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AE 523: Nanoscale Contact Mechanics

1. SHORT AND LONG RANGE ATOMIC INTERACTIONS

1.1. Short range forces: Admissible potentials for atomic force interactions, short range electrostatic interactions

1.2. Long range forces: Electronic and dipole interactions between atoms/molecules, origins of attractive/repulsive van der Waals forces and their retarded forms, electrostatic, capillary, double layer, steric forces, Lennard Jones and Morse potentials

1.3. Molecular and particle force interactions: Derjaguin approximation, "bottom-up" derivation of adhesive forces

2. MECHANICS OF CONTACT AND ADHESION

2.1. Herzian contact: Problem formulation, solution, application to brittle and ductile Herzian contact

2.2. Sneddon contact: Boussinesq problem, solution for singular, non-singular and indeterminate contact profiles.

2.3. Nanoindentation: Problem formulation, derivation of equations for common singular contact profiles from Sneddon's solutions

2.4. Adhesive models based on continuum formulations: JKR, DMT, Maugis/Dugdale, fracture mechanics equivalence, analogies between DMT/Bradley and JKR/Lennard Jones models

2.5. Capillary forces: Effect of thermodynamic parameters on capillary properties

3. APPLICATION OF CONTACT MECHANICS TO PROBE MICROSCOPY

3.1. Scanning probe microscopes: Instrumentation, spatial and force calibration, scanner artifacts, tip imaging deconvolution of objects of revolution, thermal noise, energy dissipation at the AFM tip

3.2. AFM imaging in non-contact mode: Dynamics of AFM cantilevers in free space and under surface and capillary forces, atomic resolution by non-contact AFM

3.3. Force spectroscopy: Analysis of force displacement curves for van der Waals, repulsive, electrostatic, double-layer, mechanical deformation, (capillary) adhesion, and unbinding of receptor–ligand forces, jump-to-contact instability, force resolution

4. LABORATORY ASSIGNMENTS

4.1. AFM controls: Calibration of AFM cantilever dynamics for high fidelity imaging, PID controls and tip shape determination

4.2. AFM feature deconvolution: Tip-surface deconvolution, tip calibration and true nanoscale measurements of objects of revolution (nanofibers, nanowires, and nanoparticles)

4.3. Force-displacement curves: Measurement of force interactions on hydrophilic and hydrophobic surfaces

4.4. Nanoindentation Lab: Independent determination of tip area functions, calibration of tip area functions for pile-up, application of nanoindentation to spherical particle nanocomposites

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