2D Oxide Nanosheets: New Solution to Nanoelectronics

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Two-dimensional (2D) nanosheets with atomic or molecular thickness and infinite planar lengths have been emerging as important new materials due to their unique properties. Inspired by the intriguing properties of graphene, many efforts have been devoted to synthesising 2D inorganic nanosheets of various materials with atomic thickness including metal oxides, hydroxides, and transition-metal chalcogenides as well as primarily investigating their unique electronic structures and physical properties. Among the types of inorganic nanosheets, oxide nanosheets are important, fascinating research targets because of the virtually infinite varieties of layered oxide materials with interesting functional properties. We are working on the creation of new oxide nanosheets and the exploration of their novel functionalities in electronic applications [1,2].

A variety of oxide nanosheets (such as $Ti_{1-\delta}O_2$, $Ti_{1-x}Co_xO_2$, MnO_2, and perovskites) were synthesized by delaminating appropriate layered precursors into their molecular single sheets *via* soft-chemical process. These oxide nanosheets have distinct differences and advantages compared with graphene because of their potential to be used as insulators, semiconductors, and even conductors, depending on their composition and structures. Recently, we found that titania- or perovskite-based nanosheets exhibit superior high- performance (ε_r = 100–320) even at a few-nm thicknesses, essential for next-generation electronics. Additionally, nanosheet-based high- capacitors exceeded textbook limits, opening a route to new capacitors and energy storage devices.

Another attractive aspect of oxide nanosheets is that nanosheets can be organized into various nanoarchitectures by applying solution-based synthetic techniques involving electrostatic layer-by-layer assembly and Langmuir-Blodgett deposition. It is even possible to tailor superlattice assemblies, incorporating into the nanosheet galleries with a wide range of materials such as organic molecules, polymers, and inorganic/metal nanoparticles. Sophisticated functionalities or nanodevices can be designed through the selection of nanosheets and combining materials, and precise control over their arrangement at the molecular scale. We utilized oxide nanosheets as building blocks in the LEGO-like assembly, and successfully developed various functional nanodevices such as all nanosheet FETs, artificial Pb-free ferroelectrics, spinelectronic devices, magneto-plasmonic materials, Li-ion batteries, metamaterials, etc. Our work is a proof-of-concept, showing that new functionalities and nanodevices can be made from nanosheet-architectures.

[1] M. Osada and T. Sasaki, *J. Mater. Chem.* **19**, 2503 (2009) [Review].
[2] M. Osada and T. Sasaki, *Adv. Mater.* **24**, 210 (2012) [Review].