Phonon-Based Thermometry in 2D Crystals: Layer-Dependent Thermal Analysis via Raman Spectroscopy

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Two-dimensional (2D) materials continue to drive advances in nanoelectronics, photonics, and quantum technologies due to their exceptional electronic, vibrational, and thermal properties. Precise knowledge of temperature at the nanoscale is essential for understanding carrier dynamics, device reliability, and thermal transport in these ultrathin systems. However, the intrinsic size of 2D layers renders conventional thermometry techniques inadequate. Here, we demonstrate how Raman-based thermometry enables accurate temperature measurements in a range of 2D materials.

The Raman spectra of 2D materials exhibit temperature-dependent phonon shifts, providing a direct method for quantifying local heating with sub-micrometre spatial resolution. By integrating a temperature-controlled stage with our Raman microscope, we achieve temperature sensitivities on the order of a few degrees Celsius. Crucially, these phonon modes are also sensitive to structural factors such as layer number, strain, and substrate coupling. This allows temperature calibration to be combined with structural characterisation: for example, shifts in characteristic Raman peaks distinguish single, double, and multi-layer materials, enabling simultaneous thermometric and layer-number analysis.

Together, these capabilities highlight Raman thermometry as a powerful tool for investigating heat dissipation, phonon transport, and device reliability in next-generation 2D-material platforms. This approach is increasingly vital as research progresses toward high-power, high-density, and flexible nanoelectronic systems.