Materials science at ultrahigh electric field using electric double layer transistor

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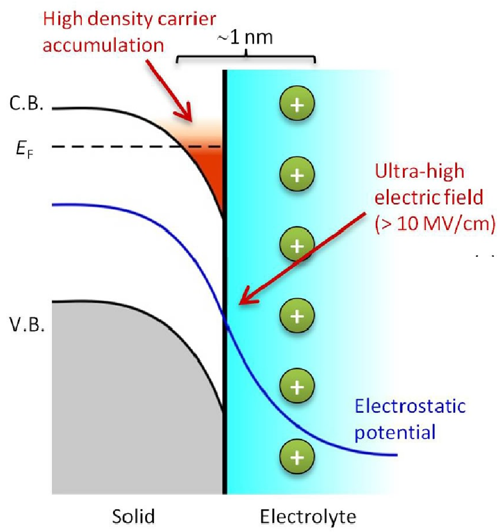
Electric double layer (EDL), a nano-gapped capacitor self-organized at the interface between solid-liquid interfaces, is an electrochemical concept proposed by Helmholtz 150 year ago. Taking the advantage of its large capacitance and high density charge accumulation, EDL has been used in market as capacitor devices, called Supercapacitor or EDLC. In the field of electrochemistry, researchers have paid attention only to electrolytes, *i. e.* the arrangement of ions and electrochemical reaction. Here we emphasize that the electric field at EDLs can be as large as 50 MV/cm, which is more than one order of magnitude larger that is realized in all solid devices. The important thing is that such a large electric field can penetrate within a length scale of Thomas-Fermi screening length (nm scale or less), as shown in Figure, and causes a large band bending right at the interface. This electric field produces two dimensional electron systems (2DES) with extremely high carrier density, which is also more than one order larger than that in solid devices.

A straightforward and easy method to probe this 2DES is fabricating two electrodes on the surface of solids and measuring electrical resistance along the surface. Since this device structure is equivalent to the field effect transistors (FETs), just a replacement of solid dielectric with EDL, we named our electrochemical device electric double layer transistor (EDLT). With EDLT, we anticipate to establish a new paradigm that is materials science at ultrahigh electric fields.

With EDLTs, we have demonstrated electric field induced superconductivity in insulators such as $SrTiO_3$, ZrNCl, and $KTaO_3$, which has never been realized with solid gated FETs. Following this, we are extending EDLTs to Mott-Hubbard insulators, where a large number of pre-existing electrons are localized because of the strong Coulomb interactions. We found that all these electrons are driven to motion by application of EDLT, and even more importantly, this delocalization of carriers occurs not only right at the interface but also in a larger scale of nealy 100 nm. This observation indicates that the transistor operation in Mott-Hubbard insulators very much differs from that in conventional semiconductors or insulators.



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