news and views

S. cerevisiae cells to carry a Sup35 protein that had the chimaeric prion domain instead of the natural, S. cerevisiae prion domain. Cells bearing this Sup35蛋白 in its non-prion form could be changed to a state analogous to {PSI}^+\, called {XI}^+, when the natural prion domain from C. albicans or S. cerevisiae Sup35 was temporarily overproduced. Surprisingly, most of the {XI}^+ strains induced by the C. albicans domain were strong, while most of those induced by the S. cerevisiae domain were weak or unstable. Perhaps these strong and weak in vivo strains correspond to the different chimaeric conformations formed in vitro with C. albicans or S. cerevisiae fibre seeds. In vivo proof of this will require the demonstration either that direct introduction of the differently shaped fibres into yeast specifically transmits the strong or weak {XI}^+ strain, or that Sup35 aggregates isolated from yeast with the strong or weak strains have the expected differences in conformation and seeding specificity.

The authors have shown that, depending on the species from which the seeding fibre originates, their purified chimaeric prion domain can fold into two different conformations, themselves with distinct in vitro seeding specificities. The results suggest that prion conformation may hamper the spread of prion diseases between species. But, given the seeding specificities. The results suggest that prion conformations, themselves with distinct origin, their purified chimaeric prion may vary in their ability to cross species barriers. With their strong and weak {XI}^+ yeast strains, Chien and Weissman have opened the door for this theory to be tested in vivo. It may be time to consider the disturbing possibility that certain bovine prion forms have an enhanced ability to cross these species barrier to humans.

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Condensed-matter physics

Superconducting plastic

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Polymer materials that can conduct electricity have been known for some time, but they have defied attempts to make them into superconductors. The answer, it turns out, is to inject them with charge — but how does it work?

Polymers make versatile plastics, but until the 1970s, they were not expected to conduct electricity. The discovery of conducting organic polymers led to fresh applications in electronics and, later, in optoelectronic devices. The main advantage of organic polymers over conventional metals and inorganic semiconductors used in electronics is their low cost. But unlike metals, they have never been made to superconduct — until now. On page 189 of this issue, Schön et al. report superconductivity below 2.5 K in a thin film of the organic polymer (3-hexylthiophene) (P3HT).

Materials that can superconduct lose all their electrical resistance below a specific temperature, known as the critical temperature, T_c. For most metallic superconductors this temperature is relatively low, and the search for so-called high-temperature superconductors has been influential in the development of condensed-matter physics.

This was true, for example, in the late 1960s when the highest available T_c was raised from 18 K to 21 K by the synthesis of a new intermetallic compound. But progress was slow, so researchers considered other systems such as polymers. This prompted W. A. Little to suggest a provocative new theory, which offered an alternative to the popular Bardeen, Cooper and Schrieffer (BCS) picture of superconductivity in conventional metals. In the BCS theory superconductivity occurs because tiny vibrations in the underlying crystal lattice — known as phonons — help electrons to overcome their mutual repulsion and form pairs that flow without resistance.

For his model, Little replaced the phonons with an ‘exciton’ mechanism in which electron pairing is mediated by other electrons. These electron–electron interactions are characterized by a typical energy that is much larger than that of the phonons.

As a result, Little’s model promised superconductivity at substantially higher temperatures (possibly above room temperature) than is allowed by the BCS phonon mechanism — but it also imposed severe constraints on the design of any such material. For example, Little’s model was based on using conducting organic polymer chains modified with highly polarizable dye-like side groups. Until Schön and colleagues’ experiment, the only polymeric material to show superconductivity was a crystalline inorganic polymer. So although Schön et al. have obtained only a modest critical temperature for their polymer system, can we say that their polymer’s superconductivity fits with Little’s theory?

To explore this idea, we must first understand why some polymers conduct electricity. Conducting polymers, such as P3HT, have a ‘conjugated’ structure of alternating single and double bonds linking the carbon atoms in their backbone (Fig. 1). This bond structure allows one electron from each carbon atom to move along the molecule and become conducting. But the one-dimensional nature of the electron movement along the polymer chain makes them relatively poor conductors, especially at low temperature. This all changed 25 years ago, when it was discovered that chemically doping these materials with suitable impurities — halogens such as chlorine or alkali metals such as sodium, for example — leads to a surplus or deficit of electrons, making the polymers almost as good as metallic conductors. This finding widened the possible applications of polymer devices in electronic and optical systems, and was recognized by the Nobel Prize in Chemistry last year.

Despite their high conductivity at room temperature, doped polymers do not really mimic metals because their conductivity is not enhanced when they are cooled. Better conductivity — and ultimately superconductivity — at lower temperatures is the trademark of a good metal. The problem for the polymers is that their electronic properties are dominated by structural disorder, which leads to charge localization at lower temperatures. This is a shame because there is evidence for strong electron–photon interactions in polymers — favourable ingredients for BCS superconductivity.

In an effort to minimize the problem of disorder, Schön and colleagues’ used a solution-processing casting technique to exploit the self-organizing properties of polymer films deposited on a substrate. And instead of using chemical doping, the team injected charge carriers into the system using a field-effect transistor (FET) geometry. In an FET, applying a voltage to a ‘gate electrode’ triggers a flow of charge along the surface of the thin film. A similar procedure had been used previously to make conducting thin films of oligothiophenes. A later study had shown that...
P3HT molecules can self-assemble into two-dimensional conjugated sheets, which can be oriented either parallel or perpendicular to the surface of the film. By injecting charge into a similar highly ordered film of P3HT, Schön et al. have now observed superconductivity below 2.35 K. To inject enough charge they use a field-effect transistor geometry: source and drain electrodes are placed on top of the insulating surface (red), whereas the gate electrode is placed below. Applying a voltage to the gate electrode triggers a flow of charge along the surface of the thin film between the two other electrodes. (Redrawn from ref. 9.)

The nature of the superconducting pairing.

There is no evidence for one-dimensionality in the polymer films studied by Schön et al., and the nature of the pairing mechanism remains to be found. Strong hints in favour of a conventional explanation in terms of phonon-mediated superconductivity come from a similar study of the organic molecules pentacene, tetracene and anthracene, which would not be altogether surprising if electron–electron interactions became important in the two-dimensional electron gas created in the FET studies.

Even if Little’s model for superconductivity does not apply to these new results, we are probably witnessing a healthy revival of organic solid-state physics, which moved out of the mainstream of condensed-matter physics in the 1960s. The work of Schön et al. emphasizes that interdisciplinary work, involving both synthetic chemistry and condensed-matter physics, will advance the frontiers of both fields.

The major application of turbines with water-loaded blades will be chemical, however. Many processes generate a weak slurry of some nasty organic chemical, and it is appealing to burn this in a turbine to a solution of CO2 in water, and get useful power in exchange. The pharmaceutical industry, with innumerable waste streams on the way to a few useful products, would be an obvious customer. And the sewage business is dedicated to turning its customers’ waste into a weak water slurry, and getting rid of this somehow. Burning it in turbines could generate vast amounts of electricity. Even the waste heat, now represented by the hot fizzy water rejected by the turbines, should be easy to discharge. Expensive cooling towers might not be needed.

Even better, many reactions of ‘green chemistry’ seek to replace messy industrial processes by neat supercritical ones from which the product can be elegantly recovered by simple processing. What a pity that supercritical dry cleaning, a powerful and spontaneous oxidizing agent. A turbine fed not with cooling water, but with an oxygenated fuel slurry, would therefore generate heat in its turbine blades by burning the fuel circulating in them. So DREADCO engineers are now building turbines whose combustion is distributed between the combustion chambers and the first few rows of blades. Indeed, Daedalus reasons that an internally heated blade could generate torque on its own account, making possible an entirely new sort of turbine.