Tunneling Effects in Crossed $\text{Ta}_2\text{Pt}_3\text{Se}_8$–$\text{Ta}_2\text{Pd}_3\text{Se}_8$ Nanowire Junctions: Implications for Anisotropic Photodetectors

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Project Summary: Transition metal dichalcogenides (TMDCs) with van der Waals gaps (vdW) have been a subject under extensive studies, since 2D thin layers of these materials exhibit a plethora of technologically useful properties, e.g. large direct band gap and high photoresponsibility. Quasi-one-dimensional (1D) transition metal vdW materials are also predicted to not only inherit some features of 2D TMDCs, such as strong light - matter coupling and thickness-dependent band gaps, but also possess unique thermal, electrical, and optical properties due to their distinctive chain structures. However, quasi-1D vdW materials are less experimentally explored. Yaqiong Xu’s group at Vanderbilt University recently demonstrated nanoscale crossed p-n junctions formed by two quasi-1D vdW materials, i.e. p-type $\text{Ta}_2\text{Pd}_3\text{Se}_8$ ($\text{TPdS}$) and n-type $\text{Ta}_2\text{Pt}_3\text{Se}_8$ ($\text{TPtS}$). Such p-n junctions exhibit asymmetric nonlinear output behaviors, inelastic tunneling effects, and isotropic photocurrent signals. This study not only offers a way to build nanoscale junctions but also provides fundamental understandings of the electronic and optoelectronic properties of vdW nanowires and their heterojunctions.

2DCC Role: High quality $\text{Ta}_2\text{Pd}_3\text{Se}_8$ and $\text{Ta}_2\text{Pt}_3\text{Se}_8$ single crystals used in this project were synthesized by the 2DCC researchers using the chemical vapor transport method.

Left panel: Schematic diagram of a nanoscale crossed junction between perpendicularly stacked n-type $\text{Ta}_2\text{Pt}_3\text{Se}_8$ ($\text{TPtS}$) and p-type $\text{Ta}_2\text{Pd}_3\text{Se}_8$ ($\text{TPdS}$) nanowires. Inset: Optical micrograph of a typical device. S and D indicate the source and drain electrodes, respectively.

Right panel: Band diagrams of the $\text{TPtS}$–$\text{TPdS}$ junction (top) and $I_{ds}$–$V_{ds}$ characteristics of the $\text{TPtS}$–$\text{TPdS}$ junction with a gate voltage of $-80$ V at various temperatures (bottom).

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