Synthesis, characterization, and quantum properties of ultrapure transition metal dichalcogenide crystals

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Two-dimensional transition metal dichalcogenides (TMDs) have attracted tremendous interest due to the unusual electronic and optoelectronic properties of isolated monolayers and the ability to assemble diverse monolayers into complex heterostructures. To understand the intrinsic properties of TMDs and fully realize their potential in applications and fundamental studies, high-purity materials are required. This talk will review progress in synthesis and characterization of TMD crystals using a flux synthesis technique. Using scanning tunnelling microscopy, we identify dominant charged and isovalent defects in these crystals. The flux method reduces density of both defect types by roughly one order of magnitude compared to crystals grown by chemical vapor transport. To further reduce defect density, we have implemented a two-step method [1] that minimizes possible sources of contamination. We find that the two-step method reduces density of by roughly an order of magnitude compared to the single-step flux technique. For WSe_2, we show that increasing the Se:W ratio during growth further reduces point defect density, with crystals grown at 100:1 ratio achieving charged and isovalent defect densities below 10^{10} cm^{-2} and 10^{11} cm^{-2}, respectively. STM spectroscopy and imaging, combined with conductive AFM imaging and statistical analysis, provide clues as to the nature and location of these defects. Initial temperature-dependent electrical transport measurements of monolayer WSe_2 yield record values for both room-temperature and low-temperature mobility, as well as fully developed quantum Hall states. Using these high-quality crystals, we demonstrate that WSe_2 can function as a high-quality barrier in Josephson junctions toward compact qbits.

References

[1] Song Liu, Yang Liu, Luke Nemetz Holtzman, Baichang Li, Madisen Holbrook, Jordan Pack, Takashi Taniguchi, Kenji Watanabe, Cory R. Dean, Abhay Pasupathy, Katayun Barmak, Daniel A. Rhodes, James Hone, Two-step flux synthesis of ultrapure transition metal dichalcogenides, submitted.

Figures

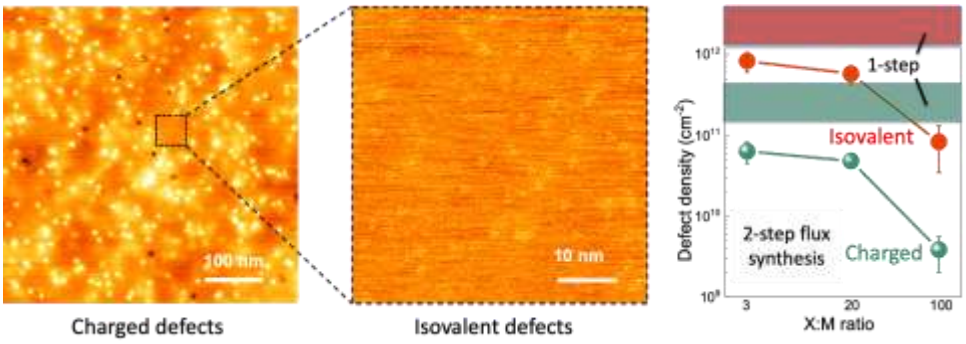

Figure 1: Defects in flux-grown TMDs. Left, large-scale STM image showing charged donor (bright) and acceptor (dark) defects. Middle, smaller-scale STM image showing isovalent defects. Right, density of both defect types as a function of selenium:tungsten ratio.