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Friction from formation and rupture of molecular contacts

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Frictional motion plays a central role in diverse systems and phenomena that span vast ranges of scales, from the nanometer contacts inherent in micro- and nanomachines and biological molecular motors to the geophysical scales characteristic for earthquakes. Despite the practical and fundamental importance of friction and the growing efforts in the field, many key aspects of dynamics of friction are still not well understood. One of the main difficulties in understanding and predicting frictional response is the complexity of highly non-equilibrium processes going on in any tribological contact which include detachment and re-attachment of multiple microscopic contacts (bonds) between the surfaces in relative motion while still in contact. In this lecture I will discuss microscopic models which establish relationships between the dynamics of formation and rupture of individual contacts and frictional phenomena. First, I will introduce a phenomenological model that describes friction through thermally activated rupture and formation of molecular contacts. Then, I will focus on a microscopic model that includes the effect of thermally activated jumps of the surface atoms between the sliding surfaces on nanoscopic friction. I will show that the proposed models explain a nonmonotonic dependence of friction on temperature, which has been observed in recent friction force microscopy experiments for different material classes. These models offer a new conceptual framework to describe the dynamics of nanoscale friction.