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Stick-Slip Motion of the Wigner Solid on the Surface of Liquid Helium

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We present time-resolved transport measurements of a Wigner solid (WS) trapped above the surface of superfluid ^{4}He, which reveal new insights into the dynamical coupling between the electron system and excitations at the liquid surface[1]. The WS forms at high electron densities and low temperatures, as electrons trapped in surface states above the helium surface self-organize to form a triangular lattice. The static WS is dressed by quantized capillary waves (ripplons), resulting in the formation of a shallow depression (or ‘dimple) in the helium substrate beneath each electron[2]. Because the combined electron-dimple mass is much greater than the bare electron mass, the SE conductance drops dramatically when the system enters the WS phase. However, the WS can be decoupled from the dimple lattice (DL) by the application of a strong electric field parallel to the helium surface. After decoupling, the WS ‘slides freely across the helium with high velocity. Here we present time-resolved measurements of the WS-DL decoupling process. In our experiment the helium is confined in a microchannel several microns in width, and the electron density at the helium surface is controlled using an array of gate electrodes[3]. On applying a smoothly ramped driving potential, the WS initially remains coupled to the DL, and its velocity is limited to the ripplon phase velocity[4]. As the driving force builds, the WS eventually decouples from the DL and electron velocity increases dramatically. The driving force is then released, allowing the WS to re-couple with the DL, and the cycle is repeated. The consequent stick-slip motion of the electron system results in spontaneous current oscillations, the frequency of which depends on the strength of coupling between the WS and the helium substrate. We discuss the influence of lattice defects on the WS-DL coupling, and examine the transport of the WS when it is decoupled from the DL, a regime that until now has remained largely unexplored.

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