materials properties. Several questions remain to be answered to fully grasp the technological implications of this work. Will a similar improvement be observed in higher mobility organic semiconductors? Since charges in highly crystalline, high-mobility organic semiconductors are already delocalized, it will be important to verify whether the approach of Orgiu and colleagues remains valid as the quality of materials improves. Can other geometries be adopted to extend this enhancement principle to other types of electronic device? Indeed, non-planar devices such as diodes or vertical transistors would also benefit from a mobility boost. Can ordered subwavelength hole arrays be manufactured at high yield and low cost? For instance, the dimensions and spacings of the features (on the order of a few hundred nanometres) are compatible with potentially cheap imprint or lithography patterning technologies, whose scaling up to large areas is currently being investigated. Positive answers to these questions may change the way we think about designing and producing organic electronic devices and induce us to reconsider the line between materials and device engineering. ❒

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MATERIAL WITNESS

MATERIALS TOUCH ACROSS THE VOID

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In the hierarchy of intermolecular interactions, van der Waals (vdW) or dispersion forces used to rank pretty low. They were just the generalized, vaguely sticky background against which all the more powerful, selective and directional forces between atoms and molecules shaped matter: covalent, ionic, hydrogen bonding and so forth. They seemed to do little more than mediate physisorption and glue together, rather feebly, the sheets of graphite.

Now it's different. For one thing, improved computational methods have shown that vdW forces can supply a rather significant fraction of the cohesive energy and bulk modulus of hard solids such as silicon and sodium chloride[1,2] — as much as 10–15% in some cases. But the renaissance of fluctuation-induced forces — for that's where the vdW force originates — is not just about the little guy who turns out to be bigger than you thought. He is also better connected.

An appreciation that the vdW force and the Casimir force between metal surfaces at very small separations share a common origin goes back several decades[3,4]. The latter, once commonly discussed as an exotic effect of virtual-particle formation in a vacuum and featuring in quantum chromodynamics, is now more prosaically regarded as a limiting case of the vdW force in which the influence of fluctuations of the electromagnetic field in one object on that in another nearby is modified by the finite speed of wave propagation between them. It is, in effect, what the vdW force becomes at larger separations of a few nanometres. The force was first described by Hendrik Casimir in 1948; the corresponding case of interactions between polarizable atoms, or between such an atom and a metal surface, was studied by Casimir and Dik Polder, and is called the Casimir–Polder force. The Casimir force is now recognized as a significant influence on the behaviour of nano- and micromechanical devices, and may even be used to actuate them[5].

It stands to reason that both the electronic structure of a material and its consequent interactions with electromagnetic radiation must therefore exercise a strong influence on these fluctuation-based forces. This has led to the notion of tuning Casimir interactions via the materials properties of the interacting components and the intervening medium, even to the extent of turning attraction to repulsion[6]. But some of the exotic electronic and optical materials developed over recent years can now bring dazzling diversity to the study of vdW and Casimir interactions, as a review by Woods *et al.* explains[7].

Their survey goes beyond previous considerations of such effects in real materials[8] by bringing together many of the most interesting materials systems currently under investigation: graphene and other low-dimensional systems, optical metamaterials, photonic crystals, topological insulators, molecular crystals, carbon nanotubes, biological adhesives, plasmonic nanostructures. It's not hard to see why, for example, a material such as graphene in which the charge carriers behave like massless Dirac fermions will exhibit fluctuation forces distinct from ordinary conductors. Inevitably, one can't generalize about the outcomes, except perhaps to say that the materials diversity makes for a playground in which theoretical methods can be tested and applications explored. And that these humble forces turn out to be incomparable unifiers of a vast galaxy of materials-based systems. ❒

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