Pentagonal tiles pave the way towards organic electronics

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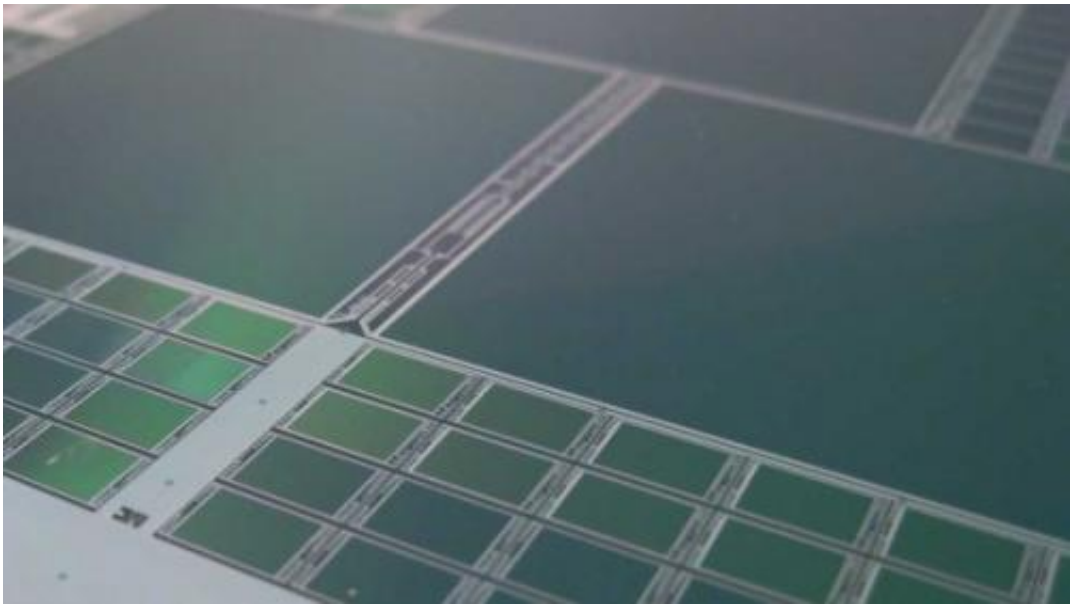

(PhysOrg.com) -- New research paves way for the nanoscale self-assembly of organic building blocks, a promising new route towards the next generation of ultra-small electronic devices.

Ring-like molecules with unusual five-fold symmetry bind strongly to a copper surface, due to a substantial transfer of charge, but experience remarkably little difficulty in sideways diffusion, and exhibit surprisingly little interaction between neighbouring molecules. This

unprecedented combination of features is ideal for the spontaneous creation of high-density stable thin films, comprising a pavement of these organic pentagonal tiles, with potential applications in computing, solar power and novel display technologies.

Currently, commercial electronics use a top-down approach, with the milling or etching away of inorganic material, such as silicon, to make a device smaller. For many years the computing power of a given size of computer chip has been doubling every eighteen months (a phenomenon known as Moore's law) but a limit in this growth is soon expected. At the same time, the efficiency of coupling electronic components to incoming or outgoing light (either in the generation of electricity from sunlight, or in the generation of light from electricity in flat-screen displays and lighting) is also fundamentally limited by the development of fabrication techniques at the nanometre scale.

Researchers are therefore looking for ingenious solutions in the creation of ever smaller electronics. The field of nanotechnology is taking a bottom-up approach of creating electronics using naturally self-assembling organic components, such as polymers, which will be capable of spontaneously forming devices with the desired electronic or optical characteristics.

The latest findings are from scientists at the University of Cambridge and Rutgers University who are working on the development of new classes of organic thin films on surfaces. By studying the fundamental forces at play in self-assembling thin films, they are developing the knowledge that will allow them to tailor these films into molecular-scale organic-electronic devices, creating smaller components than would ever be possible with conventional fabrication techniques.

Dr Holly Hedgeland, of the Department of Physics at the University of Cambridge, one of the co-authors of the paper reporting the research,

said: "With the semiconductor industry currently worth an estimated $249 billion per year there is a clear motivation towards a molecular scale understanding of innovative technologies that could come to replace those we use today."

It is not simply the electronic properties of a molecule on a surface that will control its potential to form part of a device, but also whether it will move by itself into the required structural configuration and remain stable in that position even if the device becomes heated in use.

Molecules that are strongly bound to the substrate with a high degree of transfer of charge offer a range of new possibilities, though little is currently known of their behaviour. A number of organic molecules, usually featuring carbon rings across which electronic charge can conduct, potentially demonstrate the right electronic properties, but the long-range forces which will govern their self-assembly during the first phases of growth often remain a mystery.

Now the interdisciplinary team based in the Departments of Physics and Chemistry at the University of Cambridge, and the Department of Chemistry and Chemical Biology at Rutgers University, have reported the first dynamical measurements for a new class of organic thin film where cyclopentadienyl molecules (C5H5) receive significant electronic charge from the surface, yet diffuse easily across the surface and show interactions with each other that are much weaker than would typically be expected for the amount of charge transferred.

Hedgeland explained: "By coupling the experimental helium spin echo technique with advanced first-principles calculations, we were able to study the dynamic behaviour of a cyclopentendienyl layer on a copper surface, and to deduce that the charge transfer between the metal and the organic molecule was occurring in a counter-intuitive sense."

Dr Marco Sacchi, of the Department of Chemistry at the University of Cambridge, who carried out the calculations that helped explain the startling new experimental results, said that "the key to the unique behavior of cyclopentadienyl lies in its pentagonal (five-fold) symmetry, which prevents it latching onto any one site within the triangular (three-fold) symmetry of the copper surface through directional covalent bonds, leaving it free to move easily from site to site; at the same time, its internal electronic structure is just one electron short of an extremely stable `aromatic' configuration, encouraging a high degree of charge transfer from the surface and creating a strong non-directional ionic bond."

The researchers' findings, reported in *Physical Review Letters* today, Friday 06 May, highlight the potential of a new category of molecular adsorbate, which could fulfil all the criteria required for useful application.

Hedgeland concluded: "The unusual character of the charge transfer in this case prevents the large repulsive interactions between adjacent molecules that would otherwise have been expected, and hence should enable the formation of unusually high-density films. At the same time, the molecules remain highly mobile and yet strongly bound to the surface, with a large degree of thermal stability. In all, this is a combination of physical properties that offers huge potential benefit to the development of new classes of self-assembled organic films relevant for technological applications."

More information: The paper is entitled "Weak intermolecular interactions in an ionically bound molecular adsorbate: Cyclopentadientyl/Cu(111)" and will be published in *Physical Review Letters* on Friday, 06 May.

Provided by University of Cambridge