Figure 1 Current-voltage plot for the 'molecular electronics' device built by Vilan *et al.*². A characteristic diode junction allows current to flow only when positive voltage is applied. The curves shown here are recorded from metal-semiconductor junctions that are identical except for the group attached to a molecular layer on the semiconductor surface. The groups have either increased or decreased dipole moments compared with the unmodified junction, and the change in current flow through the modified junctions is due to this dipole control.

Interfaces between electrodes and individual molecules are required in 'molecular wire' circuits, whose preparation, measurement and modelling are being intensely studied^{1,3-11}. The energy properties that dominate such circuits are the effective work function, $q\phi$, of the metal and the electron affinity, χ_{sc} , of the semiconductor, both of which characterize the transport of charges in these materials. A molecular layer can produce a substantial shift in the values of these parameters from $q\phi^0$ or χ_{sc}^0 of the bare electrode. This modification can be understood in several ways, ranging from simple electrostatics to reasonable electronic structure calculations¹². Qualitatively, much of the change from $q\phi^0$ or χ_{sc}^0 to $q\phi$ or χ_{sc} arises from the way in which the molecular dipole distribution at the interface perturbs the potential felt by the electrons in the bulk phase. This perturbation will substantially shift the current-voltage characteristics of a molecular wire circuit^{1,3,4} or the voltage dependence of the charge injection in organic light-emitting diodes.

Because the molecular layers can so dramatically alter the surface work function, they can provide a substantial level of control over the electrode properties. Vilan *et al.*² show that the tunnelling barrier height for a pure metal-semiconductor junction can be controlled by the molecular dipole layer, so that the net barrier height $q\phi^b$ for the junction is given by $q\phi^b = q\phi_{metal}^0 - \chi_{sc} + q\phi_{dipole}$. The unmodified junction height (without the molecular layer) is given by just the metal and semiconductor terms, as defined previously. The extra term, $q\phi_{dipole}$, is the change in barrier height due to the molecular layer. By

changing the molecular dipole moment value and sign, the barrier height can be altered.

Vilan *et al.* demonstrate this control by changing the polarity of the group attached to the molecular layer — from dipoles, such as CF_3 and CN , that increase $q\phi_{dipole}$, to others (CH_3 and OCH_3) that reduce it. As the dipole effect changes, so does the net barrier height $q\phi^b$. The actual barrier heights were calculated from the current-voltage characteristics of the junctions (Fig. 1), and the value increases linearly by 90 millielectron volts on changing from CN to OCH_3 (see their Fig. 2 on page 167). What is so striking is that electron transport through the molecules seems to contribute little or nothing to the change in junction properties — the effect is due entirely to the molecular dipoles.

Several recent contributions have shown that molecular layers can modify the surface properties of semiconductors in a significant way¹³⁻¹⁵. The demonstration by Vilan *et al.* that changes in the molecular dipole moment are linearly reflected in changes in the junction barrier is an important advance in the engineering of charge transport at molecular electronics interfaces. In cases where the current is actually carried through the molecule, the change in charge injection properties can alter the conductance by changing the effective state density. This means that states into

which the electrons tunnel become available at altered energies. If the charge is transported through the films by gaps, shorts or direct tunnelling (that is, if the monolayer is not perfect), tuning the molecular dipole layer can, as Vilan *et al.* show, lower or raise the threshold for tunnelling conductivity. Both molecular wire circuits and charge injection in organic devices vary strongly with effective barrier heights; the adsorption of molecular dipole layers apparently offers a general and practical approach to customizing these barriers.

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Entomology

Love is not puffed up

When it comes to picking a mating partner, the females of most species usually get to do the choosing. Sometimes, as in the case of the long-tailed dance fly *Rhamphomyia longicauda*, the roles are reversed. David Funk and Douglas Tallamy show in *Animal Behaviour* (**59**, 411-421; 2000), however, that even here the females seem to be holding all the cards.

Female dance flies cannot hunt for prey for themselves, and instead rely on nuptial gifts presented to them by the males in exchange for mating. This trade-off takes place in female leks, where females gather and wait for the males to bring them food. In contrast to many species, this means that it is the males that get to do the picking. But Funk and Tallamy reveal that the females have evolved a clever way to increase their odds of being chosen.

The males prefer to mate

with females with swollen abdomens. The likely reason is that abdomen size is perceived to be a good indicator of egg maturity — for a related species, *R. sociabilis*, multiple regression analysis revealed a significant relationship between these two variables. Funk and Tallamy propose that, given that males want their sperm to be the ones that fertilize the egg, waiting until the eggs are mature is a good way to ensure that this happens.

But female *R. longicauda* cheat. The females puff up their abdomens (pictured) — probably by 'swallowing' air — so creating the impression that their eggs are more mature than they really are. (Multiple regression analysis showed no significant relationship between egg maturity and the size of the inflated abdomen.) But it seems that the males of this species are still fooled. The

males hover beneath the females, and all that they see is the expanded shape of the abdomen. They have no further clues to the actual state of the females' eggs.

All of this means that females whose eggs are not yet mature can gain the sustenance needed to complete egg development at least once. It seems that, contrary to appearances, it is the females who still retain the upper hand in this mating game.

Amanda Tromans