

each fold up into its characteristic kinked state. The typical macroscopic consequence of such melting is a contraction of the system.

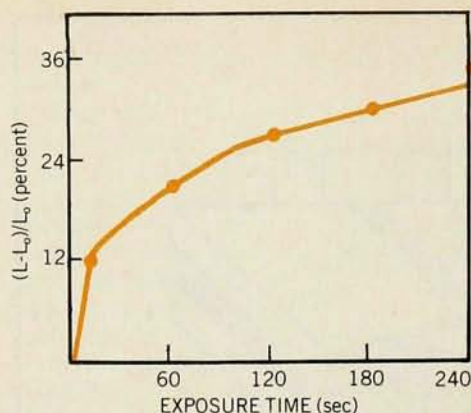
Aviram's photo-induced distortion was done with a gel. In contrast to the highly ordered crystalline case, a gel (for example, jellied consommé) is an amorphous, partially cross-linked system of polymeric molecules. The degree of cross linking must be sufficient to prevent dissolution, but not so extensive as to prevent the intrusion of liquid "diluent" into the matrix.

When a gel exhibits mechanochemical behavior, it is usually a dilation due to an increase in the amount of diluent sucked up by the matrix, or a contraction resulting from expulsion of diluent. Polymers that are capable of such mechanochemical deformation generally have functional groups sticking out from the backbone of the polymeric chain. The cross-linking between molecules is effected between the ends of these functional groups, somewhat like railroad ties between rails. In Aviram's work, the functional groups are photochemically ionized. With the gel immersed in a diluent liquid of highly polar molecules, the charge on the functional groups then attracts additional diluent into the interstices of the porous polymeric matrix, resulting in a very considerable swelling of the gel.

The backbone of Aviram's polymeric molecules is a long chain of units of glutamic acid, a common amino acid. To each glutamic acid link in the polymeric chain he attached a para-phenylene-diamine functional group, with a dimethyl-amino group protruding from its free end. The partial cross-linking of dimethyl-amino groups between neighboring molecules that produces the gel is then accomplished by dissolving the polymer in bromoethyl-naphthalene.

Aviram chose this dimethyl-phenylenediamine functional group because it is easily stuck onto a polymeric backbone and because it is known to experience photo-oxidation under ultraviolet light near 290 nanometers, in the presence of an organic halide such as carbon tetrachloride. Assisted by a uv photon, the group is ionized by giving up an electron to the carbon tetrachloride, producing chloride ions in the liquid and a residual positive charge on the functional group. From nmr studies it appears that the positive charge resides near the nitrogen linking the two methyl groups at the end of the functional group. Once the groups are ionized, large amounts of the polar liquid enveloping the gel are attracted into the pores of the partially cross-linked matrix, resulting in a maximum dilation of the gel to $2\frac{1}{2}$ times its original volume.

Aviram immersed thin films of his poly(dimethylamino)-glutamanilide gel in a diluent of dimethyl formamine (a



Fractional expansion in each dimension of a thin film of Aviram's polymeric gel, as a function of the duration of exposure to ultraviolet light.

highly polar liquid) and carbon tetrachloride (or tetrabromide), and irradiated the film with uv from a high-pressure mercury lamp, filtered to provide maximum radiant intensity at 365 nanometers. The gel requires several minutes of exposure, depending on the intensity of the irradiation, to soak up enough diluent to swell to maximum size. As Aviram puts it, mechanochemistry is notoriously sluggish.

Applications. When the thin film of gel floats freely on the diluent, it expands by a maximum 35% in each dimension. But for applications in printing and photocopying technology, one is interested in what happens to an irradiated film that is free to expand only in the direction normal to the plane. For this purpose Aviram chemically bound thin films of his gel to silicon substrates. He then irradiated the film through masks containing various designs, to produce raised relief patterns on the film. The mechanophotochemical effect is sufficiently local so that after irradiation the patterns showed up clearly on the film, raised about 35% above the masked areas of the gel. There is however some distortion, resulting from the desire of the gel to expand also in the plane of film.

For this sort of application, Aviram has contrived to keep the gel dry until after exposure to the ultraviolet light, by having CBr_4 mixed into the film from the start. The expansion is then initiated when the exposed film is immersed in the diluent liquid. This process is all very much like conventional photographic development, except that the result is in raised relief. The expansion effect could be very useful in printing technology, using a computer-guided uv beam.

The mechanochemical engine reported by Katchalsky and coworkers¹ in 1966 ran entirely on the contractile forces generated when a band of collagen (made from animal connective tissue) was immersed alternately in concentrated and dilute lithium-bromide solutions. The power generated by this little table-top engine, 0.03 watts per gram of collagen, is almost identical to the output of a frog's muscle

(per gram of contractile protein). With regard to the possible use of Aviram's gel for a mechanochemical engine, he points out that crystalline polymeric fibers like collagen convert chemical free energy to mechanical work much more efficiently than do amorphous gels. But if he can find a way to make his expansion process reversible, Aviram looks forward to the possibility of a mechanophotochemical engine. —BMS

References

1. I. Z. Steinberg, A. Oplatka, A. Katchalsky, *Nature* **201**, 568 (1966).
2. A. Aviram, *Macromolecules* **11**, 1275 (1978).
3. G. Smets, J. Bracken, M. Irie, *Pure and Appl. Chem.* **50**, 845 (1978).
4. G. Van Der Veen, W. Prins, *Polyelectrolytes*, Selegny and Reidel, New York (1974), page 483.

300-MVA superconducting generator being designed

The Electric Power Research Institute has contracted with Westinghouse Electric Corporation to design and construct the world's first commercial superconducting generator. The 300-MVA power generator, which is to be built in East Pittsburgh, Pa., is expected to cost \$19 million over a five-year period with the cost divided between EPRI and Westinghouse. At present the largest superconducting generator is a 5-MVA machine built by Westinghouse. Pioneering work on superconducting generators was done by an MIT group, where a 3-MVA generator is operating and other machine concepts are being developed. General Electric is building a 20-MVA generator in Schenectady. Plans for generators in this power range are being developed in Leningrad and in Japan as well.

in brief

Los Alamos Scientific Laboratory's Laser-Fusion Program is seeking scientists and engineers with experience in specialties related to the development of large, short-pulse CO_2 laser systems to participate in a new program that will allow industrial scientists and engineers to spend one to two years (renewable) with the Los Alamos project. For information, contact Eugene Stark, LASL, P.O. Box 1663, MS-529, Los Alamos, N.M. 87545.

A detailed review of current and proposed studies of the solar-terrestrial environment has been released by NASA. *Solar Terrestrial Programs—A Five-Year Plan* details proposed plans for space-based research of the Sun, the heliosphere, the Earth's magnetosphere and the upper atmosphere. □