Evidence of a one-dimensional metal in twin-grain boundaries of $MoSe_2$

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In monolayer van der Waals-materials, grain boundaries become one-dimensional (1D) line defects. Here we show using angle resolved photoemission spectroscopy (ARPES) that twin-grain boundaries in the 2D semiconductor $MoSe_2$ exhibit parabolic metallic bands. The 1D nature is evident from a charge density wave transition, whose periodicity is given by k_F/π, where the Fermi momentum k_F is determined by ARPES. Most importantly, we provide evidence for spin- and charge-separation, the hallmark of 1D quantum liquids. ARPES shows that the spectral line splits into distinctive spinon and holon excitations whose dispersions exactly follow the energy-momentum dependence calculated by 1D Hubbard model, with suitable finite-range interactions. Our results also imply that quantum wires and junctions can be isolated in line defects in 2D materials, which may enable quantum transport measurements and devices.

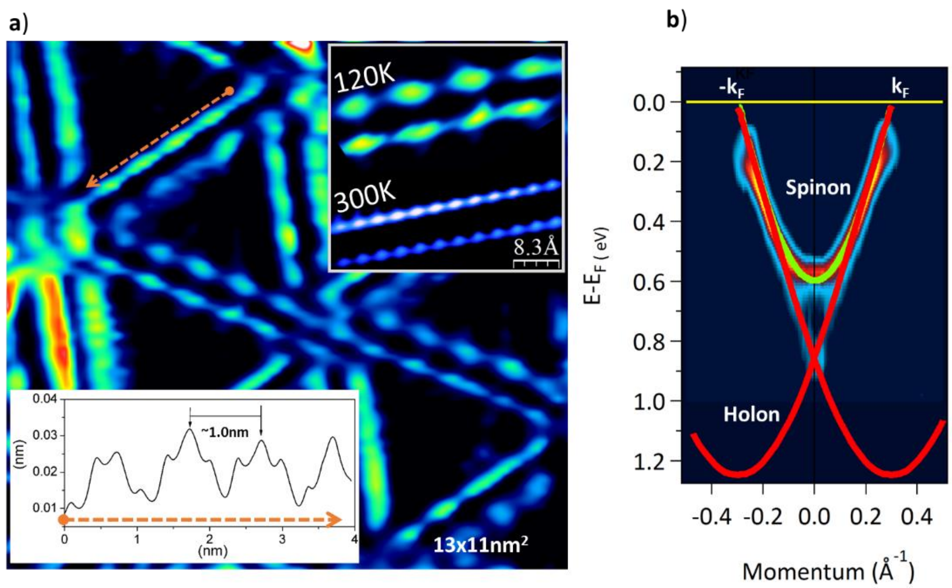

Figure. (a) STM images at lower temperatures exhibit a periodicity of ~1 nm (~ 3 the lattice constant of $MoSe_2$) along the defect lines. Comparison of the corrugation along the line defects at room temperature and at 120 K is shown in the in-set. At room temperature only a periodicity corresponding to the atomic corrugation is observed. The periodicity of 3 times the lattice constant is attributed to a CDW and corresponds to π/k_F. **(b)** Second derivative of ARPES data with theoretically computed spinon and holon branch lines.