Lecture: P1_Wk2_L6

Combining contact mechanics with intermolecular interactions

Ron Reifenberger

Birck Nanotechnology Center

Purdue University

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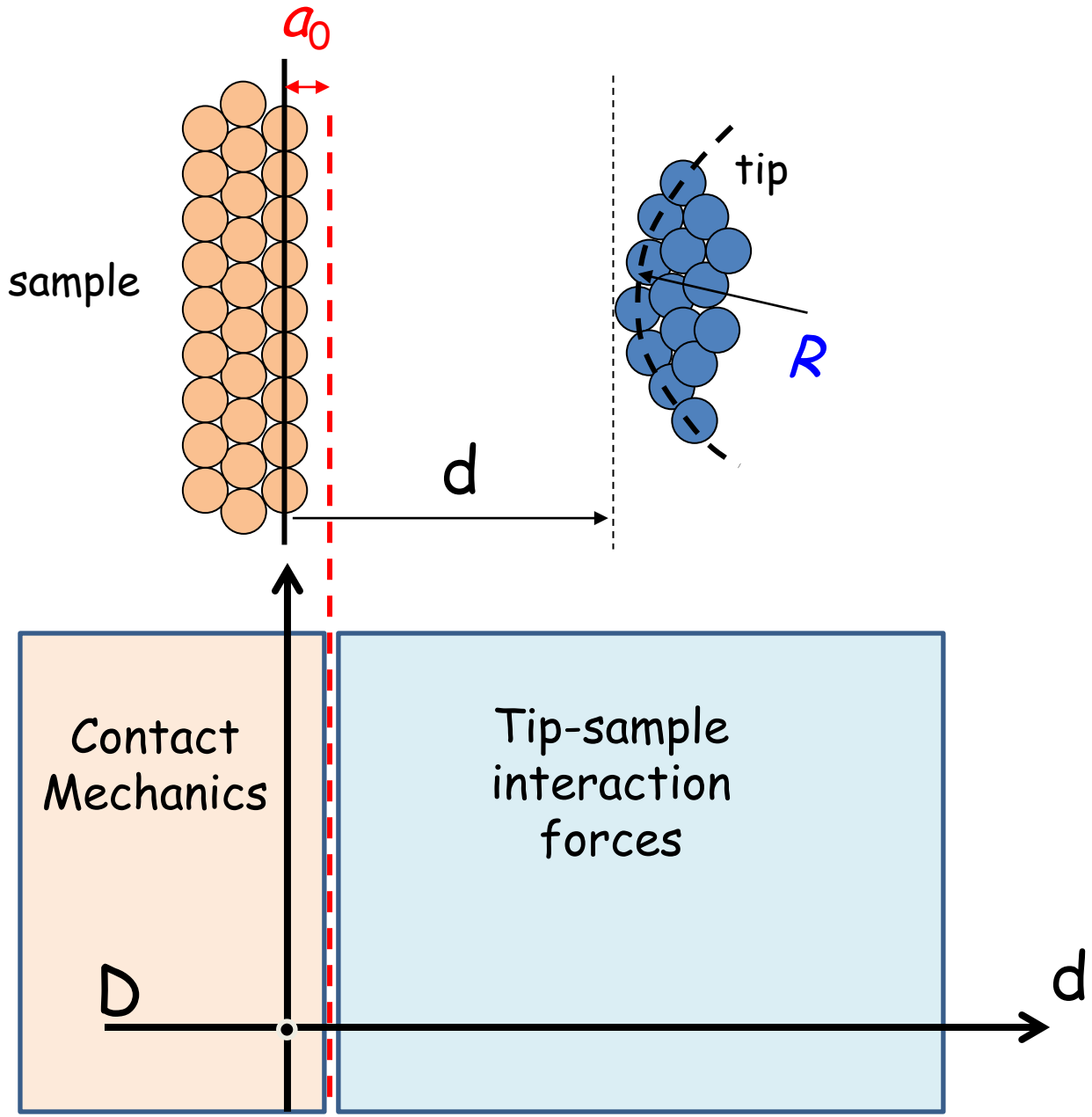
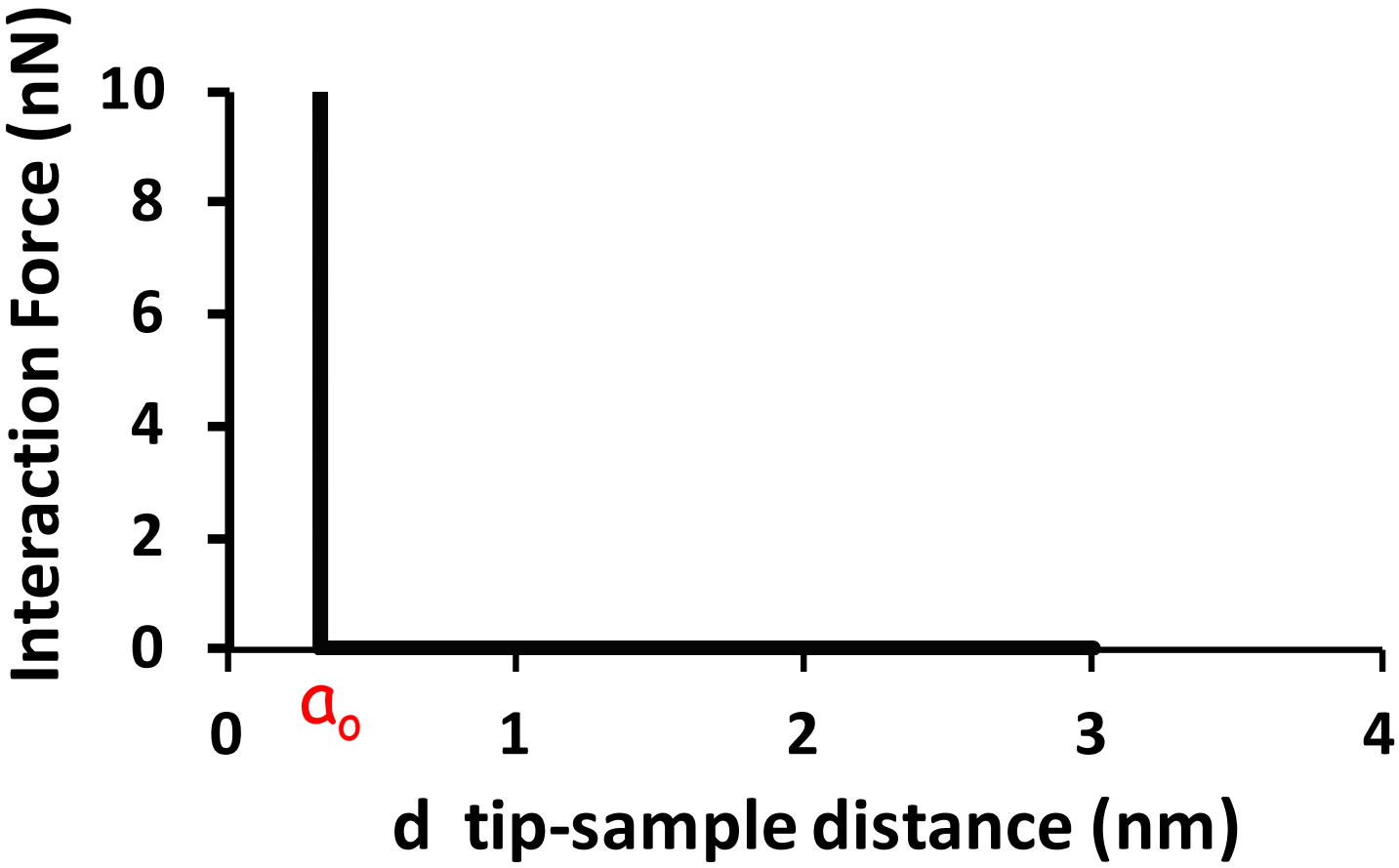
PURDUE UNIVERSITY

How to Model?


a_0
sample
tip
R
d
Contact Mechanics
Tip-sample interaction forces
D
d

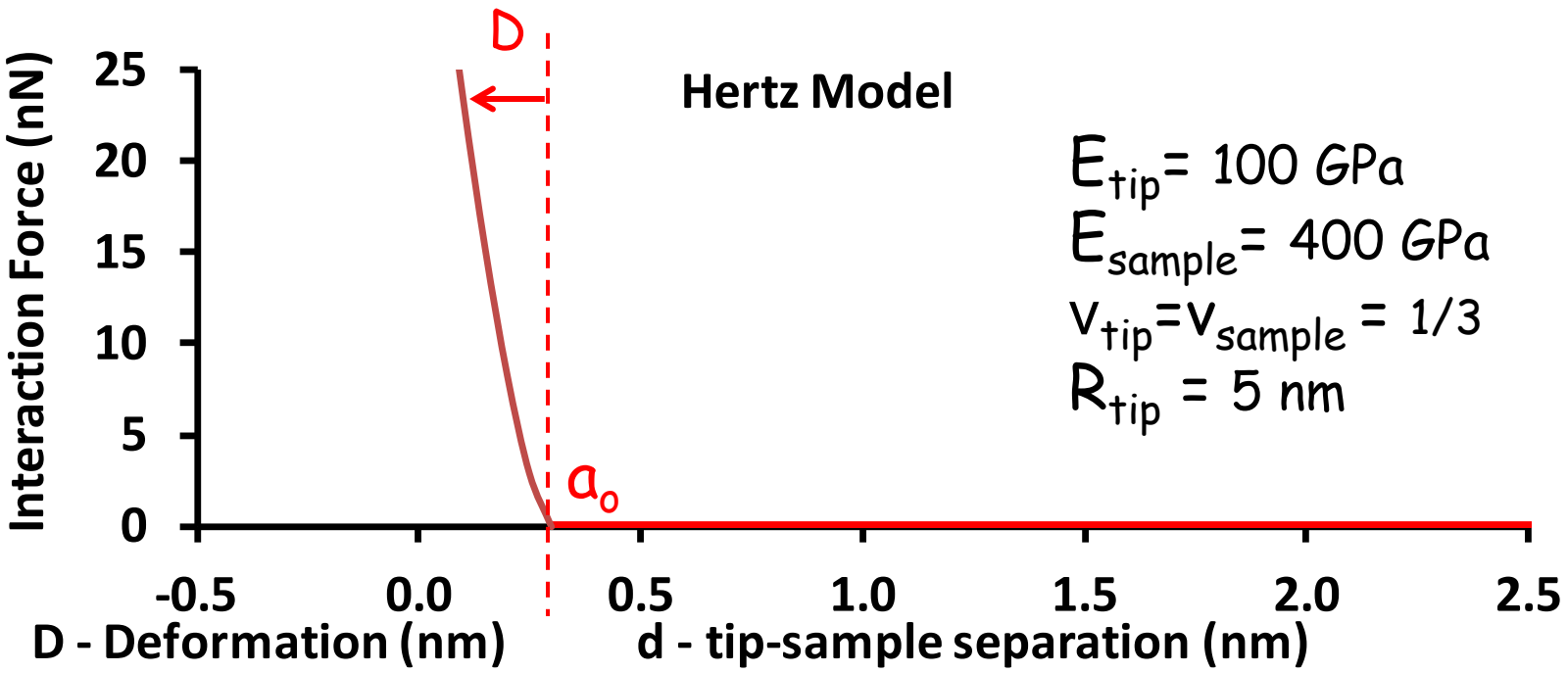
The infinitely hard tip/sample with no surface forces



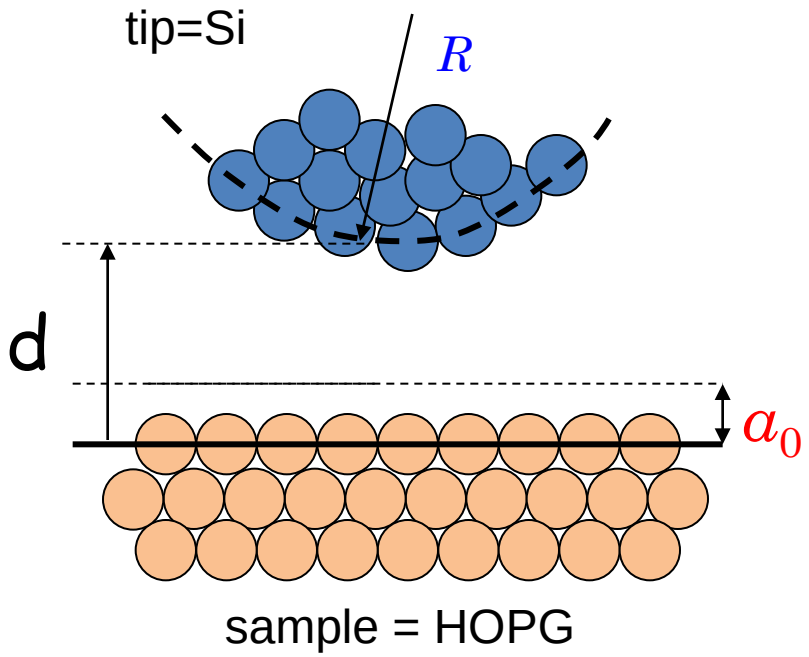
Hertz Contact - indentation, no surface force

$$F_{Hertz}(d) = \begin{cases} 0 & d > a_o \\ \frac{4}{3} E^* \sqrt{R} \left(a_o - D\right)^{3/2} & D \le a_o \end{cases}$$

$$E^* = \left[\frac{1 - \nu_{tip}^2}{E_{tip}} + \frac{1 - \nu_{sample}^2}{E_{sample}} \right]^{-1}$$



Combining van der Waals force & DMT contact



H : Hamaker constant (Si-HOPG)

R : Tip radius

E^* : Effective elastic modulus

a_o : Intermolecular distance

$$F_{DMT}(d) = \begin{cases} -\dfrac{HR}{6d^2} & d > a_o \\ -\dfrac{HR}{6a_o^2} + \dfrac{4}{3}E^*\sqrt{R}\left(a_o - D\right)^{3/2} & D \le a_o \end{cases}$$

$$E^* = \left[\frac{1-\nu_{tip}^2}{E_{tip}} + \frac{1-\nu_{sample}^2}{E_{sample}}\right]^{-1}$$

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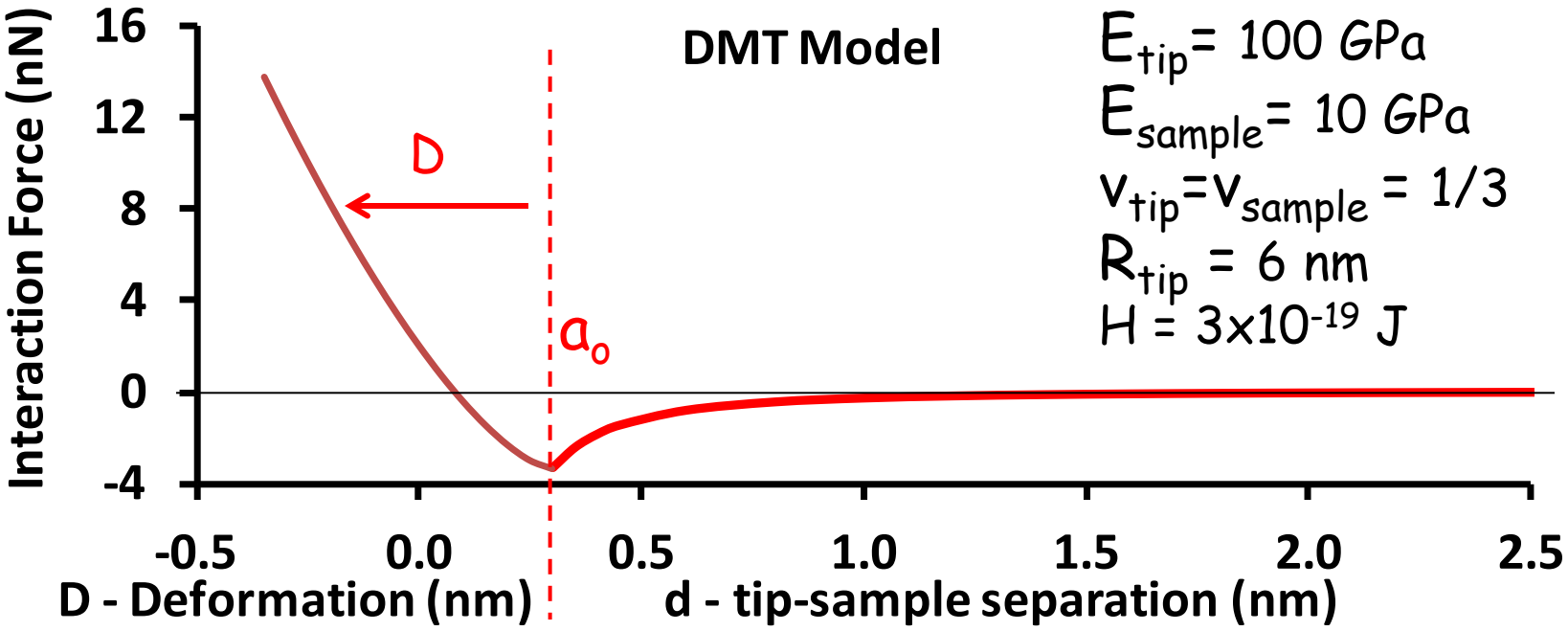
Raman et al, Phys Rev B (2002), Ultramicroscopy (2003)

DMT Contact – indentation and surface forces

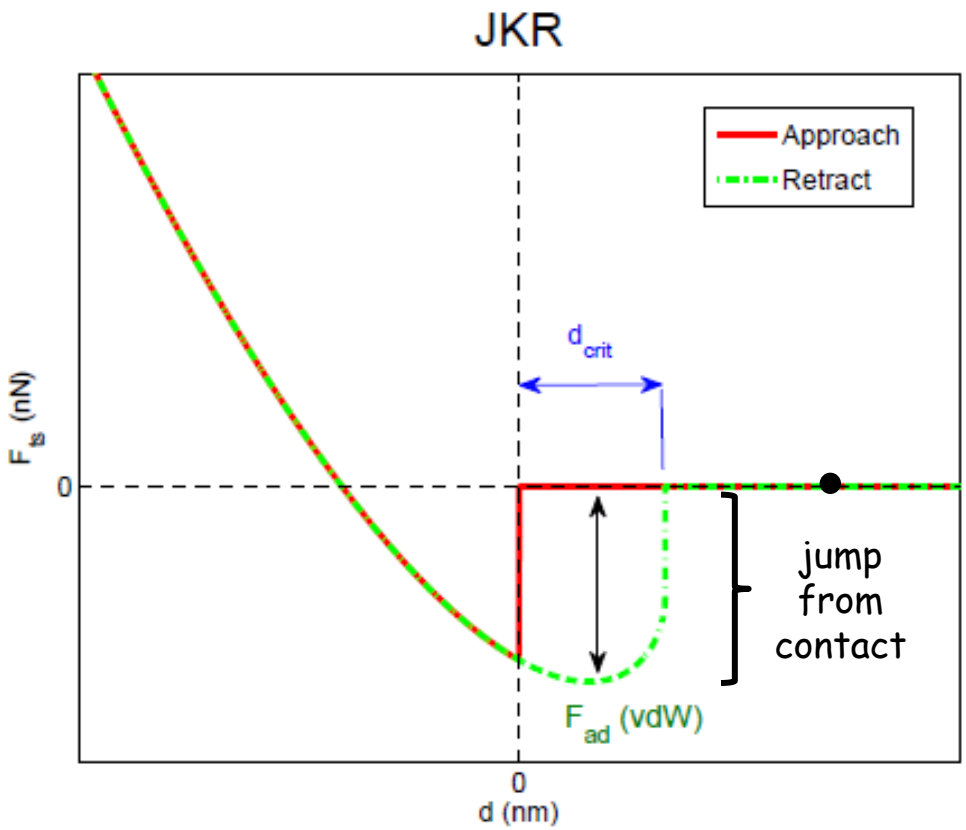
$$F_{DMT}(d) = \begin{cases} -\dfrac{HR}{6d^2} & d > a_o \\ -\dfrac{HR}{6a_o^2} + \dfrac{4}{3}E^* \sqrt{R}\left(a_o - D\right)^{3/2} & D \le a_o \end{cases}$$

$$E^* = \left[\frac{1-\nu_{tip}^2}{E_{tip}} + \frac{1-\nu_{sample}^2}{E_{sample}}\right]^{-1}$$



JKR Contact

$$F_{jkr}(d) = \begin{cases} 0, & Approaching, d > 0 \\ \frac{4E^* a^3}{3R} - \sqrt{8\pi W_{jkr} E^* a^3}, & (Approaching\ and\ d < 0)\ or\ (Retracting\ and\ d < d_{crit}) \\ 0, & Retracting, d > d_{crit} \end{cases}$$



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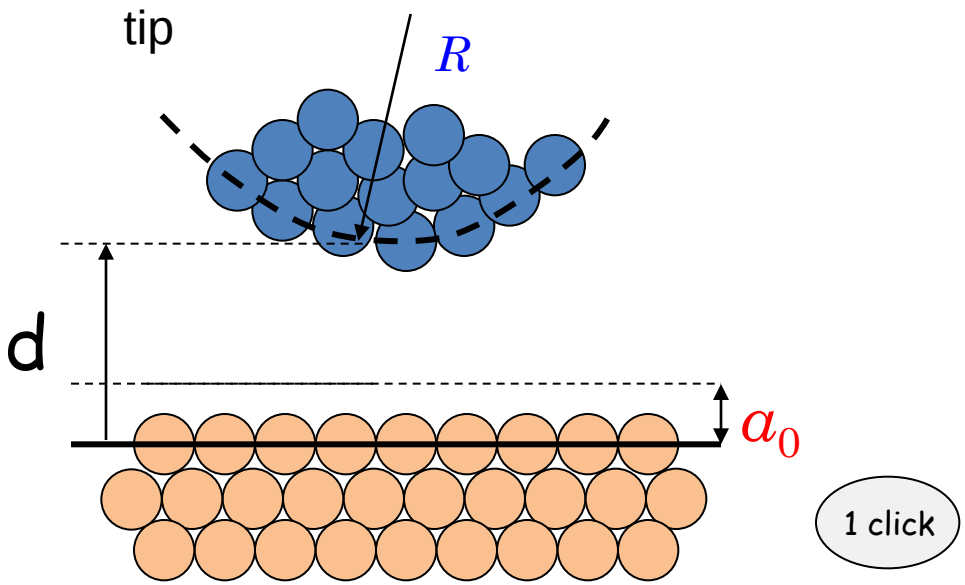
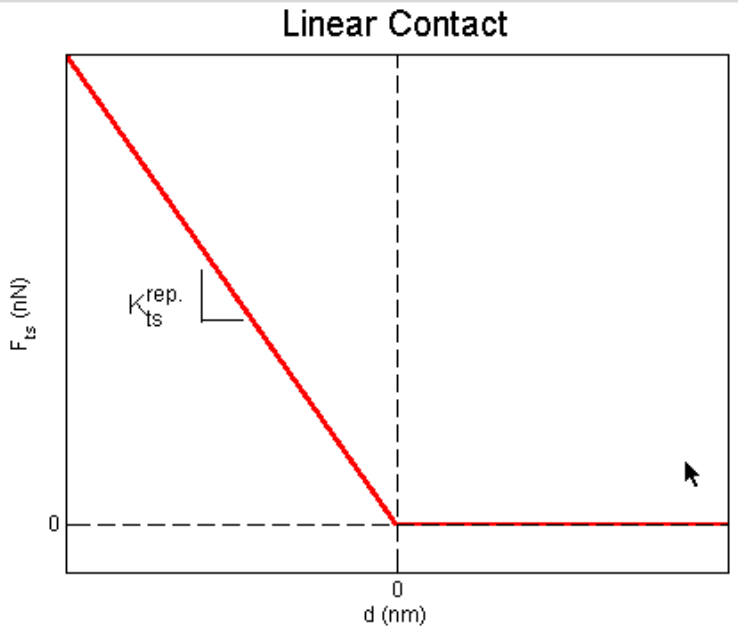
The model you choose must fit your experiments

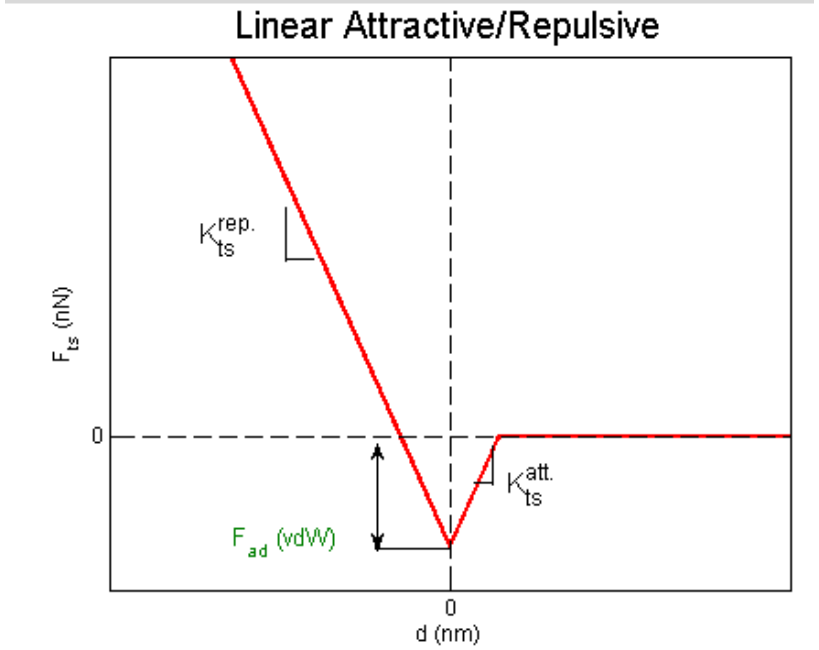
VEDA Models:

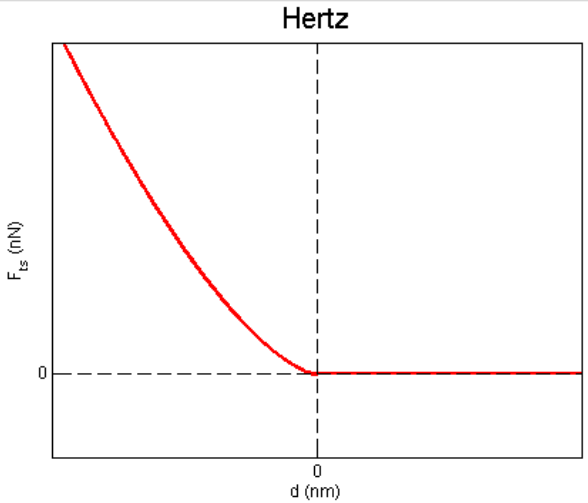
- Linear contact
- Linear attractive/repulsive
- Hertz contact
- DMT contact
- DMT + DLVO interactions (liquids)
- JKR
- Chadwick
- vdW + Morse potential
- vdW + Lennard Jones potential
- Electrostatic force – non contact
- Magnetic dipole

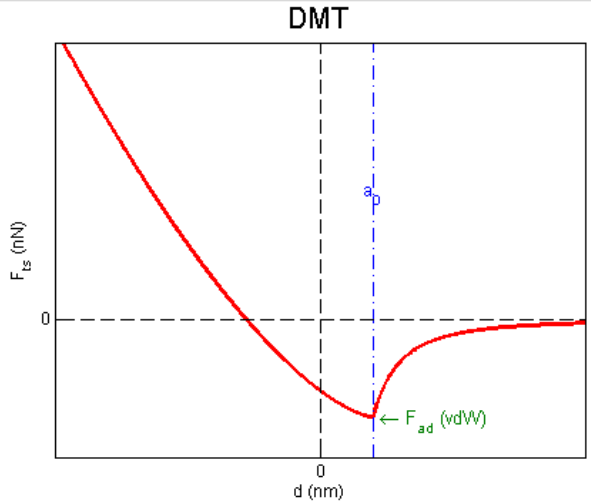


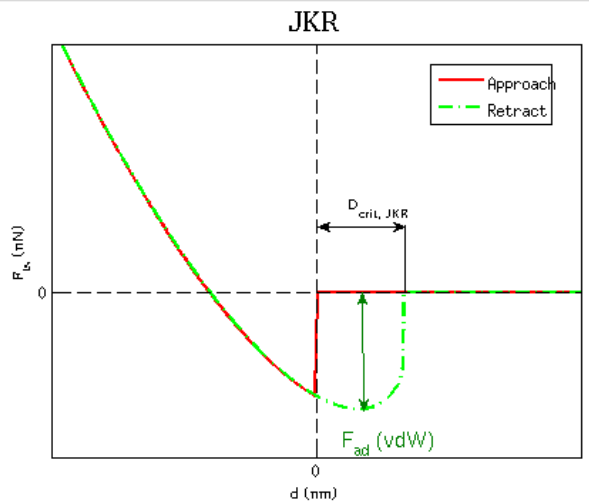
Plots of a few VEDA models











Week 3: Brief introduction to VEDA plus discussion of AFM Instrumentation