JKR ADHESION TESTING BETWEEN BIOLOGICALLY RELEVANT SURFACES

Adam J. Nolte, Heqing Huang, and Christopher M. Stafford
Polymers Division, National Institute of Standards and Technology, Gaithersburg, MD, USA
chris.stafford@nist.gov

Introduction

In this work we report recent observations obtained using an adhesion testing device that utilizes the contact mechanics theory of Johnson, Kendall, and Roberts (JKR).[1] Our goal is to develop a system capable of measuring adhesive forces between biologically functionalized surfaces, thus providing a route for researchers to probe interactions such as receptor-ligand binding or the effect of substrate characteristics such as roughness and surface energy on the adhesion of protein molecules in relevant solution environments.

Our device consists of a hemispherical poly(dimethylsiloxane) (PDMS) lens that is pressed into a substrate of interest and then pulled off. By monitoring the contact radius (a) of the lens with the substrate and the force (P) during loading and unloading, one can measure the energy release rate ($\mathcal{G}$), which is a type of instantaneous measurement of the interfacial energy between the lens and substrate surfaces:

$$\mathcal{G} = \frac{\left(4Ea^3/3R - P\right)^2}{8\pi Ea^3}, \qquad (1)$$

where E is the plane-strain Young's modulus of the lens (assuming a rigid substrate) and R is the lens radius of curvature. Our figure of merit in this work is the adhesion hysteresis ($\mathcal{G}_{HYS}$), which is defined as the difference between $\mathcal{G}$ as measured during the unloading and loading portions of the experiment:

$$\mathcal{G}_{HYS} = \mathcal{G}_{UL} - \mathcal{G}_{L}. \qquad (2)$$

In this way, the value of $\mathcal{G}_{HYS}$ reflects the development of specific adhesion interactions that form while the lens is in contact with the substrate.

Experimental

Equipment and instruments or materials are identified in this work in order to adequately specify the experimental details. Such identification does not imply recommendation by the National Institute of Standards and Technology (NIST), nor does it imply that the materials are necessarily the best available for the purpose.

PDMS lenses were prepared by mixing Sylgard 184 PDMS in a 10:1 ratio by mass of base to crosslinker. The mixture was degassed under vacuum for 1 h, followed by curing in a 75 °C oven for 2 h. Soxhlet extraction was performed overnight in toluene to remove uncrosslinked chains, after which the lenses were dried in a fume hood for a few hours, and then placed back under house vacuum for a longer time (≈ 1 d) to remove residual solvent.

Layer-by-layer (LbL) films composed of poly(allylamine hydrochloride) (PAH) and poly(acrylic acid) (PAA) were assembled onto PDMS lenses as described previously.[2] Polymer brush layers were also prepared on PDMS lenses using a published procedure.[3]

Results and Discussion

Our results indicate that JKR is capable of detecting adhesive interactions resulting from complementary molecular interactions between the contacting surfaces. Our results indicate increased adhesion between acid-functionalized lenses and base-functionalized substrates over substrates where only acidic functionality is present. In addition, we have found that the method by which functional groups are introduced onto the lens surface is an important determining factor regarding adhesion interactions. For example, the high Young's modulus of LbL films[2] can decrease the apparent adhesion hysteresis in the dry state when utilizing a lens functionalized with this method.

Future work will focus on biological interactions such as biotin-avidin binding and the sensitivity of JKR measurements to variations in the surface density of binding groups.

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References

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