Van der Waals ferroelectric heterostructures for in-memory computing and emergent electronics

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2D ferroelectric materials are attracting fast growing interest for the implementation of complex more-then-Moore and beyon-Moore architectures that are challenging to design with standard thin film technology.[1] Here, I will present recent developments on the coupling of a 2D vdW electon gas with various ferroelectic gate controls. We will discuss how these systems allow for rethinking circuit topology and memory-logic interaction, opening up new research directions in the area of frugal computational enhancement and neuromorphic computing for AI.

I will first detail how by making use of the switchable polarization state of two splitted ferroelectric gates, the electrical potential landscape within a semiconductor channel can be permanently and **reconfigurably** modified.[2] While using the non-volatile ferroelectric states encoded in each gate, the **ferroelectric logic circuits** can function as six alternative logic gates, while CMOS circuit are limited to a single function. Such Re-FeFET circuits demonstrate high compactness, with an up to 80% reduction in transistor count compared to standard CMOS design.

Then, I will show the emulating of **synaptic plasticity** in vdW Ferroelectric Field Effect Trasistor (FeFET) using unipolar or ambipolar 2D semiconductior.[3,4] Combined electronic transport and piezo force microscopy investigations allows to carefully investigate the fine tuning of multidomains polarization landscape of the vdW ferroelectric gate, and its transduction into the conduction of the 2D semiconductor channel down to 50 nm scale for emulating artificial synapse plasticity. This dynamic synaptic reconfigurability offer new possibilities for next-generation neuromorphic computational architectures.

Finally, I will present how **light-structure interactions** in vdW systems allow for implementing the non-volatile electrical and optical control of the ferroelectric polarization in ferroelectric/semiconductor heterostructures.[3,5,6] The wavelength-dependent study unveils ferroelectric polarization control and decouples the mechanisms driven by photogenerated carriers for each material and at the interfaces. Following, long-term potentiation/depression, and spike rate-dependent plasticity are shown using electrical AND optical controls, enabling **optically-stimulated and optically-assisted synaptic devices** implementation.

References

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