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Materials Science and Engineering
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Department of Materials Science and Engineering
PhD Dissertation Defense

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Solution Processing and Optical Properties of Two-Dimensional Transition Metal Carbides (MXenes)

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Potentially the largest family of 2D materials, known as transition metal carbides and/or nitrides (MXenes), have a chemical formula of $M_{n+1}X_nT_x$, where M represents a transition metal (Ti, Mo, Nb, V, Cr, etc.), X is either carbon and/or nitrogen, and T_x represents surface terminations. The diversity in composition offers a plethora of structures and chemistries to investigate. The first discovered MXene, titanium carbide, has shown unique light-matter interactions enabling applications such as electromagnetic interference shielding, wireless communication, photothermal therapy, and as a transparent conducting electrode. Combining the optical properties with ease in processing, high electronic conductivity and mechanical strength, MXenes have the characteristics necessary to develop as optical materials, however the solution processing routes to achieve controlled nanoparticle dispersions and quality thin films are not optimized and only a few compositions have been explored.

This dissertation focuses on the development of colloidal solution processing approaches, including size selection, and stability control, of carbide MXenes in various solvents, fabrication of MXene films of optical quality, and characterization of the optical properties of MXenes in the colloidal and solid state. Control of the MXene dispersion allowed for the preparation of a range of MXene compositions, varying M and *n*, exhibiting an unusually broad and visually striking color spectrum. The origin of the color variation, spectroscopic information from the ultraviolet to the near infrared, and a relationship between the optical spectra and the electronic properties is examined. Under the assumption that it is possible to change the optical features, optical property tuning is explored by the change in surface chemistry, modification of the composition by alloying, and the application of an electric charge through electrochemical charge injection. Using the spectroscopic details provided throughout this dissertation, a few optoelectronic applications of MXenes are demonstrated, expanding the opportunities for research on this family of optically active materials.