Assembly of MXene-Based Materials with a Multitude of Functionalities

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More than 40 stoichiometric MXene compositions and dozens of solid solutions and structures with various terminations have been reported since the first report on $Ti_3C_2T_x$ in 2011. The number of possible compositions is infinite if one considers solid solutions (more than 50 have been made in our lab) and combinations of surface terminations. New subfamilies of in- and out-of-plane ordered MXenes, oxycarbides, 2D borides, and silicides further expand the family of non-oxide 2D materials based on transition metals. MXenes have also opened an era of computationally driven atomistic design of 2D materials, and we are only starting our journey into the world of atomistically designed materials. MXenes possess electronic, optical, mechanical, and electrochemical properties that differentiate them from other materials. MXenes are 2D building blocks for assembling functional materials and devices that will power future technologies. Chemically tunable superconductivity has been demonstrated in Nb- and Mo-based MXenes. Highly nonlinear optical properties of MXenes are being explored. Several MXenes have been predicted to act as topological insulators. Many MXenes are metallic conductors but with a tunable density of states at the Fermi level, like in semiconductors. Moreover, their properties are tunable by design and can be modulated using an ionotronic approach, leading to breakthroughs in the fields ranging from optoelectronics, electromagnetic interference shielding, and communication to energy storage, catalysis, sensing, and healthcare. In several applications, such as electromagnetic interference shielding and thermal insulation, MXenes have already outperformed all other materials. In this talk, I'll discuss the emerging synthesis methods of MXenes, the effect of synthesis on composition and properties, and the assembly of MXenes into functional films and coating. Co-assembly with graphene and other nanomaterials will also be discussed, and prospects for applications of MXene-based materials in fields ranging from electronics to healthcare, thermal management, communication, and energy generation and storage will be outlined.