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Materials Science and Engineering
College of Engineering

Department of Materials Science and Engineering

PhD Dissertation Defense

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Synthesis and Characterization of Multifunctional Polymer-matrix Nanocomposites with Transition Metal Carbides/Carbonitrides (MXenes)

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Abstract

Composite systems offer a wide range of functions in various applications since they can be engineered to be lightweight, mechanically strong, electrically conductive, flexible, thermally stable and more. Polymers have gained much attention in the last few decades due to their easy processing, low cost, electrically insulating, and environmentally friendly properties making them ideal candidates for composite matrices. The most common polymer composites are reinforced with carbon or glass fibers that improve overall mechanical performance while retaining the lightweight feature. However, additional functionalities can be added to these systems through the use of nanomaterials. The field of 2D nanomaterials, which has been growing since 2004, has provided a new class of fillers that can further enhance existing mechanical characteristics and add a variety of new functionalities for desired applications.

MXenes, an emerging family of two-dimensional nanomaterials, have been gaining increased attention over the last decade due to their metallic conductivity, mechanical stability, and easy solution processing. $Ti_3C_2T_x$, the most commonly studied MXene, has been used in energy storage systems, biomedical applications, water desalination, and more recently, polymer, metal and ceramic matrix composites. However, to take full advantage of the unique properties of

MXenes, fundamental studies into filler morphology, dispersion throughout the matrix, and interfacial strength need to be conducted. This dissertation investigates the development of processing methods for $Ti_3C_2T_x$ nanocomposites using biopolymers and thermoset matrices. Different processing techniques were explored for producing nanocomposite films through filtration, printing, and casting. The relationship between transfer of electrical properties of MXene to the biopolymer composites and potential applications like electromagnetic interference (EMI) shielding was explored. For the thermoset system, dispersion techniques were developed to uniformly distribute $Ti_3C_2T_x$ and Ti_3CNT_x fillers and improve the interface for enhancement of viscoelastic and mechanical properties of the resulting nanocomposites. Additionally, the effect of MXene filler during the thermoset crosslinking process was investigated. This study presents a major step toward the realization of MXene and its nanocomposites for applicable use as EMI shielding materials and potential of MXene fillers in epoxy systems for improving composite properties at low filler content via optimized processing.