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Raman spectroscopy of 2D transition metal carbides and nitrides (MXenes)

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In the past decades, the development of the field of 2D materials led to many new developments that used to be considered not possible: quantum computing, transformation optics, drug delivery to name a few. Although 2D materials remaining mainly in the laboratory settings, the scientific community works to bring those discoveries to real-life by establishing the connection between material structural properties, their processing, and performance. In the core of those connections, lays characterization, which is often overlooked. The most used characterization tool for 2D materials is undoubtedly Raman spectroscopy.

Raman spectroscopy is known as a fast and non-destructive tool to characterize molecular vibrations, also known as molecular fingerprints. It has been used to evaluate not only the composition and defects in the structure but also to determine the mechanical and thermal properties of 2D materials. Moreover, Raman spectra could be collected even from 2D monolayers and also used to determine the number of layers in films. This big impact on the field shows that it is an essential tool for studying new families of 2D materials. One of those families is MXenes, 2-dimensional transition metal carbides and nitrides, which were discovered at Drexel University in 2011 and already explored in a variety of applications.

During my Ph.D. studies, I performed the first systematic study of Raman spectra of various stoichiometric MXenes and their solid solutions and investigated the effects of their physical state, composition, surface chemistry, and flake stacking on the vibrational modes, and use the knowledge for the quality analysis and in-situ experiments, such as Raman electrochemistry and SERS. This study is the first step towards meaningful in-situ experiments that will allow us to understand electrochemical, mechanical, and many other properties on a micro-scale, ultimately leading to a better understanding of the correlations between MXene structure, processing, properties, and performance.