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From molecular to multi-asperity contacts: the role of roughness in the transient friction response

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Friction is a universal phenomenon occurring at sliding interfaces between solids, in man-made and natural systems, from geological faults to atomic force microscopy probes. It stems from the atomic interactions between the contacting surfaces [1], but due to roughness, which distorts the picture of atomic friction, macroscopic friction models remain phenomenological. Rate-and-state models [2, 3] describe the experimentally observed aging and rejuvenating of the frictional interface with an *ad-hoc* state variable and a memory length-scale D_0, but ignore details of the surface roughness and the micro-contact behavior, while atomic descriptions of friction almost exclusively assume flat surfaces, and do not describe how roughness can change the nano-scale friction picture. Here we bridge the gap between the macro and nano scales, and link aging, rejuvenation and D_0, in the friction of adsorbed fatty acid monolayers, to the existence of contact junctions due to the surface roughness. We show how the dynamics of these junctions emerges from molecular motion and how it relates to the macroscopic transient friction response [4]. Using a combined experimental and numerical approach, we obtain a value of $D_0 = 3.5$ nm, much smaller than the characteristic contact diameter, despite a sub-nanometer root-mean-square roughness. We also demonstrate that aging and rejuvenating do not occur in the absence of roughness, i.e. in a contact without discrete junctions. We correlate the observed transient friction response to the number of pair interactions between atoms of opposite surfaces, which gives a physical interpretation of the state variable. We combine our findings into a theoretical model which unifies friction models at the nano and macro scales and correctly predicts the transient friction response.

References

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