Can TMDs compete with silicon in terms of thermal properties?

Klaas-Jan Tielrooij
Catalan Institute of Nanoscience and Nanotechnology (ICN2), BIST & CSIC, Campus UAB, 08193 Bellaterra (Barcelona), Spain
Klaas.tielrooij@icn2.cat

Proper thermal management of electronic and optoelectronic devices is extremely important for correct device functioning and preventing damage. The first line of defense in thermal management is formed by the active semiconductor material – usually silicon, which has a relatively high thermal conductivity of ~150 W/m/K. When considering technological applications based on semiconducting layered crystals, such as transition metal dichalcogenides (TMDs), it is crucial to take their thermal properties into account.

Together with co-workers at ICN2 (Spain), ICFO (Spain), Université de Liège (Belgium) and Utrecht University (the Netherlands), we have studied the thermal conductivity of the TMD $MoSe_2$ as a function of crystal thickness, down to the monolayer [1]. This joint experimental-theoretical work shows that bulk $MoSe_2$ has a somewhat lower thermal conductivity than bulk silicon: ~40 W/m/K. However, $MoSe_2$ starts outcompeting silicon for thin films below ~100 nm. And even monolayer $MoSe_2$ has almost the same thermal conductivity as bulk crystals: ~20 W/m/K. Furthermore, highly efficient out-of-plane dissipation to air molecules occurs for the thinnest crystals. This shows that TMDs are an excellent choice of material system for applications that require ultrathin semiconducting films with uncompromised thermal management properties, such as flexible devices.

References

[1] D. Saleta Reig, et. al. *Advanced Materials*. 2108352, (2022)

Figures

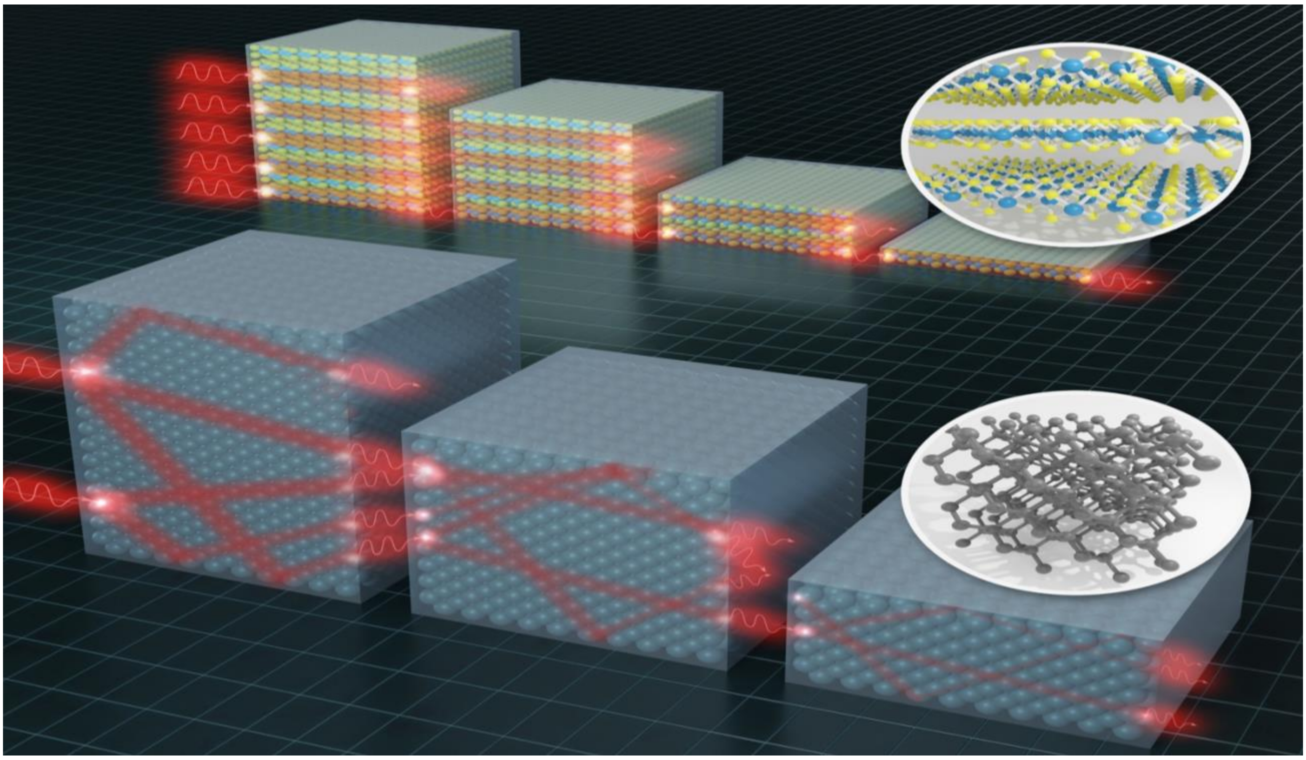

Figure 1: Comparison between in-plane thermal transport in increasingly thin films of layered TMDs and 3D-bonded silicon, where the latter suffers more strongly from increasing surface scattering.