Giant frictional dissipation peaks and charge-density-wave slips at the $NbSe_2$ surface

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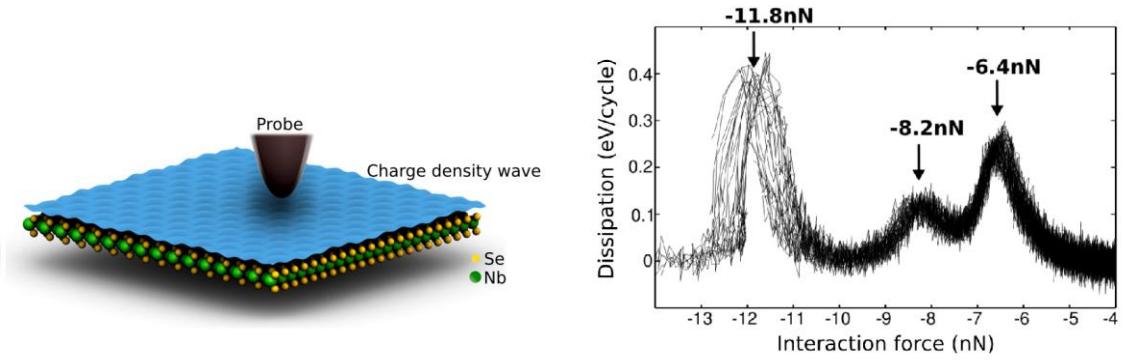
Understanding nanoscale friction and dissipation is central to nanotechnology. The recent detection of the electronic friction drop caused by the onset of superconductivity in Nb by means of an ultrasensitive non-contact pendulum atomic force microscope (AFM) raised hopes that a wider variety of mechanical-dissipation mechanisms become accessible. Here, we report a multiplet of AFM dissipation peaks arising a few nanometres above the surface of $NbSe_2$ — a layered compound exhibiting an incommensurate charge-density wave (CDW). Each peak appears at a well-defined tip–surface interaction force of the order of a nanonewton, and persists up to 70 K, where the short-range order of CDWs is known to disappear. Comparison of the measurements with a theoretical model suggests that the peaks are associated with local, tip-induced 2π phase slips of the CDW, and that dissipation maxima arise from hysteretic behaviour of the CDW phase as the tip oscillates at specific distances where sharp local slips occur.



(Left) An oscillating AFM tip in proximity to the charge-density wave on the $NbSe_2$ surface. (Right) Energy dissipation versus tip–sample interaction force. Three dissipation maxima appear, indicating tip-induced CDW phase slips.