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Atomic Defects in 2D Semiconductors - From Chemical Doping to Quantum Technologies

Chemical doping is a vital technology to tune the conductivity and optical properties of semiconductors. While dopants in bulk materials usually create shallow states that can contribute mobile charge carriers, the electronic states of dopants in 2D materials exhibit much more localized wavefunctions and higher binding energies. This offers exciting possibilities to engineer atomic quantum systems by chemical design rules.

In this talk I will give an overview on the recent progress in understanding the physical properties of single impurity atoms in 2D semiconductors and its implications for devices based on 2D materials.

Individual point defects in pristine and intentionally doped semiconducting transition metal dichalcogenides (TMDs) were studied by means of high-resolution scanning probe microscopy. We directly resolve the discrete electronic spectrum of single dopants in a charge neutral or ionized state and map out their associated defect orbitals [1-4]. Different types of defects reveal the interplay between chemical impurity states [1,3], multi-valley hydrogenic bound states [4], and electron-phonon coupling [3,5] at reduced dimensions.

Furthermore, tip-induced hydrogen desorption of CH-doped WS_2 is demonstrated, creating reactive surface sites with atomic control [5] and offering new avenues for atomic precise functionalization of 2D manifolds.

We also show electrically driven photon emission from individual defects [6]. Atomically resolved luminescence maps from single sulfur vacancy defects are presented. The widely tunable optical emission generated by charge carrier injection into localized defect states in a 2D material is a powerful platform for electrically driven single-photon emission.

References

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