Nafion Ionomer as a Dielectric Layer in Rubrene Single-Crystal Transistors for Improved Charge Carrier Mobility

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Organic transistors have significant potential in emerging modern electronics, including the area of bioelectronics due to their ability to amplify low electrical signals and applications in wearable and flexible sensors. As organic transistors are applied to these new applications, various gating mechanisms are being explored to achieve the desired device performance. Electrolyte-gated transistors (EGTs) and organic electrochemical transistors (OECTs) are gated using electrolytic or ionic materials as their dielectric layer, which has been shown to produce good signal amplification and sensitivity to low voltages.

Solid-state ionic materials, such as ionomers, are currently of interest due to being more processable than liquid ionic materials for EGTs. In EGTs, the conduction channel is formed at the semiconductor-dielectric interface due to the accumulation of ions within the electrolyte layer through the formation of an electrical double layer (EDL). To analyze the properties of the dielectric layer, rubrene organic single-crystals are used as the semiconductor in the fabricated EGTs as their complete crystallinity prevents any ion injection into the semiconductor. Rubrene single crystals are formed through physical vapor transport (PVT), which produces high-purity crystals and are known to exhibit high charge carrier mobilities for an organic semiconductor.

This work uses Nafion, a fluoropolymer consisting of a hydrophobic polytetrafluoroethylene (PTFE) backbone with a perfluorinated ether side chain capped with a hydrophilic sulfonic acid, as the dielectric material in the EGTs, since it has proven to be an excellent proton conductor while maintaining good thermal and chemical stability. This work demonstrates the improvement of charge carrier mobility by the addition of an ionomer dielectric layer in single-crystal rubrene transistors with a correlation between the mobility and Nafion thickness.