MAR05-2004-010116

Abstract for an Invited Paper
for the MAR05 Meeting of
the American Physical Society

Oscillating viscoelastic JKR contacts

KATHRYN J. WAHL, U.S. Naval Research Laboratory, Washington DC 20375 USA

Adhesion of micron-scale probes with model elastomers was studied with a depth-sensing nanoindenter under oscillatory loading conditions. Force-displacement curves were highly reversible, consistent with Johnson-Kendall-Roberts (JKR) behavior. However, experiments revealed striking differences between the measured tip-sample interaction stiffness and the theoretical prediction from the JKR relationship. Measured stiffness was always greater than zero, and varying probe radius or polymer modulus resulted in stiffness curve shapes remarkably similar to Maugis JKR/DMT transition curves. These apparent paradoxes are resolved by considering viscoelasticity of an oscillating crack tip. Under well described conditions determined by oscillation frequency, sample viscoelasticity, and Tabors parameter, an oscillating crack tip will neither advance nor recede. Thus, contact size is fixed at any given instant, and experimentally measured stiffness is equal to the punch stiffness. For fixed oscillation frequency, transition between JKR and punch stiffness can be brought about by increasing probe radius, decreasing sample modulus, or varying frequency. Comparisons of experiments and theory will be presented. Storage modulus and surface energy measured from nanoscale JKR results were compared to calculated and measured with conventional nanoindentation and JKR force-displacement analyses. With this method it is possible to make localized mechanical property measurements for contacts with diameters smaller than the optical limit.

Collaborators: S.A. Syed Asif (Hysitron, Inc.); K.L., Johnson, J.A. Greenwood (Cambridge Univ., UK)