Dr Paddy Chan Kwok Leung's journal article entitled **“Crystallized Monolayer Semiconductor for Ohmic Contact Resistance, High Intrinsic Gain, and High Current Density”** in *Advanced Materials*

Previously, one key problem in reducing the size of OFETs is that if the contact resistance of OFET is large, the transistor channel is patterned to be shorter, and most of the applied voltage will be dissipated in the contact rather than the channel. The OFET properties will then be dominated by two contacts and behave like two back-to-back connected diodes rather than a proper functioning transistor.

Dr Chan’s team adopted an unconventional approach to tackle the challenge. Traditionally, the staggered structure OFETs required the thermal evaporation of the small molecules or spin coating of the polymer to deposit the active layers. Both methods would result in a relatively thick channel with a thickness around tens of nanometers to hundreds of nanometers. This would inevitably restrict the charge injection from the metal contact to the channel area. The team believed that further improving the contact resistance of those OFETs with thick channel was not the right way. Therefore, instead of tackling the interface directly, they addressed the problem by developing a highly crystallized monolayer organic semiconductor layer, thinking this ultrathin layer may favour charge transfer if the molecules are packed properly.

Knowing that the contact resistance of OFETs also depends on the effectiveness of the carrier transfer in organic semiconductors, the team dedicated great effort in developing highly crystallized materials with well controlled grain boundaries, and invented various methods like ultraslow shearing (USS) nucleation, seed control shearing (NCSC), dual shearing, as well as analytical models. These techniques and findings provided the team with strong foundations to narrow the thickness of the deposited 2D crystals to a few monolayers. Eventually the team has achieved a monolayer thickness of only 1 molecular length of C10-DNTT molecules i.e. 3.9nm.

On the monolayer organic crystals, the conventional electrode fabrication method such as thermal deposition or sputtering cannot be used because the high energy metal atoms under ballistic transport would bombard the organic semiconductor and damage it. To overcome this bottleneck, the team adopted an electrode transfer method by using the high surface energy property of the ultra-flat monolayer surface to “adhere” metal electrode without using any interfacial layer. This metal electrode transfer method is like adhering cartoon stickers favoured by children, but the stickers now are only 35 μm wide and 200 μm long. The team had to pick up and transfer them with a sharp needle under a microscope. Using the transferred electrode to pattern an OFET channel down to 2 μm is extraordinary and needs lots of hands-on experiences.

By combining the monolayer crystal with the transferred electrode, the team has achieved a record low contact resistance of 40 Ω cm. The intrinsic carrier mobility of the C10-DNTT monolayer is 12.5 cm2V-1s-1 with a width normalized current density of 4.2 μA/μm. This density level is among the highest for different classes of OFETs.

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