The Transport of Contaminants in Thin Film Deposition Processes

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October 17, 2001

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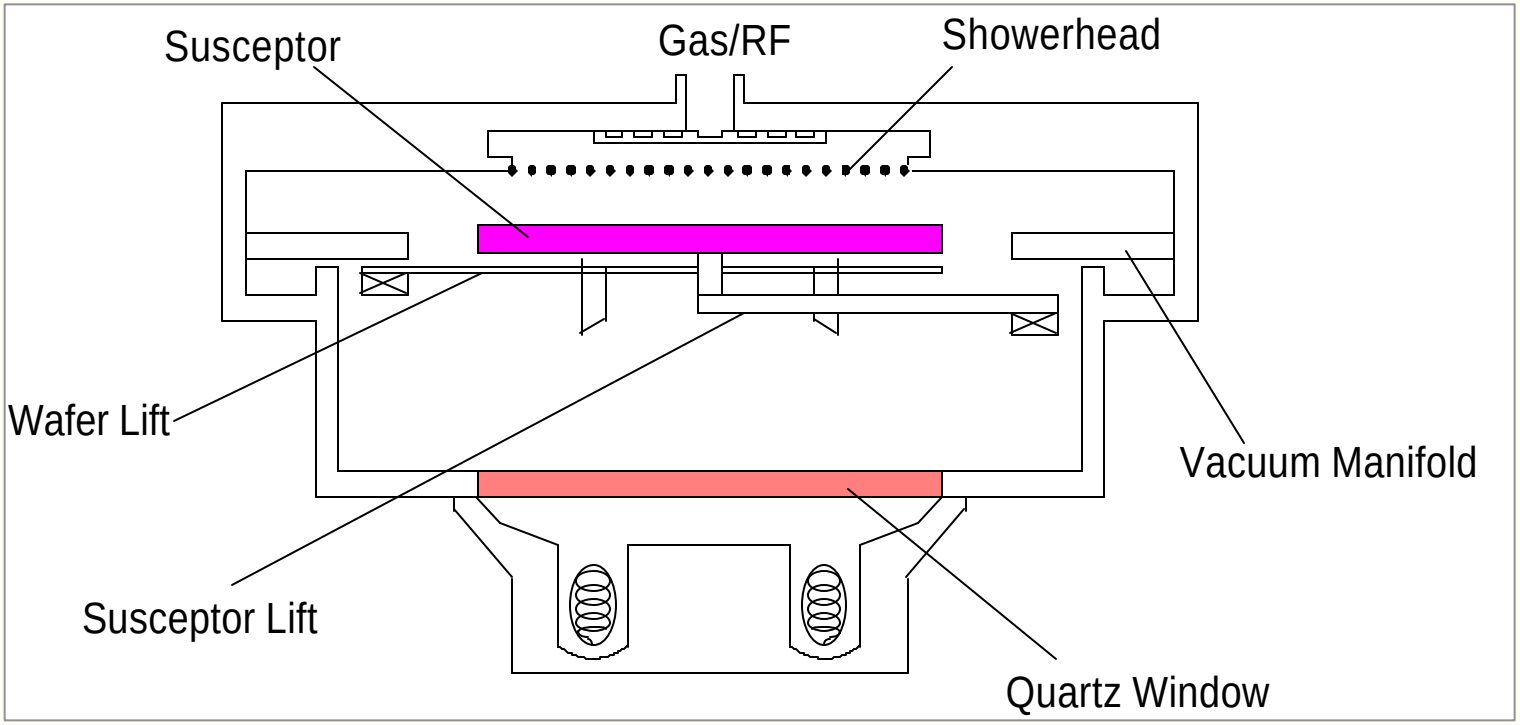
Goals

- Study the transport and deposition of contaminant particles in low-pressure processes such as CVD and PVD, ion implant, etc.
- Determine the effect of process conditions on wafer contamination during wafer processing and handling.
- Study the fundamental relationships between contaminant transport and deposition and the thermophysical behavior of the flow, and process conditions.
- Study the elimination of particle contamination using control by means of flow, electrostatics or geometrical design changes, material selection and particle traps.

Sample problem: LPCVD Reactor

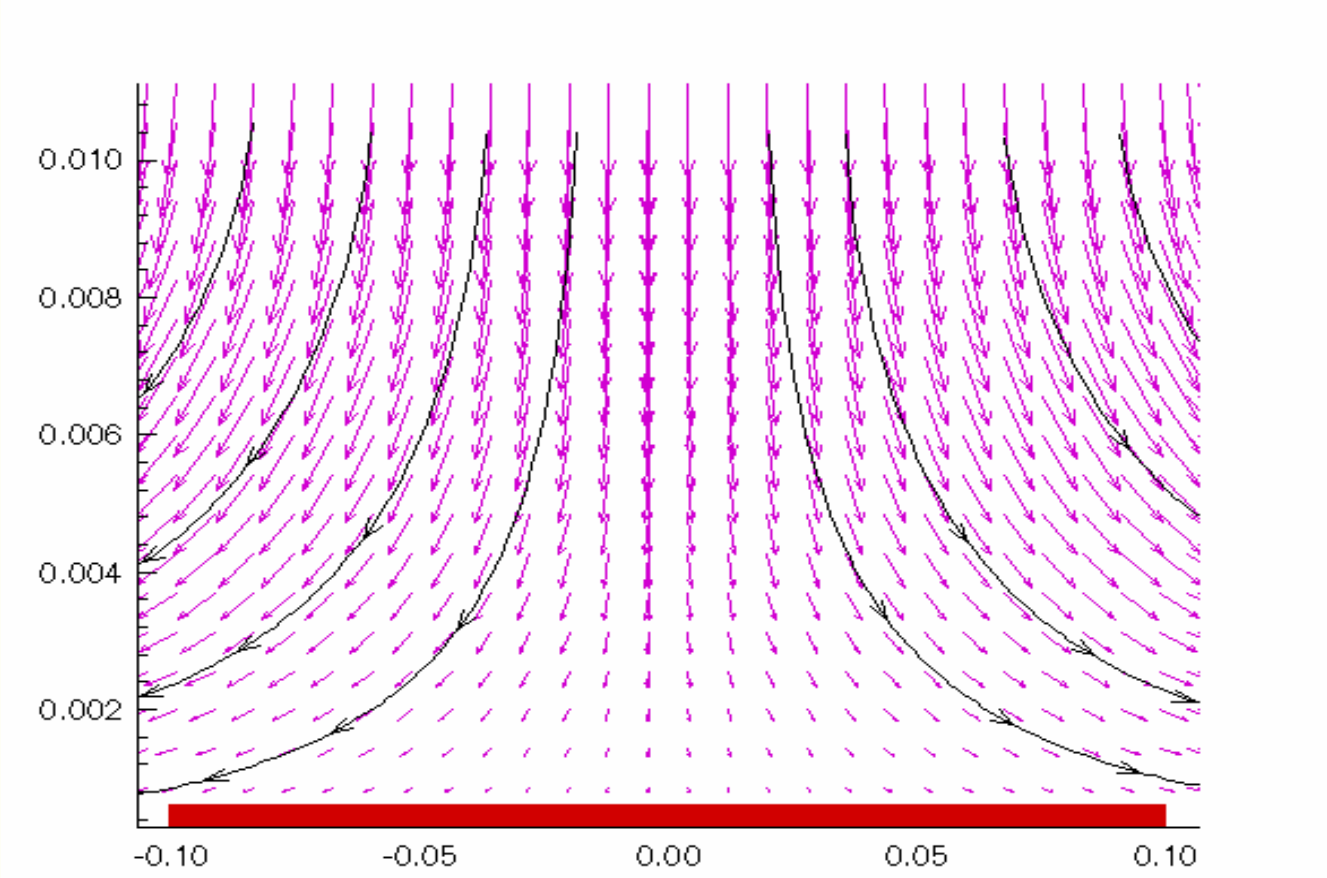


Simulation of Particle Transport and Deposition in the Reactor

- **Importance of Fluid Dynamic/Thermal modeling**
- **Lagrangian Equation of motion for particles: Identify particle forces**
- **Determine the effects of thermophoresis, Brownian motion, electrostatic forces, drag, and lift.**
- **Determine the critical deposition diameter, d_{cr}**

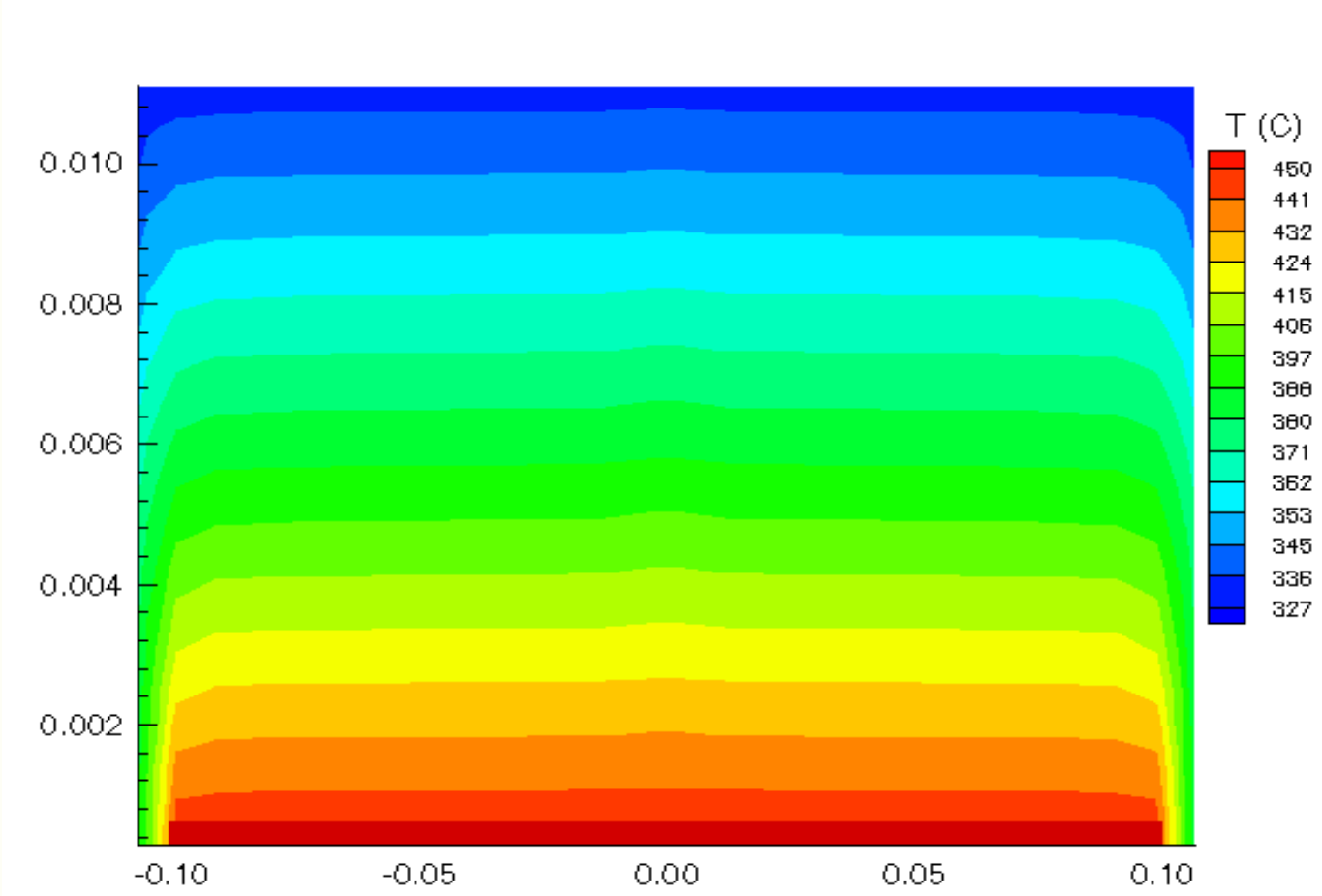
  Definition: **Any particle greater than d_{cr} will deposit on the wafer**

Velocity Vectors and Streamlines



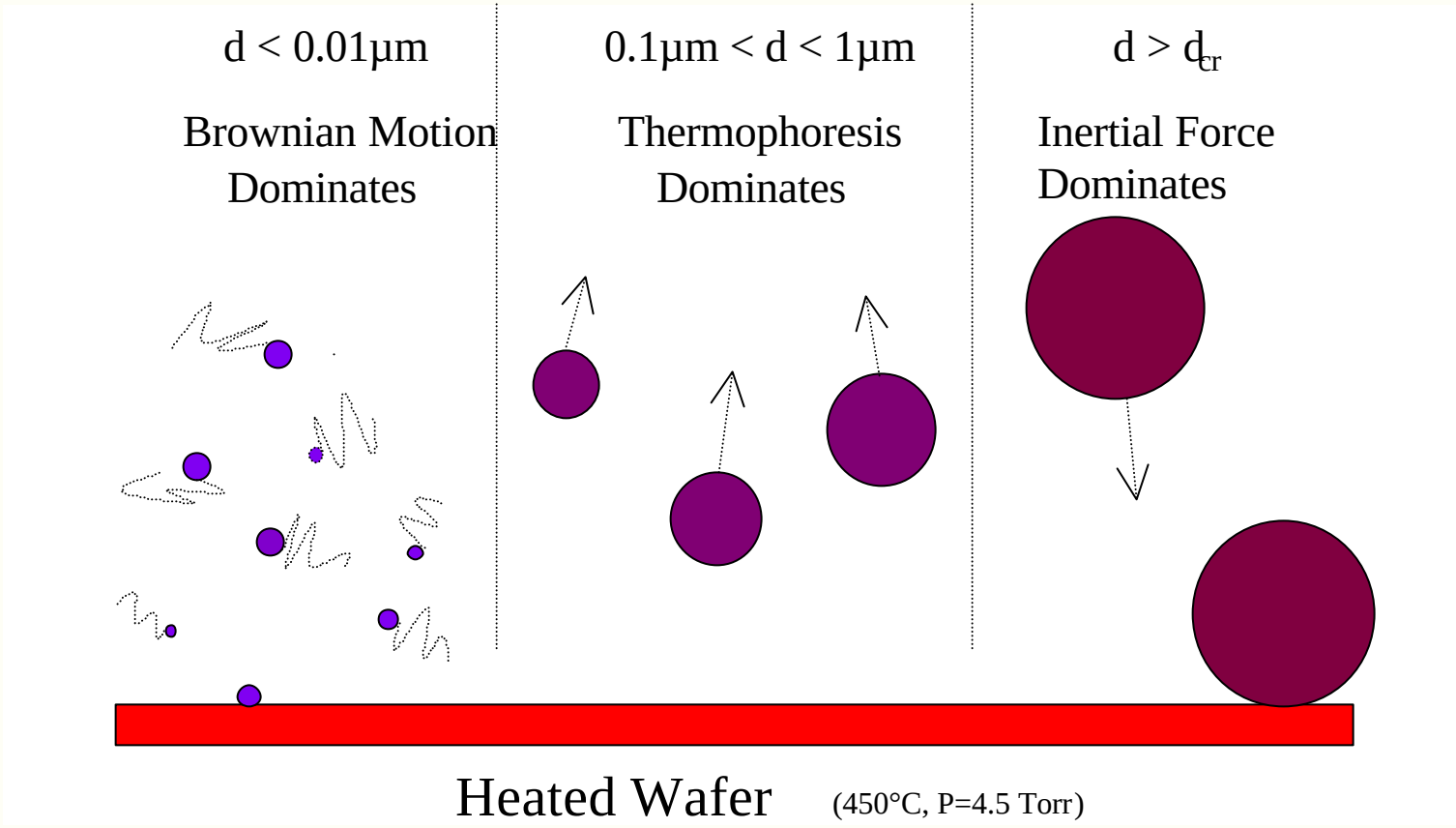
P = 4.5 Torr, Inlet Velocity = -0.575, Q = 3100 sccm

Temperature Contours



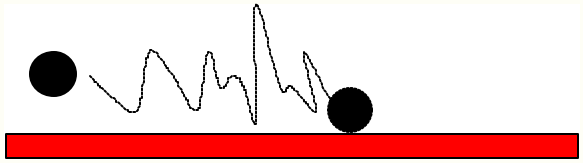
P = 4.5 Torr

Domains of Particle Motion



Effect of Brownian Motion

- **Irregular particle motion caused by the random collisions of gas molecules against the particle**
- **Affects small particles (<0.1μm)**
- **When particles are generated close to the wafer surface, they may deposit due to the Brownian motion**

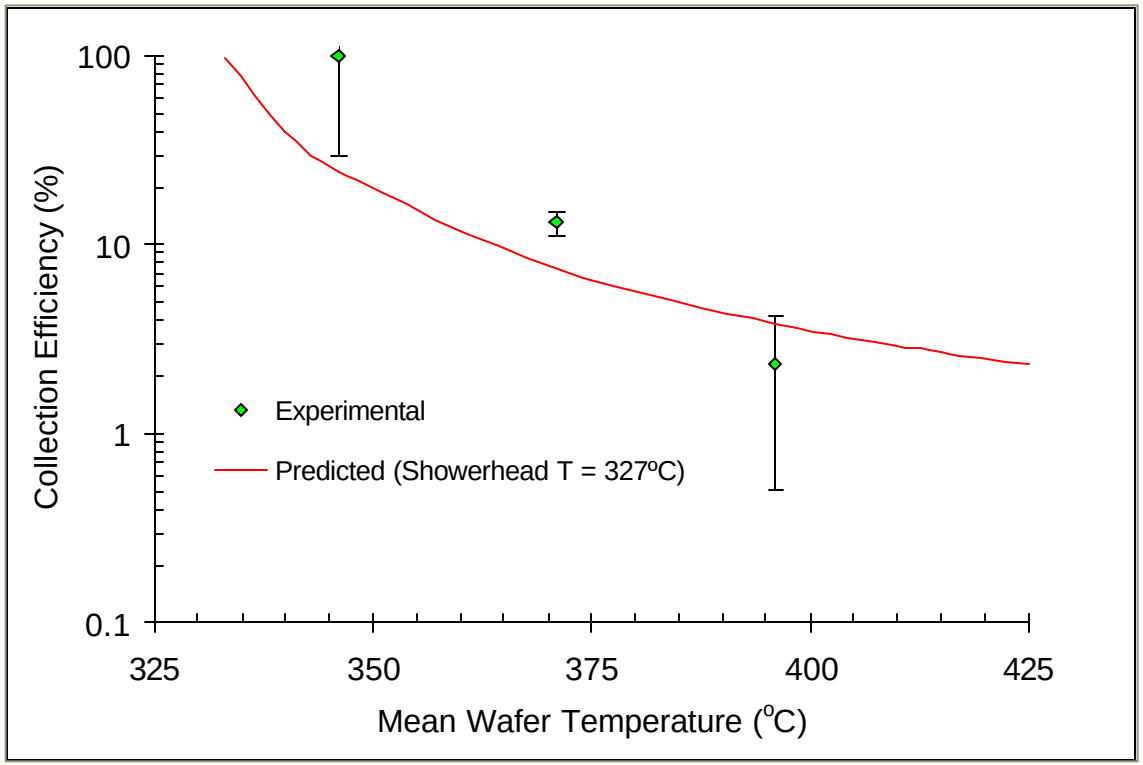


Thermophoresis

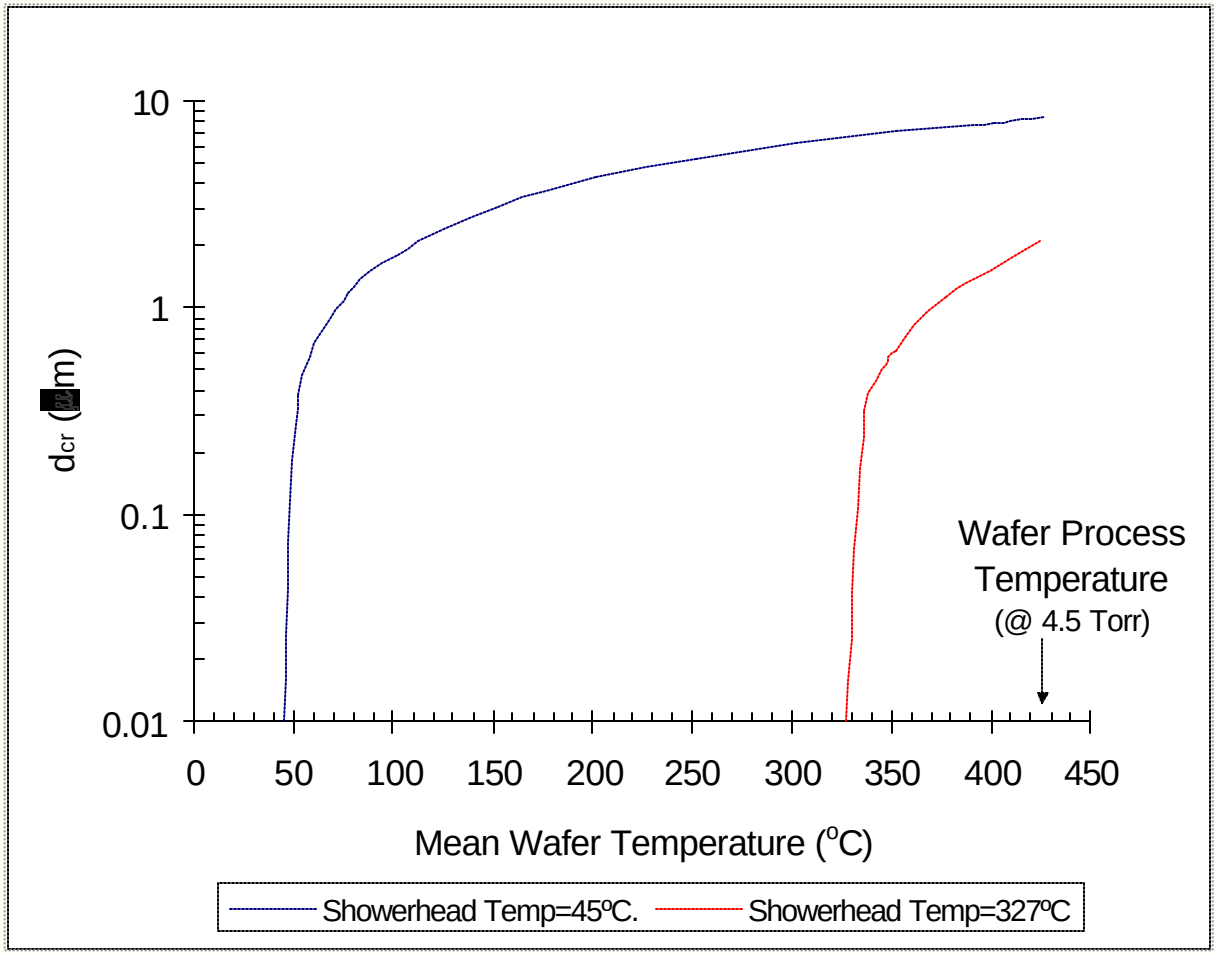
- Non continuum effect: the gas mean free path must be comparable to or larger than the particle diameter.
- Temperature gradient causes a particle motion toward low temperature.
- Origin of the force is that molecules from the high temperature region contribute more momentum to the particle than molecules from the low temperature region.

Effect of Thermophoresis

- **Particles repelled from hot surfaces, attracted to cold surfaces**



Critical Deposition Diameter, d_{cr}



Prior work on Thermophoresis

- "Laser Modification of Thermophoretic Deposition", J. W. Cipolla and T. F. Morse, *J. Colloid and Interface Sci*., **97**(1984)137.
- "Laser Enhancement of Thermophoretic Deposition Processes", J. W. Cipolla, T. F. Morse, C. Y. Wang, and D. DiGiovanni, *J. Lightwave Technology*, **LT-4**,(1986)151.
- "Thermophoresis in an Absorbing Aerosol", J. W. Cipolla and T. F. Morse, *J. Aerosol Science*, **18**, (1987)245.
- "Thermophoresis of a Radiating Aerosol in Laminar Boundary Layer Flow" J. W. Cipolla, Y. Yener and G. Jia), *J. Thermophysics and Heat Transfer*, **6**, (1992) 476.
- "Thermophoretic Focussing in Optical Materials Processing", J. W. Cipolla, I. Yannakis and T. F. Morse. Presented at the *International Symposium on Manufacturing and Materials Processing, Dubrovnik, August 1990*, Proceedings edited by W. Aung, (Begell House, NY, 1997), Vol 2, pp 795-809.
- "The Effect of Thermophoresis on Particle Deposition in a Low Pressure CVD Reactor", B. S. Mac Gibbon, A. Busnaina and B. Fardi, *J. Electrochemical Society, Solid State Science and Technology*, **146** (1999).

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- Study the fundamental relationships between contaminant transport and deposition and the thermophysical behavior of the flow, and process conditions.
- Study the elimination of particle contamination using control by means of flow, electrostatics or geometrical design changes, material selection and particle traps.
- Study the influence of the ion beam on particle generation and transport