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Friction and Adhesion Behavior of Graphene and other Two-Dimensional Materials

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Two-dimensional materials provide a rich playground for exploring new and unexpected physical phenomena, including tribological behavior such as friction and wear. This talk will focus on friction and adhesion behavior of nanoscale contacts with such materials. For contacts to graphene, MoS_2, NbS_2, and BN, we find that the friction force exhibits a significant dependence on the number of 2-D layers [1] which we attribute to an out-of-plane "puckering" deformation that occurs when the 2-D material is weakly bound to its substrate. However, adhesive behavior does not follow this dependence. Instead, we find that sliding can induce an increased adhesive force due to local delamination of the topmost layer of graphene [2]. Finally, we observe a large, order-of-magnitude increase in friction that occurs when graphene is fluorinated. This result is interpreted in the context of the Prandtl-Tomlinson model of stick-slip friction.

[1] *Frictional characteristics of atomically thin sheets.* C. Lee, Q. Li, W. Kalb, X.-Z. Liu, H. Berger, R. W. Carpick, J. Hone. **Science**, 328, 76-80 (2010).

[2] *Nanoscale adhesive properties of graphene: The effect of sliding history.* X.-Z. Liu, Q. Li, P. Egberts, and R.W. Carpick, **Adv. Mat. Interf.**, accepted (2013).