More recently, a Russian team⁷ electro-deposited a copper-nickel multilayer on a single-crystal gallium arsenide substrate, and again found the layers to be in epitaxy, allowing more uniform and reproducible growth. Because of the mismatch between the lattice constants of GaAs and the metals, intense strains are generated in the initial metallic layers, but they attenuate as further layers are added.

Undoubtedly, the most piquant use of

The change in resistance R due to an applied magnetic field of nanowires made of alternating layers of copper and cobalt. The effect increases with decreasing thickness (from ref. 8).

the electrodeposition approach to making multilayers is a recent study by two Swiss physicists⁸. Doudin and Ansermet wished to make fine wires of multilayered construction (long stacks of thin disks, in other words) so as to measure the giant magnetoresistance (GMR) along the wires while a field was applied normal to the wires. They achieved this seemingly impossible task by using a thin polymeric membrane with ultra-fine holes 0.1 μm in diameter, coating one side of the membrane with a gold electrode, and plating copper and cobalt from a complex plating bath through the holes. The membranes (six micrometres thick) are made by irradiating polycarbonate films with heavy ions and etching through the films along the radiation-damage tracks^{9,10}, a technique originally developed in the 1950s for quite different purposes. By making thousands of layers, Doudin and Ansermet were able to achieve unusually high resistance values in these fine wires. The figure shows how the magnetoresistance effect changed with reduction of the layer thickness, as expected.

As an aside, the authors refer to a number of applications of track-etched membranes by scientists with very diverse interests. The first such use, in 1962, was to filter cancer cells from blood by using such membranes as ultrafilters¹⁰; that is why such membranes are commercially available today.

Another effect of annealing, this time at temperatures up to 270 $^{\circ}\text{C}$, is to reduce by a third the magnetoresistance of copper-cobalt multilayers made by

sputtering¹¹. The variation of GMR with magnetization was consistent with the notion that changes in GMR are due to changes in the antiferromagnetically aligned volume fraction. In this study, perhaps because of the modest temperatures used, there was no evidence of any changes in the interfaces between the layers.

One aspect of multilayers that has given rise to some dispute is the so-called supermodulus effect, which I reported in these columns a decade ago¹² when it had been newly discovered. Large changes in flexural elastic modulus (stiffness) were observed in copper-nickel multilayers, with the maximum effect around two-nanometre periodicity. I presented the rival models advanced to explain this curious effect, but some years later Kumar *et al.*¹³ found themselves unable to reproduce the supermodulus effect in copper-cobalt, and interest waned. More recently still, a Japanese team¹⁴ used improved methods in an attempt to re-establish the effect. They had single-crystal GaAs as a substrate as did the Russians, but instead of electrodeposition, they used molecular-beam epitaxy to deposit high-quality multilayers in parallel orientation. They were critical of the direct mechanical methods that had been used earlier to measure flexural moduli, and instead measured surface acoustic waves to obtain an indirect but precise measure of elasticity. They found an increase in the elastic constant of around 60%, so it seems that the supermodulus effect has been rescued. Now, perhaps, applications will be found. The very international nature of the research effort on multilayers suggests that this may not take long. $\square$

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Travel by cola

DAEDALUS once proposed a sea-going hovercraft pressurized, not by air pumped into it from above, but by evaporation of the water below. Its hot underside was to warm up, and thus increase the vapour pressure of the water beneath it. To obtain 0.1 atmospheres of pressure, the water surface would have to be heated by about 30 $^{\circ}\text{C}$ during the passage of the craft.

Sadly, this rate of heat transfer proved unfeasible. But Daedalus now has a new twist. He points out that carbonated soft drinks are pressurized to several atmospheres. Yet when you pour them out, most of the gas stays dissolved as a supersaturated solution. A hovercraft travelling over a lake or canal filled with such a drink could, in principle, exploit the massive vapour pressure of its surface.

In this connection, Daedalus recalls that the evaporation of water from a reservoir can be impeded by covering its surface with a monolayer of cetyl alcohol. Such monolayers flow over a water surface as a sort of two-dimensional liquid. By compacting them between barriers, they can be compressed to the equivalent of hundreds of atmospheres. So Daedalus reckons that even the most ferociously carbonated soda water would hold its gas stably if it were covered with a compact monolayer of cetyl alcohol, oleic acid, or other film-forming surfactant.

Imagine, says Daedalus, a lake or canal full of soda water loaded with many atmospheres of carbon dioxide, kept in solution by a surface monolayer. The 'carbocraft' comes along, supported on the cushion of compressed carbon dioxide beneath it. This cushion presses on the water surface, indenting it into a depression beneath the flying vehicle. The deformation, of course, increases the surface area of the water. The monolayer cannot stretch to cover the extra area; it separates to uncover free water surface, from which gas evaporates at many atmospheres. The craft is thus levitated on a cushion of the gas released by its passage. When it has passed, the monolayer closes and heals again, and no further gas is lost.

The carbocraft will be swift, silent and simple. Daedalus hopes that it can be propelled and steered by a jet efflux of the gas it harvests from the water. It could ply its trade on special canals, kept supersaturated by a pipe along the bottom releasing carbon dioxide under pressure. But it would be most at home on those volcanic lakes that are naturally supersaturated by some underground source of geological carbon dioxide.

David Jones