2D Oxide Materials and Devices

Minoru Osada,
Takayoshi Sasaki
International Center for Materials Nanoarchitectonics (WPI-MANA),
National Institute for Materials Science (NIMS), Tsukuba, Japan
osada.minoru@nims.go.jp

The discovery of graphene, made of a single atomic layer of carbon, can be considered as a defining point in the research and development of stable, truly 2D material systems. This breakthrough has opened up the possibility of isolating and exploring the fascinating properties of 2D nanosheets of other layered materials, which upon reduction to single/few atomic layers, will offer functional flexibility, new properties and novel applications. We are working on the creation of new oxide nanosheets and the exploration of their novel functionalities in electronic applications (Fig. 1) [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-κ performance (ε_r = 100–320) even at a few-nm thicknesses, essential for next-generation electronics. Additionally, nanosheet-based high-κ capacitors exceeded textbook limits, opening a route to new capacitors and energy storage devices.

Another attractive aspect is that oxide nanosheets can be organized into various nanoarchitectures by applying solution-based layer-by-layer assembly. 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, etc. Our work is a proof-of-concept, showing that new functionalities and nanodevices can be made from nanosheet-architectures.

References

[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].

Figures

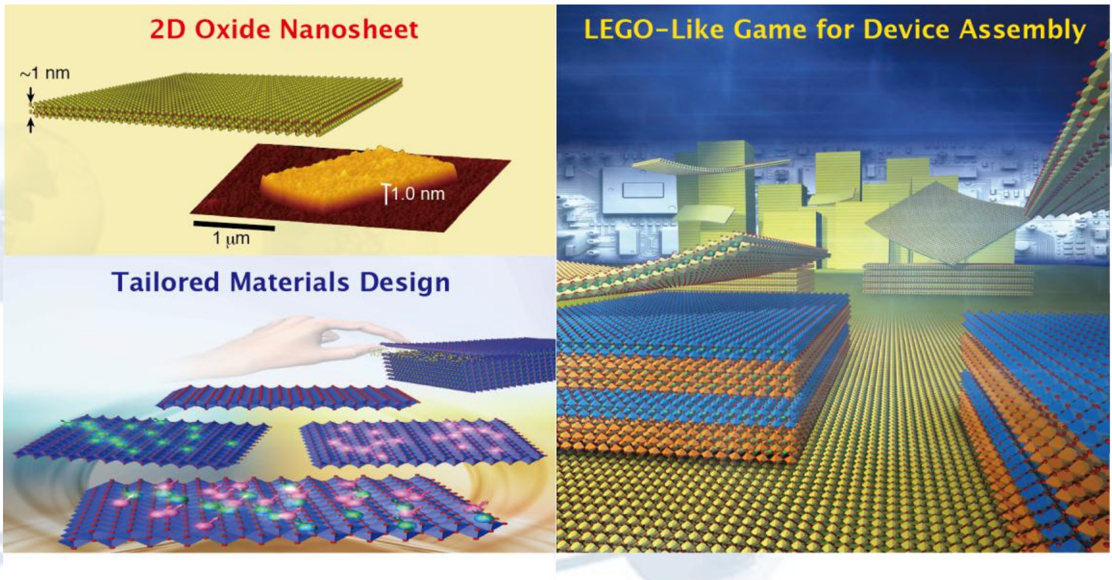

Fig1: General outline of our work.