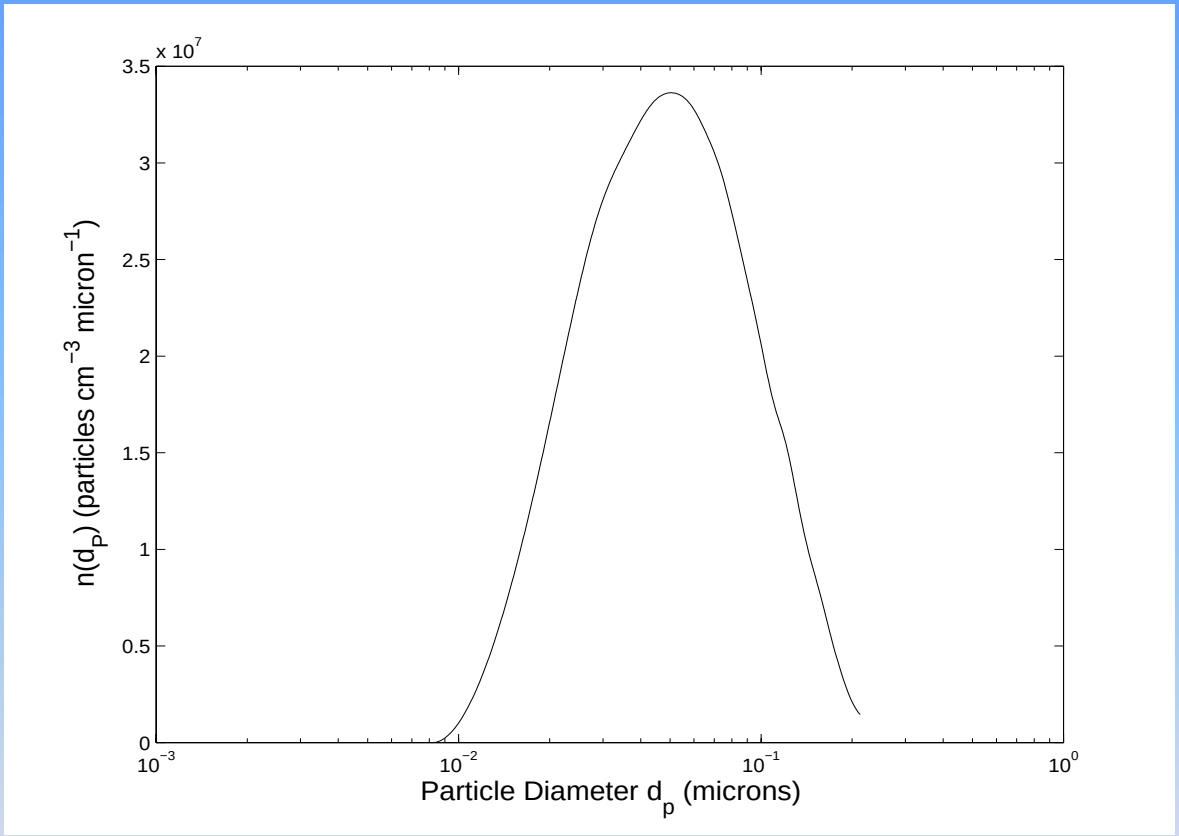

Figure 2

Particle Size Distribution Plot

Conclusion

- Hydrogenated silicon nanoparticles formed during laser-induced nucleation of SiH_4
- Particle nucleation system operational
- Data inversion program successful

Future Studies

- Apply same particle nucleation process to other materials
- Validate kinetic models of particle nucleation and growth
- Detail chemical kinetics and transport models of reactor

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Special Thanks

- Dr. Mark Swihart
- Xuegeng Li and Suddha Taludkar
- The Chemical Engineering Department at University at Buffalo