Using Small Vibrations to Control Friction at the Nanoscale*

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Abstract

Recently, several groups demonstrated that friction [1,2] and chaos in friction [3] can be controlled and significantly reduced either by applying very small, intently focused control perturbations to the sliding system or by introducing quenched disorder onto the substrate [4]. These results point to completely new directions for realizing robust ultra-low friction in nano-mechanical devices, which steer away from the traditional lubrication techniques.

We studied the response of a nano-array of atoms to the mechanical vibration of their substrate, within the minimalist model of friction. Our motivation is twofold, namely: (i) understanding the basic mechanisms of frictional response to small periodic and random perturbations and (ii) developing robust control techniques for friction. Numerical simulations of the model suggest that the friction coefficient undergoes a sharp transition to the regime of very small values when the amplitude of the vibration reaches a critical threshold. We find a strong correlation between the friction coefficient and the phase synchronization of the sliding array. In particular, at the transition point, we observe a significant increase in the phase synchronization of the array. We estimate analytically the transition point and contrast the effects of periodic and random surface vibrations on the friction coefficient.

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