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What Raman Spectroscopy Can Do for MXenes

Raman spectroscopy plays a central role in advancing the understanding and adoption of two-dimensional (2D) materials by providing crucial insights into their crystal structure, bonding, and layer thickness. Among these materials, MXenes - 2D transition metal carbides, nitrides, and carbonitrides - have emerged as highly promising for applications in energy storage, biomedical devices, optoelectronics, heat management, and electromagnetic interference (EMI) shielding. However, we are just starting to understand their vibrational properties [1].

This talk presents recent progress in using Raman spectroscopy to study MXenes, from the widely investigated Ti3C2Tx to other structures and compositions. We examine how surface terminations, carbon/nitrogen ratios, and formation of metal solid solutions influence Raman spectra. Complementary Density Functional Theory (DFT) calculations help decouple complex vibrational signatures from mixed terminations. Tip-enhanced Raman spectroscopy (TERS) allows the study of single flakes of MXenes with nanoscale resolution [2].

In addition, in situ Raman spectroscopy studies and spectroelectrochemistry reveal dynamic processes such as oxidation [3], ion insertion, and surface redox reactions in MXene-based electrodes, with results validated through FTIR and UV-Vis spectroscopy. The inherently active surfaces of MXenes also enable surface-enhanced Raman spectroscopy (SERS), where various dye molecules exhibit amplified signals due to charge-transfer and chemical enhancement.

By establishing a comprehensive Raman spectral library and leveraging both in situ Raman and SERS techniques, we show that Raman spectroscopy is an indispensable tool for characterizing MXenes and unlocking their full potential. These insights pave the way for broader integration of MXenes across diverse technological domains

References

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