Analysis of the Adhesion of Particles to Thin Films:

CMP/Post-CMP Cleaning Applications

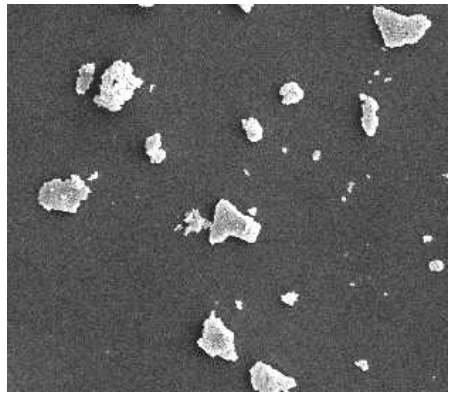
Principal Investigators: Kevin Cooper, Chemical Engineering, ASU
Stephen P. Beaudoin, Chemical Engineering, ASU
Anand Gupta, SpeedFam-IPEC Corporation

Outline

- **Motivation**
- **First Generation Model**
  - Model Description
  - Experimental Procedure
  - Experimental Validation
- **Second Generation Model**
  - Description
  - Predictions
- **Model Implications**

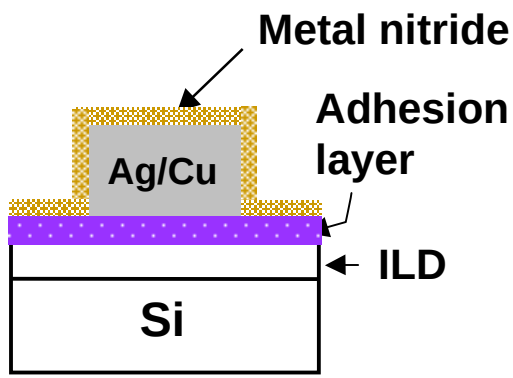
Adhesion Importance in Semiconductor Industry

- **Necessary boundary condition in modeling of post-CMP cleaning**



Alumina or silica slurry left on silicon, SiO_2, or metal film after CMP

- **Important characteristic in developing both barrier layers and thin films (both ILD and metal)**



Post-CMP Cleaning Research

Post-CMP Cleaning Model

- Input: substrate, polishing slurry, post-CMP solutions

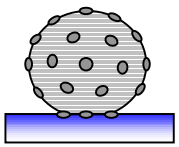
- Output: cleaning conditions

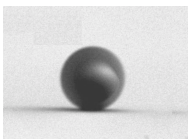
Adhesion Model

Flow Dynamics

1st generation

rough deformable spherical colloid interacting with a rough flat surface

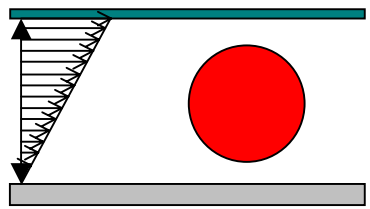


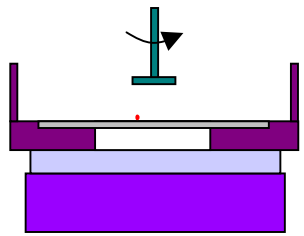


2nd generation

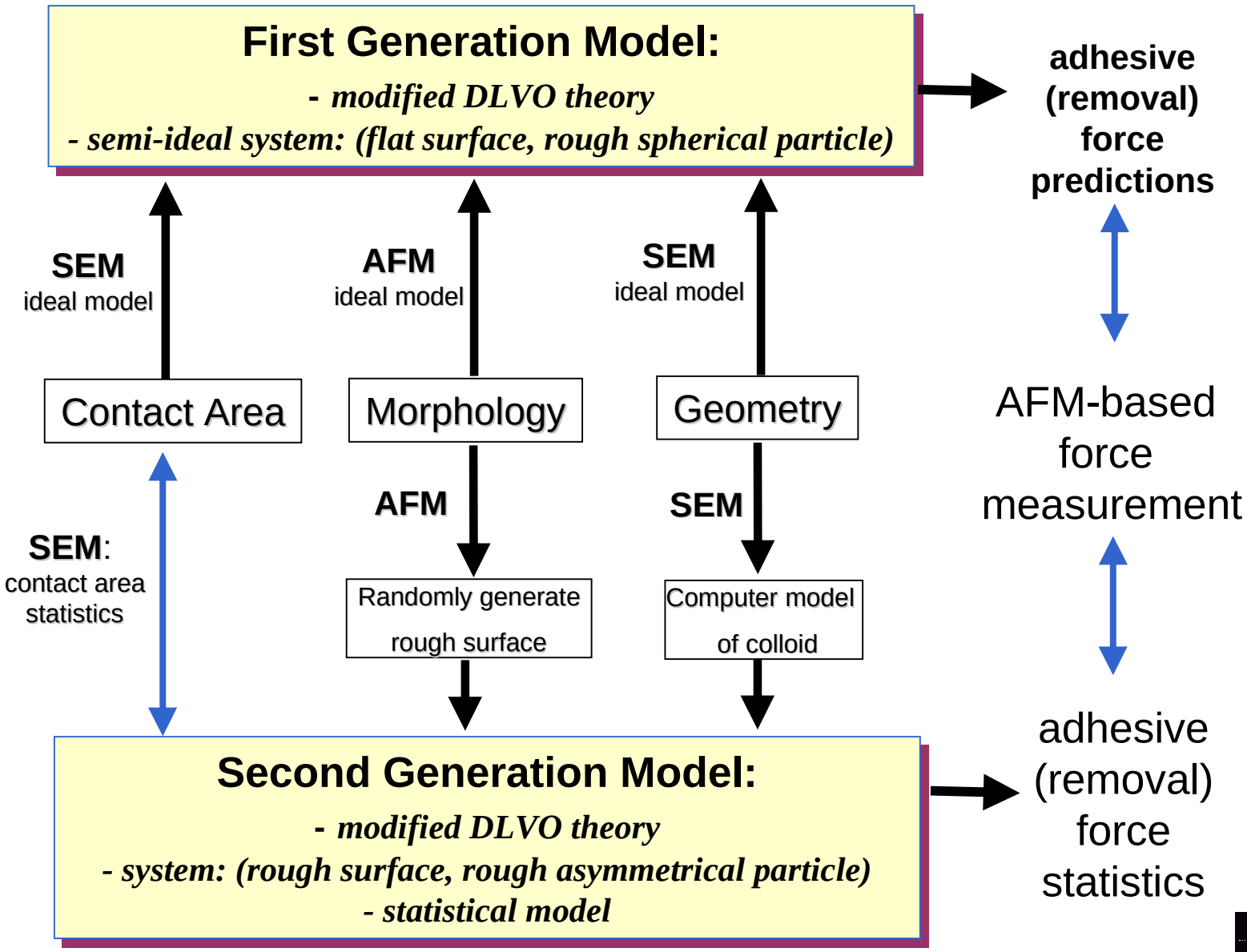
asymmetrical rough colloid interacting with any surface

Model flow field for removal of rough deformable spherical colloid interacting with a rough flat surface

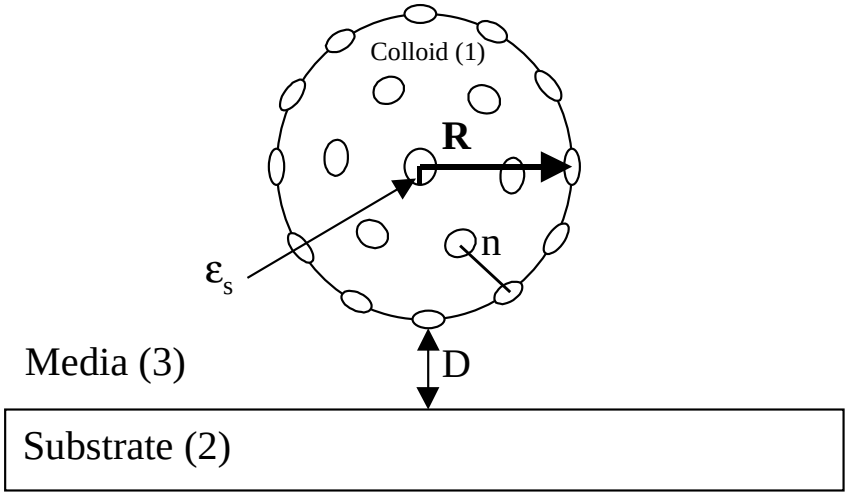


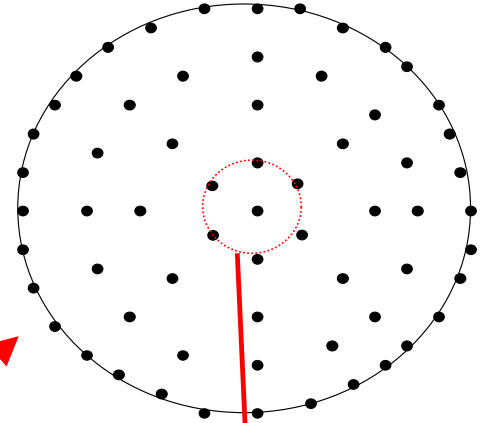


Adhesion Investigation Strategy

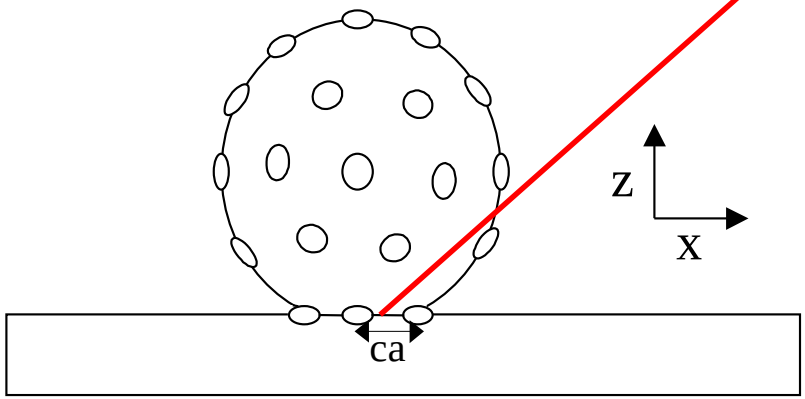


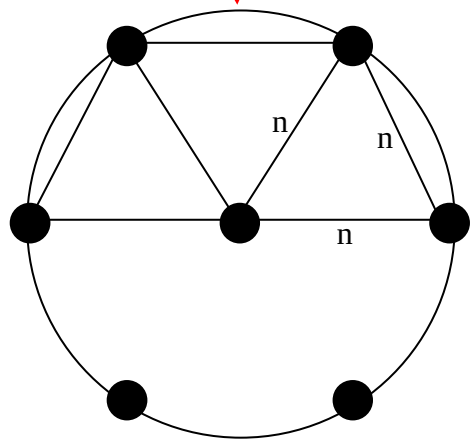
1st Generation Model





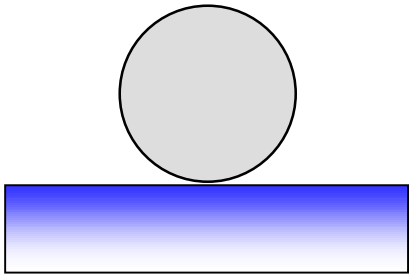
Asperities in Contact



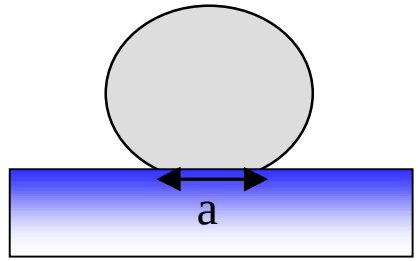


Asperities per Ring

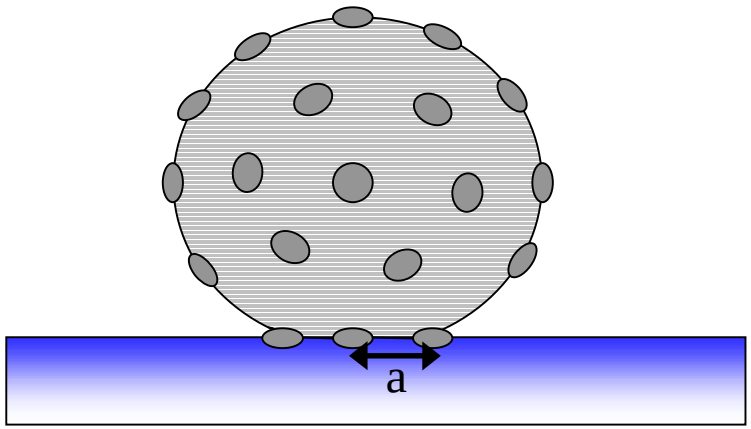
Van der Waals (vdW) Models



Ideal vdW- No deformation single contact point



Extended vdW- colloid deformation continuous contact area



Our Roughness model - colloid deformation with rigid discrete hemispherical asperity contacts

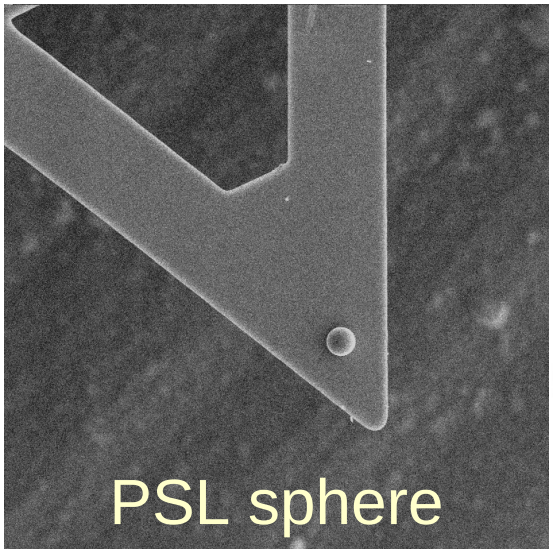
$$F_{total}(D) = -\frac{AR}{6(D+\varepsilon_s)^2} - \left[1 + \sum_{n=1}^{n=\frac{ca}{x}} \frac{360}{\arccos\left(1-\frac{1}{2\cdot n^2}\right)}\right] \cdot \left[\frac{A\varepsilon_s^4}{6D^2(D+\varepsilon_s)^3}\left[1+2\frac{D}{\varepsilon_s}\right]\right]$$

Smooth Sphere

Number of Asperities

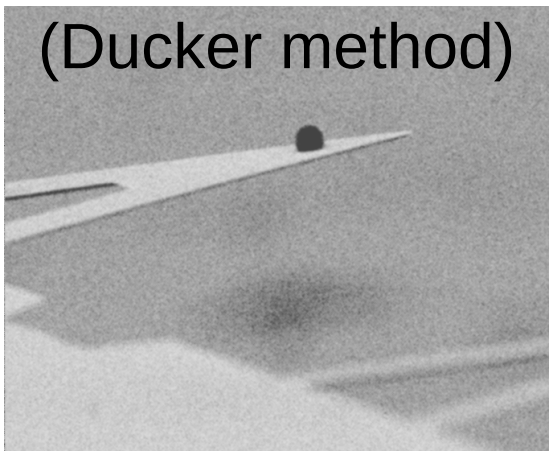
Single Asperity

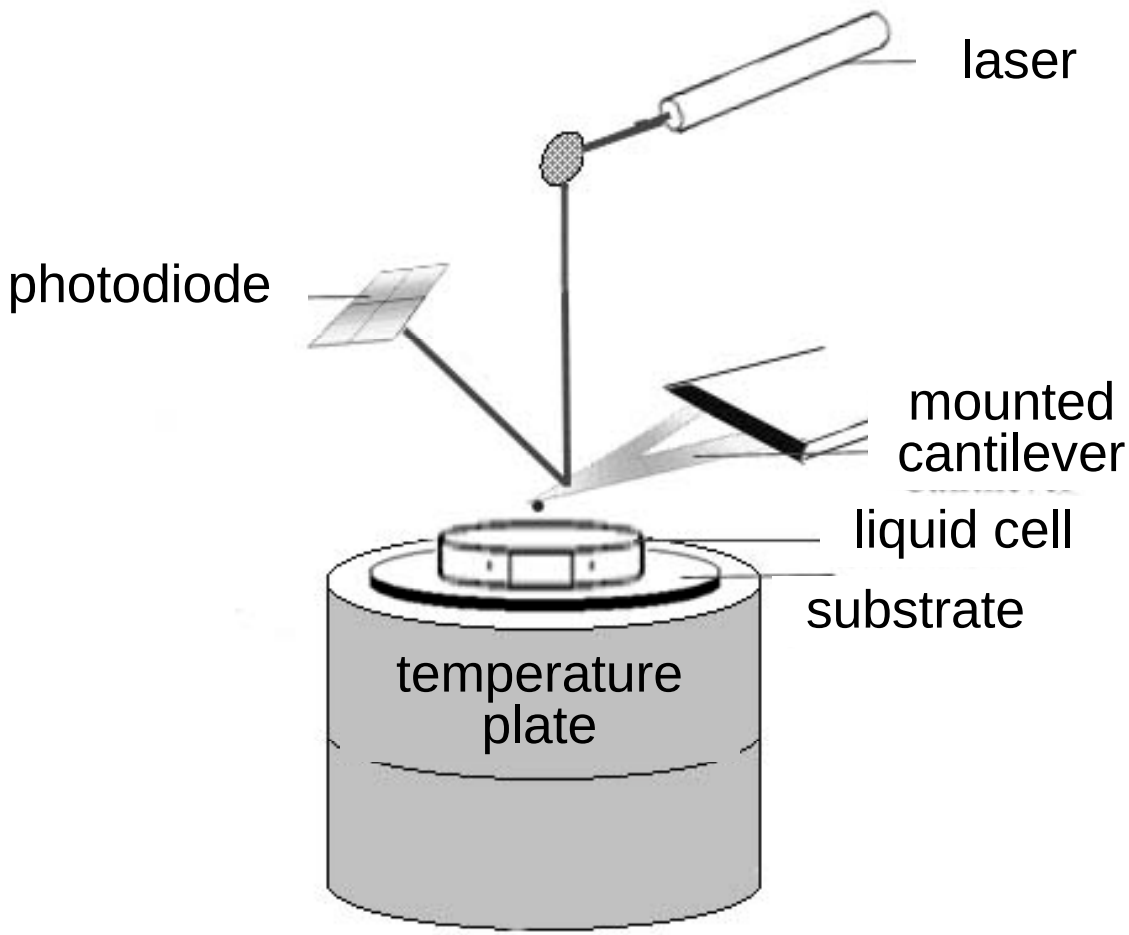
AFM Force Measurement



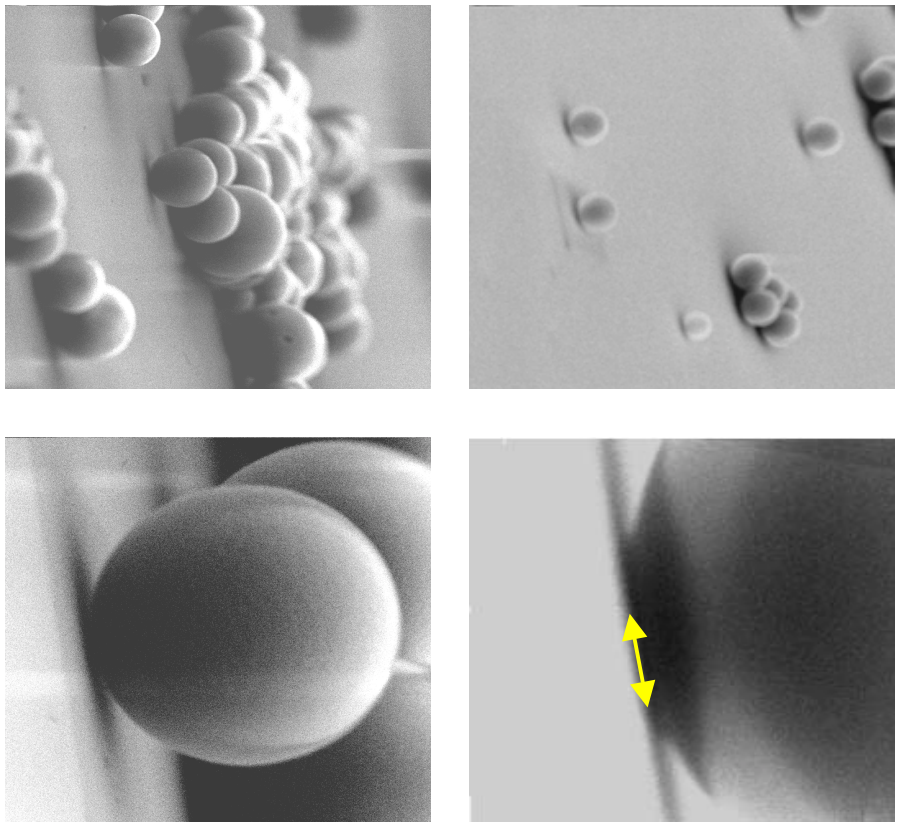
mounted on AFM cantilever

(Ducker method)





Colloid - Surface Contact Area Measurement



PSL spheres on Silicon

elastic-plastic deformation

$$C.A. = 0.43 \cdot R^{0.53}$$

adhesion-induced contact area radius (μm)

colloid radius (μm)

Comparison of Experimental Observation with Theory