Effect of Surface Roughness on Adhesion

A: Magnification of the interfacial area for a smooth sphere interacting with a smooth flat surface.

B: Magnification of the interfacial area for a smooth sphere interacting with a rough surface.
Effect of Surface Roughness on Adhesion

Modified vdW for a smooth silicon surface
Modified vdW for a rough silicon surface

Removal Force (nN)

pH

Transition Region
Effect of Surface Roughness on Adhesion

Low pH
- silicon (with native oxide)
  * not etched
  * atomically smooth
  * strong adhesion w/ PSL

High pH
- silicon (with native and grown oxide)
  * anisotropically etched (KOH)
  * rough surface (35 nm peaks)
  * weak adhesion w/ PSL
Conclusion--1\textsuperscript{st} Generation Model

- Ideal vdW models and Equilibrium Models (JKR, DMT, MP) are limited to:
  - geometric (spherical particles interacting with flat surfaces)
  - morphology (smooth systems)

- 1\textsuperscript{st} Generation model incorporates these factors
Conclusion--1\textsuperscript{st} Generation Model (cont’d)

- Aqueous media can help prevent or promote surface adhesion by:
  - Changing the surface chemistry of the interacting surfaces
  - Changing the morphology of the interacting surfaces

- Particle and surface roughness is a controlling factor in particle adhesion
Second Generation Model

**1st generation model**
- ideal geometries
- ability to model contact area
- uniform microscopic morphology

**2nd generation model**
- any geometry
- random microscopic morphology
- compression/deformation of surface asperities
- chemical heterogeneities
- bonding
- settling (tilting, shifting)
- statistical information
Second Generation Model

3-D Volume Reconstruction of Alumina/Silica Colloids -- Contact Area

Mathematically Generate Surface

2nd Generation Model
- van der Waals
- Covalent Bonds

Compression/Deformation
- surface asperities

Removal Force Statistics

AFM-based force measurement

AFM Topographic Data

Applied Load

Settling of the Particle (tilting, shifting)

Force Boundaries (Max, Min, Avg.)

SEM volume reconstruction
3-D Reconstruction
Surface Interaction

Cylindrical Volume Elements

\[ F_{\text{attr}} = - \frac{A \cdot (\text{Area cylinder})}{6 \cdot \pi \cdot D^3} \]

- Elements are placed every nm