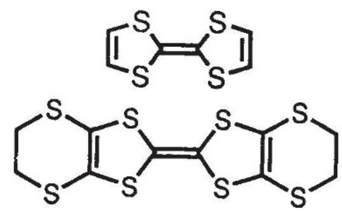

Structures of (top) tetrathiofulvalene (TTF) and (below) bis(ethylenedithiolato)–TTF (BEDT–TTF), sulphur-based heterocycles that could be found in microchips of the future.

CT salts have been fabricated over the past few years using the Langmuir–Blodgett technique[5], the deposition of molecular films from solution. However, although these films have unveiled all kinds of interesting chemical and physical effects, they are not so suitable for use in electronic devices; their thermal and mechanical stability tends to be rather low and the technique requires the synthesis of amphiphilic molecules (combining hydrophilic and hydrophobic parts) which is not always so easy. It is now clear that vapour deposition can provide more robust films with higher values of conductivity than Langmuir–Blodgett films. Two Japanese groups have developed this technique to obtain metallic films of TTF[6], and superconducting films of BEDT–TTF[7], incorporating iodide anions.

In new work[6] described by M. Yudusaka (Hoechst, Japan), tetrathiofulvalene (TTF) and iodine are co-evaporated from separate crucibles in a pyrex-glass chamber under high vacuum (3×10^{-5} torr). Deposition of the resulting TTF iodide CT salt is achieved on a glass substrate. The temperature of the crucibles and the deposition substrate is important in determining the chemical composition of the deposited film. Under the optimum conditions (TTF source, 50–70 °C; iodine source, 0 °C; and substrate glass, 0–20 °C) TTF–$I_{0.7}$ was deposited as a thin film between 0.1–1 μm thick. With the substrate temperature below −20 °C, the films were contaminated with uncomplexed TTF, and above 30 °C nothing was deposited.

Ultraviolet spectra of the metallic film show that the TTF molecules have been oxidized by the iodine to form TTF radical cations which can provide the charge carriers. Polarized spectra show marked dichroism, providing evidence that the molecules are well oriented within the film. Consistent with this structure, anisotropic electrical properties were observed with a room-temperature conductivity value along the most highly conducting axis of 10^2–10^3 S cm^{-1}. A transition to a less conducting state occurs at about 200 K. Overall, these data are very similar to those of single-crystal samples of TTF–$I_{0.7}$.

K. Kawabata and coworkers[7] (Idemitsu Kosan Co.) have fabricated superconducting thin films of the CT salt formed by BEDT–TTF and iodine using basically the same technique, although experimental details are quite different. In these experiments, the raw material was heated to 200 °C to achieve sublimation and deposition onto a potassium chloride substrate kept at 70 °C. The raw material was either BEDT–TTF powder which was doped by reaction with iodine during deposition (as described above for TTF iodide) or, alternatively, preformed BEDT–TTF iodide salt (prepared electrochemically) was used. Both methods gave films with essentially the same quality with a typical thickness of 500 nm. The separation of the crucible and the substrate is important, 3 cm being the optimum distance.

X-ray diffraction data for the evaporated film fit well with the α-phase of $(BEDT–TTF)_2I_3$ crystals which would indicate a high degree of orientation in the film. The film's in-plane conductivity is 1 S cm^{-1} at room temperature and decreases with decreasing temperature, showing the material to be semiconducting. Single crystals of the α-phase of $(BEDT–TTF)_2I_3$ can be transformed thermally into the α_t-phase which is a stable superconductor[8] with $T_c = 9$ K. This α_t-phase was obtained from the films when they were annealed at 90 °C for 40 hours in air, along with a very small amount of BEDT–TTF resulting from decomposition of the salt. Magnetization measurements established that the annealed films undergo a superconducting transition at about 5 K. The critical temperature is very sensitive to the evaporation conditions, with the variation seen in T_c probably arising from disorder in the crystalline regions of the film.

It is to be expected that a wide range of conducting and superconducting CT salts will form well-ordered thin films using the above evaporation techniques, and hopefully materials with higher T_c values will be obtained. Indeed the recent discovery[9] of superconductivity at 18 K in evaporated films of potassium-doped fullerene C_{60} should add impetus to the study of thin films of CT salts. □

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DAEDALUS

Life after death

THANKS to the polymerase chain-reaction, antique DNA can now be detected in all sorts of long-dead fossils and museum specimens. Some of it is 20 million years old. How can this be, when DNA ought to hydrolyse completely in a mere 10 thousand years?

Daedalus sees it as just another aspect of the ruthless survival strategy of DNA. In 'selfish gene' terms, it is parasitic upon the creatures it inhabits. It gives them abilities and instincts which drive them to replicate it as copiously as possible in the next generation before they die.

Now the death of its host is certainly a setback to any parasite. To some (like the tapeworm) it is fatal; but smarter ones (like the louse) simply go off in search of a new host. DNA, the smartest parasite of them all, is most unlikely to be defeated by the death of its host. In its relentless struggle to survive and reproduce, it must have evolved the capacity to withstand the chaotic chemistry of death. As the body around it decomposes or fossilizes, it somehow contrives to keep itself largely intact — even over 20 million years.

This, of course, is only half the battle. Sooner or later the DNA has to get back into the mainstream of life. It has to infect a living host, and start replicating again. Now, DNA is rather good at forming microscopic infective particles such as viruses and plasmids. So Daedalus argues that it must escape from dead tissue in the form of fertile plasmid-like spores each containing a few genes. These thereafter drift around the environment. Every so often, such a spore will chance to be present at an act of sexual fertilization. It may then be taken up by the ovum along with the sperm, and can start a new genetic career.

There is no guarantee, of course, that it will find itself in a host of the same species, or that its insertion into the genes of that host will make any sense or do any good. Such random insertions, mainly deleterious or useless but occasionally beneficial, are of course well known. They are called mutations.

On this theory, DNA has a life-cycle as chancy and fantastic as that of any other parasite. Its spores must be everywhere. The DNA already on the replication bandwagon must mount an immune response against them, so successful mutations are quite rare. To test his challenging theory, Daedalus is mating mice, fruit-flies, and so on, in unhygienic surroundings rich with plant and animal remains, to compare their mutation rates with those of creatures mated in a scrupulously DNA-free clean room. Positive results will open up a whole new technique of genetic engineering. DAVID JONES