Liquid Gated Interface Superconductivity

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We report electric field induced superconductivity in inorganic semiconductors using a solid/liquid interface device configuration.

When voltage is applied between two electrodes in an electrochemical cell, ions in electrolyte move toward both electrodes driven by the electric field. Finally, ions are stabilized right above the electrode surface to form an electric double layer (EDL), a kind of capacitor, which produces an electric field in the order of 10 MV/cm, being difficult to achieve in solid capacitors. This capacitor device, called electric double layer capacitor (EDLC) is well known for its capability of high density charge accumulation, and is already on market as a high density and high speed capacitor. When one of the electrodes is replaced by a semiconductor with a source and drain electrodes, this device works as a field effect transistor, which can be called an electric double layer transistor (EDLT). This electrochemical device has been investigated for application to ion sensors. Since 2005, we have been investigating EDLT devices aiming at accumulating high density carriers and hopefully inducing electronic phase transitions using organic semiconductors [1].

Recently, we started to apply this technique to oxide semiconductors, and successfully demonstrated the electric field induced insulator-metal transition in ZnO [2]. Furthermore, we have observed the first electric field induced superconductivity in insulating $SrTiO_3$ [3]. In most cases, the ionic conductors are polymer electrolyte or ionic liquids [4], which offers a relatively large electrochemical window, where only electrostatic charge accumulation takes place. Very recently, we were successful in observing new electric field induced superconductivity in a layered compound ZrNCl with increased Tc of about 15 K. The present results indicate that EDLT could be a versatile technique for inducing and manipulating superconductivity at interfaces between solid-liquid interfaces.

This work has been carried out in tight collaboration between Kawasaki group at WPI-AIMR Tohoku University (A. Tsukazaki, A. Ohtomo, K. Ueno, M. Kawasaki) and our own team at IMR Tohoku University (H. Shimotani, H. T. Yuan, J. T. Ye, T. Nojima).

References

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