The effect of impurities on the mobility of single crystal pentacene

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Recommendation and Commentary by Don Monroe

Semiconductors are useful because charges can easily be added or removed, but this same property makes them very sensitive to impurities. More than fifty years ago, the purification of inorganic semiconductors made the transistor possible, but organic materials are usually more fragile and difficult to purify. In a recent article, a group from Groningen describes a technique for reducing impurities in the five-ring organic molecule pentacene. By gently and carefully heating the starting material in vacuum, they appear to have removed 75-80% of a quinone oxidation product of pentacene, as measured by infrared absorption. The quinone presumably disrupts the crystal lattice, scattering and slowing the holes that carry the current. The final crystals were grown in Argon to avoid reducing any pentacene, which is also thought to form electrical defects.

The authors use the venerable space-charge-limited current technique to estimate the resulting mobility of crystals grown from the purified material. Assuming first that the current flows through the entire thickness of the thin plate-like crystal, they infer an astonishing mobility of about 11 cm^2/V-s. Previously, the best pentacene crystals gave mobilities closer to 1 cm^2/V-s, so this is a truly major advance. (Inorganic semiconductors generally have mobilities more than an order of magnitude higher still.)

For samples like this, the conductivity varies strongly with the field direction, so the authors use a method due to Montgomery to estimate that the current flows in only the top third of the film, at least for the low field, ohmic conduction. Applying this correction to their space-charge-limited currents, the authors quote mobility about three times higher, or 35 cm^2/V-s. The validity of applying this correction factor in the high-field regime requires more justification than is given in this paper.

The mobility increases as the temperature is lowered, as expected for true band transport, instead of decreasing as expected for thermally assisted "hopping" between molecules. While the space-charge limited current technique has a noble pedigree, in recent years it has also been associated with the discredited work of Hendrik Schön, some of it in fact claiming dramatic band transport results on pentacene. There is no certainly reason to suspect the current work of similar problems. Indeed, this group has spent several years developing the materials processing and measurement techniques, which in some cases were in direct contradiction to Schön's assertions. However, the mobility increase is surprisingly good, for what seems a modest reduction in the contaminating quinone concentration, and it is important to try to supplement the measurements with alternative transport techniques. These could also begin to explore whether the high mobilities can really be used for higher speeds or drive currents in transistors.