Topotactic Ion Intercalation for Designer Magnetic Heterostructures and Devices

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Low-dimensional materials provide a framework for nanoscale functional devices with properties that can be flexibly designed for a wide range of applications, from next-generation computing to data storage and more. Stacking multiple materials into layered vertical heterostructures has been a particularly successful strategy for combining multiple emergent physical properties such as magnetism or superconductivity in a single bespoke architecture. Traditional synthesis approaches for such heterostructures, however, are often limited to materials with specific structural requirements, such as those with similar crystalline lattices or those which can be easily exfoliated into stackable sheets, which can limit either the flexibility or performance of resulting devices.

Here, a group from UC Berkeley demonstrates a new method for synthesizing heterostructures of magnetic intercalation compounds of transition metal dichalcogenides (TMDs) through directed chemical reactions. Leveraging PARADIM's capabilities for atomic-resolution imaging and spectroscopy of sensitive materials, we show that the chemical intercalation of magnetic ions is a thermally driven—contrary to previous belief. Our improved understanding of the intercalation chemistry enables us to design and realize more complex intercalated heterostructures, with independent control over both the host material and intercalant species within constituent layers. This advance opens the door to new materials combinations for both fundamental research and functional devices.

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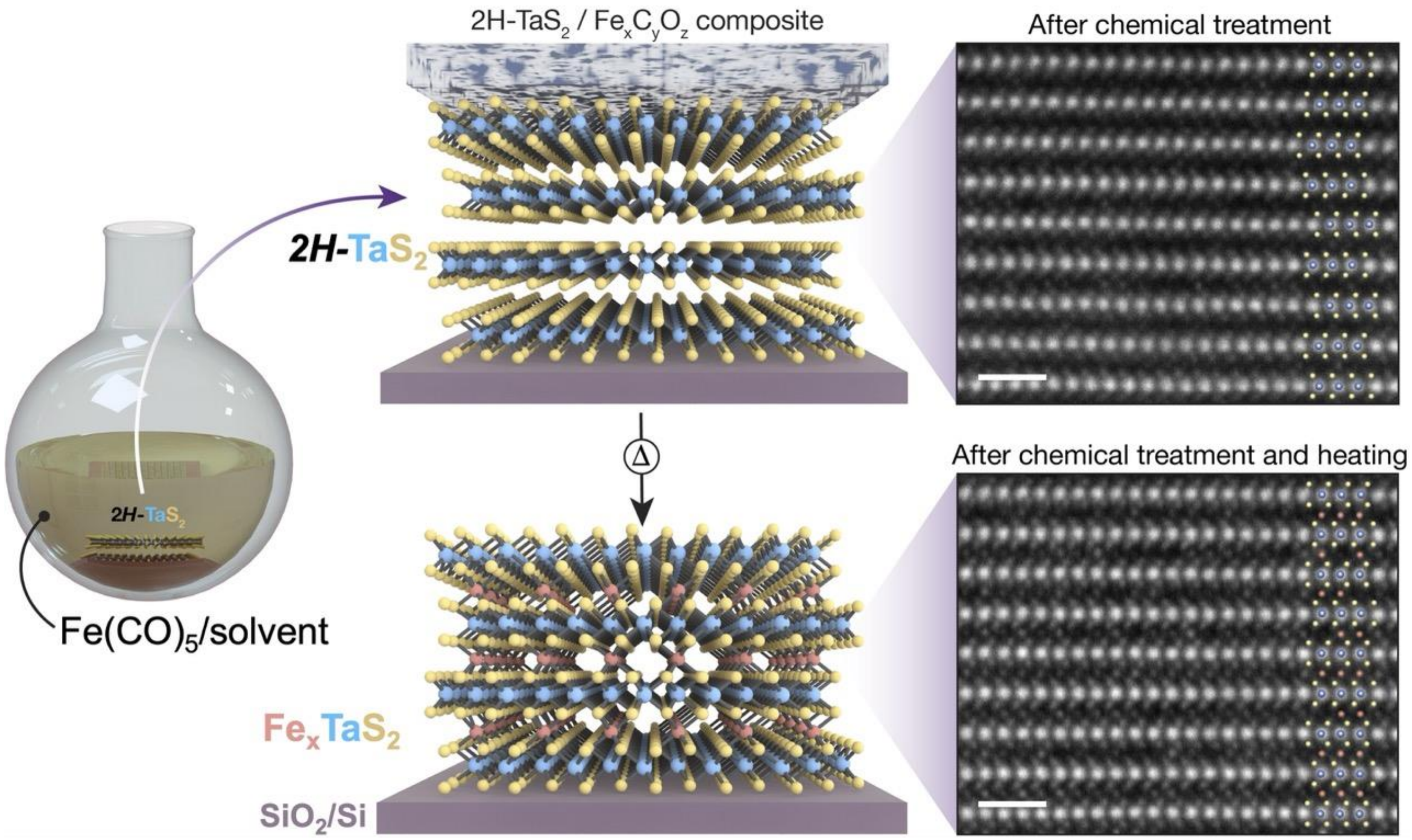

(Left) Schematic of depositing Fe precursors onto 2*H*–TaS_2 crystals on SiO_2/Si support followed by vacuum annealing to yield Fe-intercalated 2*H*–TaS_2 (Fe_xTaS_2). **(Right)** Atomic resolution electron microscopy after chemical treatment (**top**) plus annealing at 350 °C for 30 minutes (**bottom**). Scale bars 1 nm.