# Control of heat and electrical transport across van der Waals nano-interfaces

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van der Waals (vdW) interface is a critical component in the performance of flexible devices, such as electronics, thermal, and thermoelectric devices. Recent advances in interface design using two-dimensional (2D) materials have allowed for studying various controlled interface properties. From the view of thermal management for 2D electronics, the study on heat transfer through vdW interfaces of layered 2D materials is of great importance because of their high heat generation and interfacial thermal mismatches. Understanding the heat and electrical transport correlation is essential for optimizing the performance of flexible devices and 2D electronics. However, the correlation between the heat and electrical transport characteristics across 2D vdW interfaces has yet to be elucidated in detail due to experimental limitations. To understand the correlation, we have employed time-domain thermoreflectance measurements using Au as a metal transducer (Au-TDTR) [1] (Fig.1), and have investigated the correlation. First, we checked whether we can evaluate the thermal properties of artificially stacked 2D interfaces such as artificially layered transition metal dichalcogenides (TMD) like $MoS_2$ and $WS_2$ by enhancing the heat flow across the interface by putting on polymer or some metal layer on the top of samples, the thermal conductance of 4 layered homo and hetero structured TMD has been determined [2]. As reported by the other groups, we also observed ultra-low thermal conductance across 4 layered heterointerfaces [2]. Then we investigated the correlation between the thermal conductance and electrical conductance across the randomly stacked $MoS_2$ layers. Cross-plane thermal and electrical conductance can be simultaneously determined using Au-TDTR [3]. A linear correlation between thermal and electrical conductance was observed by vacuum annealing, and the change in interlayer distance can understand such behavior [3]. Moreover, we observed the difference of stacking angle affects the correlation between thermal and electrical conductance. In addition, one of the advantages of Au-TDTR is that we can perform thermal measurements during electrochemical doping/gating since the metal transducer is electrochemically stable [4]. As one of our recent results, we observed modulation of thermal conductance of conducting polymer by electrochemical doping. Precise control of vdW nanointerfaces will give us various ways to manipulate the thermal and electrical transport across the interfaces.

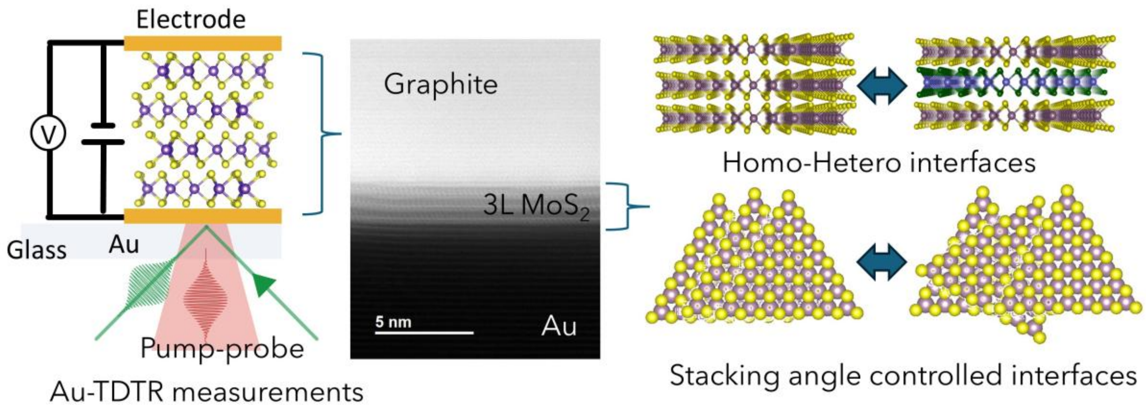


Fig1: Measurement on the correlation between heat and electrical transport across controlled van der Waals nanointerfaces

References: [1] K. Ueji et al., Appl. Phys. Lett. 117, 133104 (2020). [2] W. Yuan et al., ACS Nano 15, 15902 (2021) [3] K. Zhou et al., ACS Appl. Electron. Mater. 6, 5934 (2024) [4] K. Ueji et al., ACS Applied Nano Materials 5, 6100 (2022).