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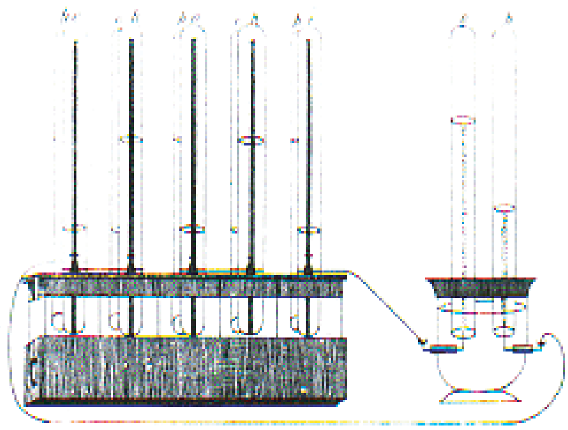
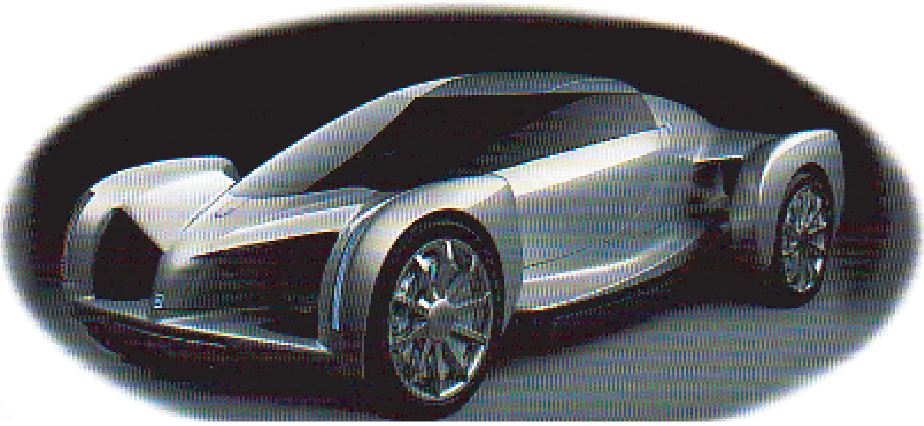
160 years of fuel cells

Solid future for ionic conductors

Getting to the heart of the matter





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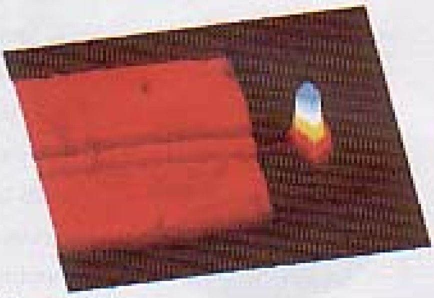
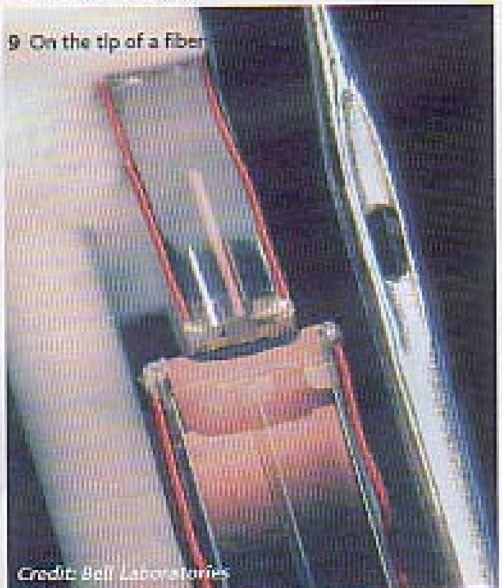
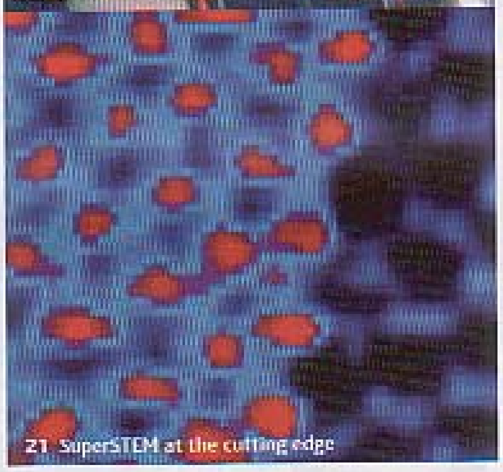


7 New face of lasers



9 On the tip of a fiber

Credit: Bell Laboratories



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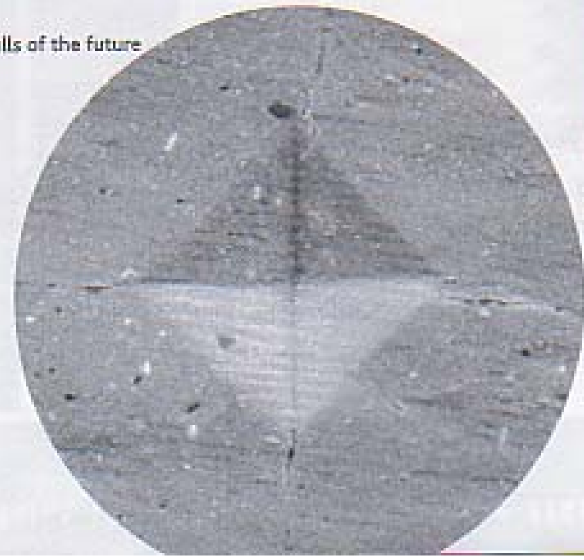

Going with the flow

NANOTECHNOLOGY

Adding to the panoply of applications promised for carbon nanotubes, researchers predict that they could make ultra-sensitive flow sensors. Researchers from the Indian Institute of Science and Raman Research Institute in Bangalore report that the flow of a liquid over a bundle of single-walled carbon nanotubes (SWNT) induces a voltage/current in the direction of flow [Ghosh, S., *et al.*, *Sciencexpress* (2003) 1079080]. The experimental results confirm predictions made by Král and Shapiro [*Phys. Rev. Lett.* (2001) **86**, 131]. Contrary to predictions, however, the researchers find that the voltage exhibits a logarithmic dependence on velocity. The magnitude of the voltage/current also depends on the ionic conductivity and polar nature of the liquid. Comparisons to graphite and multi-walled nanotubes indicate that the one-dimensional nature of SWNTs is essential for the generation of a net electrical signal.

The researchers' observations lead them to suggest a mechanism that was originally posited by Král and Shapiro. They envisage a saw-tooth (or ratchet) potential, which is deformed by the velocity gradient near the surface, resulting in an asymmetric fluctuating potential. One-dimensional confinement of charge carriers in the nanotube ensures that the uniformly biased, but randomly positioned ratchet potentials along the sample act additively to induce an overall voltage.

A flow sensor based on this phenomenon could be scaled down to micron dimensions, say the researchers, and used in very small liquid volumes. Sensitivity would be high at low velocities and response time fast. There may also be interesting biomedical applications, the researchers add.

Low temperature nitriding

PROCESSING

Chemical surface modification techniques are widely used to improve the properties and performance of materials. These processes can, however, be limited by the reaction kinetics involved. Changing the surface microstructure of a material is one means of accelerating such chemical processing reactions. Researchers from the Chinese Academy of Sciences' Institute of Metal Research and University of Technology of Troyes in France report using just such a method to reduce the nitriding temperature of iron plate to 300°C [*Science* (2003) 299, 686]. Nitriding is a widely used chemical technique that improves the wear/corrosion resistance of materials by forming a composite structure with a hard, Fe-nitride surface layer and a tough interior. However, it has to be performed at high temperatures (> 500°C) for substantial periods, which can be damaging to some types of substrate material.

The researchers used a recently developed surface mechanical attrition treatment (SMAT) to produce a nanocrystalline surface layer on pure Fe plate. The treatment generates plastic deformation in the top layer of the material by bombarding it repeatedly with 8 mm stainless steel balls. The plastic deformation at high strain rates refines the coarse grain structure into the nanoscale regime. The treated Fe has a much greater hardness than the substrate, as well as enhanced wear and friction resistance. SMAT prior to nitriding also improved corrosion resistance and enhanced chromium diffusivity. The researchers suggest that the crystalline nature of the treated surface, and the large number of grain boundaries and other defects, enhances N_2 diffusion and lowers the required temperature. The nanostructured surface also stores a large excess energy, constituting an extra driving force for the nitriding process.

This approach could allow the nitriding process to be applied to families of materials, like some alloys and steels, that currently cannot be treated.

Friction-free bearing

NANOTECHNOLOGY

Feynman first suggested molecular bearings as a fundamental component of molecular mechanical devices. The realization of such frictionless systems would be essential to enabling micro- and nano-machines. But previous work has yielded poor results.

Now researchers from Aichi University of Education, Seikei University, and the Japan Science and Technology Corporation have constructed an ultralubricated system, which confines a C_{60} monolayer between two graphite sheets [*Phys. Rev. Lett.* (2003), in press]. The C_{60} molecules act as molecular bearings, with six-membered C rings between the C_{60} molecules and the graphite-forming nano-gears. The static frictional forces in this system have a finite value, but dynamical frictional forces are zero. The researchers propose a stick-slip rolling model with a step rotation of the C_{60} molecules to explain their results. The concept opens up a new field of molecular bearings, say the researchers, which could be applied to Si substrates for the movable parts of micro- and nano-machines.

Fingerprint of fatigue

MECHANICAL PROPERTIES

Efforts to control the fracture of materials depend upon an understanding of the micromechanical behaviors that determine the damage mechanisms. Since most metals and ceramics consist of crystalline grains, macro- and microstresses are produced during deformation. These microstresses include both intergranular stresses across grains and intragranular stresses at defects. But many open questions remain.

Now researchers from The University of Tennessee, Oak Ridge, and Argonne National Laboratories have used neutron diffraction to explore the development of intergranular stresses in commercial Type 316 stainless steel during high-cycle fatigue [Wang, Y.-D., *et al.*, *Nature Materials* (2003) 10.1038/nmat812]. The general purpose powder diffractometer (GPPD) at the Intense Pulsed Neutron Source at Argonne enabled the measurement of lattice strain distributions in fatigued samples. Although the strain of individual grains cannot be spatially resolved in this way, a statistical distribution of the strain/stress as a function of grain orientation can be obtained, explain the researchers. They find that large intergranular stress develops before cracks start to appear. As the fatigue cycles increase, the intergranular stress decreases but the elastic intragranular stored energy continues to increase. The ratio of intergranular to intragranular stored energy can, therefore, be used as a 'fingerprint' of the stage of fatigue damage in a material.

Although more data are needed to build up a complete picture of the evolution of stored energy during fatigue, say the researchers, this is the first time that a correlation between intergranular stress and fatigue damage has been reported.