attractive interaction between the electrons that is responsible for the superconductivity is absent, and the electrons become quickly disentangled. Nevertheless, positive correlations between the current fluctuations in the two output leads have been observed in recent experiments at Northwestern University, indicating that pairs of electrons were emitted simultaneously[7]. The principal disadvantage of these all-metallic structures is that the pairs of electrons emitted by the superconductor are immediately drowned in the Fermi sea of the metal leads. This makes the lifetime of the electron states too short to be used in devices such as quantum computers.

A second approach recently demonstrated by two independent groups[8,9] involves the electron pairs tunnelling from the superconductor into a double quantum dot, rather than metallic leads. This is expected to increase the lifetime of the extracted electron spins significantly and allows further processing of individual spins. The electric potential of each dot can be tuned to cause electrons to tunnel on and off the dots, resulting in a series of resonant peaks when current is measured as a function of gate voltage. The small size of the quantum dots increases the Coulomb repulsion between two electrons on a single dot, so that, at low bias, each quantum dot can take only one extra electron at a time. This strong Coulomb repulsion also helps the electron pair to spatially separate.

Christian Schönenberger and colleagues at the universities of Basel and Copenhagen and the Budapest University of Technology and Economics[8] create double dots in a single InAs semiconducting nanowire adjacent to the superconductor (Fig. 1b). When tuning one of the dots through resonance, they observe an increase of the current through the second dot, signalling the simultaneous emission of electron pairs. When a small magnetic field is applied, so that the superconductor becomes a normal conductor, a decrease in current through the second dot is observed. This pair of observations suggests that Cooper-pair splitting occurs with an efficiency of 2%, although the lifetime of the spin entanglement remains to be determined.

In a separate experiment, Takis Kontos and colleagues at the Ecole Normale Supérieure in Paris, CEA Saclay, the Autonomous University of Madrid and the University of Regensburg (including this author) create the double quantum dot in a single carbon nanotube rather than a nanowire[9]. In this case, the two quantum dots are strongly tunnel-coupled. This results in the formation of an extended molecular state on the nanotube in which the electrons are still entangled (Fig. 1c). However, this stabilization of entanglement on the dot comes at a price: both electrons in a pair can leave through the same lead, which sets an upper limit of 50% on the efficiency of the splitting. Nevertheless, the efficiencies reported for both sets of experiments are orders of magnitude higher than those observed in the generation of entangled photons.

A direct determination of the pair-splitting efficiency will require a correlation experiment like the one at Northwestern University[7]. Moreover, further experiments are also needed to demonstrate that the electron spins are entangled. To address this goal, it will be necessary to measure and correlate the relative spin orientation of the emitted electrons. Such a spin-sensitive readout may require magnetic contacts, or it may be possible to take advantage of the spin-orbit interaction. The nanowire/nanotube approach[8,9] also has the advantage that it should be possible to add more quantum dots and more terminals along the length of the nanowire/nanotube, which would allow further processing of the quantum information carried by the electron spins. ❐

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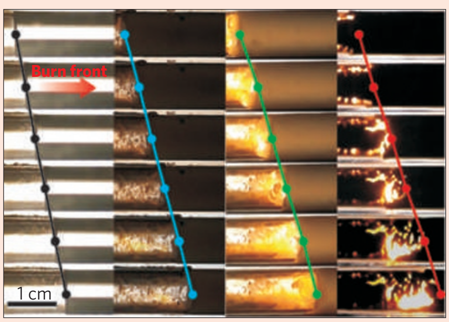
FUEL ADDITIVES

Graphene helps fuel burn faster

Advanced high-speed propulsion systems will require environmentally friendly fuels that offer high energy densities, short ignition times and low costs. However, rather than developing new fuels, many researchers are trying to improve the performance of existing fuels by adding low concentrations of colloids to boost performance. Now Richard Yetter, Ilhan Aksay and co-workers at Pennsylvania State University and Princeton University have shown that the combustion performance of nitromethane can be greatly enhanced by adding functionalized graphene sheets (*ACS Nano* doi:10.1021/nn901006w; 2009).

The Penn State–Princeton team compared the performance of neat nitromethane with samples that contained aluminium oxyhydroxide, silica nanoparticles or functionalized graphene sheets. All three additives lowered the ignition temperature and increased the burning rate, with the functionalized graphene sheets leading to the biggest increase. The change in the burning rate relative to neat nitromethane increased with the concentration of the additives and decreased with pressure. The figure shows the burn front (the diagonal line) at two-second intervals for the four fuel systems, with the neat fuel on the left and the graphene-enhanced fuel on the right.



The graphene sheets are efficient catalysts because they are easily dispersed and have large surface areas in contact with the fuel. Their high thermal and radiation conductivities might also enhance heat transfer during combustion.

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