Reference

1. B. G. Jang, G. Han, I. Park, D. Kim, Y. Y. Koh, Y. Kim, W. Kyung, H.-D. Kim, C.-M. Cheng, K.-D. Tsuei, K. D. Lee, N. Hur, J. H. Shim, C. Kim, G. Kotliar, Nat. Commun. **12**, 1208 (2021).

Miniaturize Floating-Gate Transistors to Approach a Physical Limit

On modulating the amount of electric-field-induced trapped electrons with an electrostatic gate potential, the demonstrated characteristics indicate that the engineering of an InSe interface has potential applications for nonvolatile memory.

Van-der-Waals-bonded layered materials enable the isolation and subsequent construction of heterostructures with designer interfaces and without constraint of lattice matching. Such interface engineering provides a knob that controls the electron behaviors of the artificial structures by controlling the interactions between layers through variations in the symmetry, stacking angles and chemical composition. These layered structures have been incorporated into a nonvolatile memory cell to mimic the conventional setup in which a floating gate generates a long-lasting internal electric field. In the applications of transistor-type nonvolatile memory cells, stacks of graphene and insulating oxide have been incorporated to scale the floating gate (polysilicon/SiO_2), in which a long-lasting internal electric field continuously modulates the carrier concentration in the channel. In these heterostructures, charges are confined in the floating gate because of a difference in the barrier height of interface energy between the layered materials and the insulating oxides. Upon continuous device scaling, however, progress is hampered by diffraction-limited photolithography and nonscalable tunneling oxide thicknesses that contribute to, for example, back tunneling. Innovations in cell architecture, decreased fabrication complexity and new device materials are thus in high demand.

Yi-Ying Lu (National Sun Yat-sen University), Chia-Hao Chen (NSRRC) and their teams proposed a new device concept that uses the van der Waals gating effect resulting from long-lived localized charges on the surface layer of InSe, which acts as an effective gate and which is separated by the van der Waals gap and generates a stable electron-storage effect in the underlying InSe channel. In contrast to a conventional flash memory cell in which charges are confined within potential wells formed by gate dielectric and semiconductor stacks, the charges in their structure are localized by trap sites generated by an indirect oxygen plasma treatment. Moreover, the channel current levels in InSe devices can be modulated on tuning the amounts of localized charge through the application of various back-gate voltages (V_G), enabling multilevel data storage.

To construct a back-gated field effect transistor (FET), two electrodes were deposited on both ends of InSe. The small bias current and bias voltage (I_{DS}–V_{DS}) measured at various V_G values ranging from 0 to 70 V demonstrate a linear behavior that indicates an ohmic contact. To generate charge-trapping states (in-gap traps) on the surface layer without fully oxidizing it, the InSe FET device was then subjected to an indirect oxygen-plasma treatment. To verify the underlying physical mechanism of their proposed device, an *operando* investigation of the trapping and detrapping process on the top layer was performed using a scanning photoelectron microscope (SPEM) that combines the chemical and electronic sensitivities of X-ray photoelectron spectra (XPS) with a spatial resolution ~150 nm. Moreover, SPEM has the ability to reflect the local electrical potential surrounding the probed atom. This approach allowed to explore the role of surface oxides in device behavior through observation of the changes in binding energy for the device under working conditions. The *operando* SPEM measurement setup of their devices at **TLS 09A1** beamline is illustrated in **Fig. 1(a)** (see next page). The device was scanned using a focused X-ray beam with spot size ~100 nm in ultrahigh vacuum conditions. To enable *operando* SPEM measurements during device operation, both source and drain electrodes were grounded; the gate electrode was subjected to a power bias.

To verify the van der Waals gating effect, they performed *operando* SPEM measurements at the oxygen plasma-treated channel. Upon application of a V_G 50 V, all signals moved to lower energies. To verify the trapped charge-induced core-level shifts, the In 4*d* and Se 3*d* binding energies are expressed relative to the In $4d_{5/2}$ and Se $3d_{5/2}$ signals, respectively. The relative energy difference between

In–O and In–Se signals varied from 1.91 eV (V_G = 0 V) to 1.45 eV (V_G = 50 V). This decrease in the relative energy difference under the application of a 50-V V_G indicates that compared with V_G 0 V, photoemitted electrons from oxidation sites are accelerated by the external electric field, resulting in a red shift of the binding energy. Note that, during the measurements, the InSe channel was grounded to an energy analyzer, and if there were no charge accumulation on the sample surface, there would be no potential difference between the energy analyzer and InSe due to the alignment of the Fermi level. Based on this assumption, they inferred that the external electric field was ascribed to the accumulation of induced electrons at the surface oxidation sites, producing an electrostatic potential on the InSe surface layer.

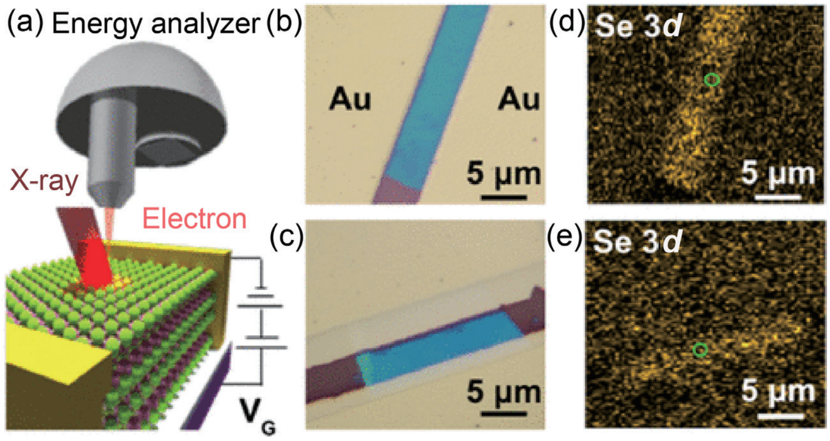

Fig. 1: *Operando* scanning photoelectron microscopic characterization of van der Waals gate devices. (a) Schematic of the *operando* SPEM measurement setup. (b,c) Optical images of pristine (top) and oxygen-plasma-treated devices (bottom). (d,e) Photoelectron intensity mapping of the Se 3*d* core-level spectra of pristine (top) and oxygen plasma-treated devices (bottom). [Reproduced from Ref. 1]

In summary, the demonstrated characteristics indicate that the engineering of an InSe interface has potential applications for nonvolatile memory. (Reported by Cheng-Maw Cheng)

*This report features the work of Yi-Ying Lu, Chia-Hao Chen and their collaborators published in ACS Appl. Mater. Interfaces **13**, 4618 (2021).*

TLS 09A1 SPEM

- XPS, AES, photoabsorption, and other spectra
- Materials Science, Condensed-matter Physics

Reference

1. Y.-Y. Lu, Y.-T. Peng, Y.-T. Huang, J.-N. Chen, J. Jhou, L.-W. Lan, S.-H. Jian, C.-C. Kuo, S.-H. Hsieh, C.-H. Chen, R. Sankar, F.-C. Chou, ACS Appl. Mater. Interfaces **13**, 4618 (2021).

A Double Perovskite Oxide Shows the Way for High Performance of Electrocatalytic Water Oxidation

In-situ/operando X-ray absorption spectra of double perovskite $Sr_2CoIrO_{6-\delta}$ identify the role of an uncommon hexavalent Ir^{6+} configuration in accelerating electrocatalytic water oxidation.

A main goal of the recently held UN Climate Change Conference was to secure global net-zero emissions of carbon dioxide by 2050. To achieve this goal, countries must phase out the use of coal, decrease deforestation, speed up switching to electric vehicles and increase renewable energy sources. The challenge of improved renewable energy technologies is thus an important part of saving our planet from severe climate change. Identifying materials that are efficient electrochemical catalysts is a major requirement of renewable energy technologies.

Further, to develop such materials, it is necessary to understand the mechanism of the oxygen-evolution reaction (OER) that exhibits sluggish reaction kinetics, and find ways to improve its efficiency. Oxygen evolution is the process of generating molecular oxygen (O_2) by a chemical reaction, generally from water, and occurs in photosynthesis, electrolysis of water and decomposition of oxides.

In a recent report in Advanced Functional Materials,[1]