Monolayer electrolyte deposition with varying salt and its potential for direct write via electric force microscopy

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Our lab has developed a two-dimensional (2D) monolayer electrolyte (ME) of cobalt crown ether phthalocyanine (CoCrPc) and lithium salt that forms and ordered array on the surface of 2D materials. Each crown ether solvates one cation that is stable in one of two states in the crown. This bistability makes the material interesting for non-volatile memory; however, we have only explored one CoCrPc and salt combination to date - $LiClO_4$ deposited from ethanol. Here, we explore whether bistability can be achieved with other CoCrPc/salt pairs. The first step is to optimize the deposition of these salts on 2D flakes, and we show that LiCl in ethanol, $LiClO_4$ in acetone, and $NaClO_4$ in ethanol give the most homogenous monolayer with our drop-casting method. In parallel to this salt screening, we are exploring an approach to locally toggle the ions through the crown. Specifically, electric force microscope (EFM) is used to attempt such local switching wherein the EFM tip acts like a mobile electrode to locally apply a field near the surface to toggle the ion back and forth through the crown. By switching the location of the ions (i.e., either closer to or further away from the tip) using a “write” voltage, differences in the electrostatic interaction between the tip and the written regions can be mapped using a “read” voltage. These differences will appear as a change in the phase, and the read voltage is chosen so as not to disturb the state of the ions. The stack to test this approach is a graphene/ME/hexagonal boron-nitride (h-BN) heterostructure prepared by dry flake transfer. Our preliminary results indicate a phase shift at a write voltage of 9 V, detected by a read voltage of 3 V (at a lift height of 45 nm), suggesting that the threshold for switching the lithium ions through the crown using the mobile electrode approach is > 9 V. The magnitude of the phase shift as a function of tip bias provides a means to quantify the surface charge. We estimate the surface charge to be 5.44×10^{12} cm^{-2} for graphene alone (without the monolayer electrolyte), and are currently working on estimating this for the monolayer electrolyte stack. This work is supported by the NSF under Grant # NSF-DMR-EPM CAREER: 1847808.