



Materials

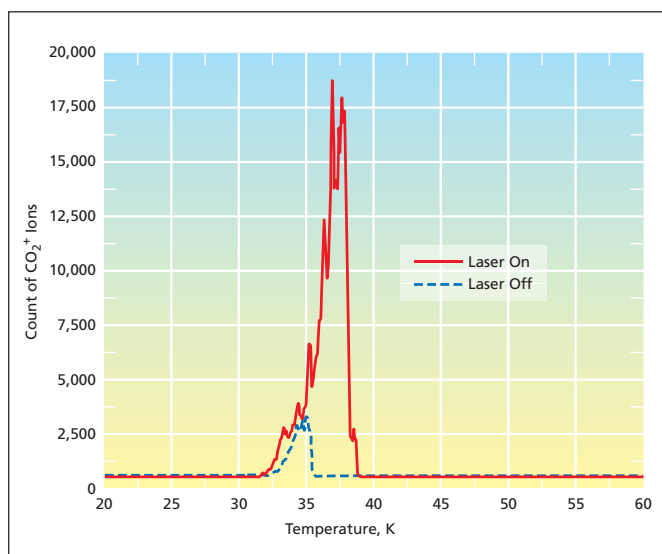
Making More-Complex Molecules Using Superthermal Atom/Molecule Collisions

Atoms adsorbed on cold surfaces react with energetic impinging atoms.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of making more-complex molecules from simpler ones has emerged as a by-product of an experimental study in outer-space atom/surface collision physics. The subject of the study was the formation of CO₂ molecules as a result of impingement of O atoms at controlled kinetic energies upon cold surfaces onto which CO molecules had been adsorbed. In this study, the O/CO system served as a laboratory model, not only for the formation of CO₂ but also for the formation of other compounds through impingement of rapidly moving atoms upon molecules adsorbed on such cold interstellar surfaces as those of dust grains or comets. By contributing to the formation of increasingly complex molecules, including organic ones, this study and related other studies may eventually contribute to understanding of the origins of life.

In the study, CO was adsorbed onto a cryo-cooled surface, then the surface was exposed to a beam of ground-state O atoms at a kinetic energy of 10 eV per



These Plots of the CO₂⁺ Reading of the mass spectrometer versus desorption temperature have been interpreted as signifying that CO₂ had been adsorbed on the surface in the reaction O + CO → CO₂. The plot labeled "Laser Off" is that of a background reading that must be subtracted from the total-reading "Laser On" reading to obtain the net CO₂⁺-ion count from the superthermal reaction.

atom. After an exposure time of 135 minutes, the surface was retracted from the O-atom beam into the field of view of a quadrupole mass spectrometer. The reaction products were desorbed by heating the cold surface according to a defined temperature-vs.-time schedule (temperature-programmed

desorption). Desorbed molecules were ionized, then detected in the mass spectrometer. The temperature dependence of the CO₂ peak in the mass-spectrometer readout (see figure) indicated that large quantities of CO₂ were desorbed; this observation was taken to be evidence for the reaction O + CO(s) → CO₂(s).

Generalizing the method used in this study, it may be possible, for example, to make simple and more-complex amines, even amino acids by reacting ice mixtures of CH₄ and NH₃ with superthermal O and H beams. In general, by choice of atomic projectiles, kinetic energies, atomic quantum states, surfaces, and exposure times, it may be possible

to create new molecular species and stabilize them on the solid surfaces on which they were created.

This work was done by Brian Shortt, Ara Chutjian, and Otto Orient of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-41300

Nematic Cells for Digital Light Deflection

Smectic A (SmA) prisms can be made in a variety of shapes and are useful for visible spectrum and infrared beam steering.

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Smectic A (SmA) materials can be used in non-mechanical, digital beam deflectors (DBDs) as fillers for passive birefringent prisms based on decoupled pairs of electrically controlled, liquid crystalline polarization rotators, like twisted nematic (TN) cells and passive deflectors. DBDs are used in free-space

laser communications, optical fiber communications, optical switches, scanners, and *in-situ* wavefront correction.

Depending on the applied voltage, the TN cell rotates the polarization of incident light by $\pi/2$ (no field, OFF state) or leaves the polarization intact (when the applied electric field reorients the

liquid crystal molecules perpendicular to the plates of the cell, ON state). The decoupled pair of a rotator and a deflector has no moving parts, and can be cascaded into N stages, making 2^N addressable beam directions. This approach allows for the separation of time response and beam deflection angles, and

the optimization of these two parameters separately. A 0.5-ms response time of dual-frequency nematic 90° TN cells was achieved by implementing an overdriving scheme of electrical switching, where an electrical signal is a sequence of high-amplitude pulses (64 V RMS, at 2 kHz and 50 kHz) and holding voltages (6 V and 4 V RMS at 1 kHz and 50 kHz, respectively).

Deflection angles can be optimized by the design of the birefringent prisms. SmA-filled prisms are attractive in low-cost applications where one needs large apertures, large angles of deflection, and/or non-trivial geometries. Mixtures of homologues of 4,4'-*n*-dialkylazoxybenzene produce SmA phases with a broad temperature range of SmA existence (from 10–20 °C to 40–50 °C) with a relatively small number of residual defects, such as focal conic domains, and high transmission characteristics. In this innovation, the typical magnetic fields needed to remove director distortions around the mechanical inclusions and focal conic domains have been determined. For the SmA prism, the optical axis (and thus the preferred orientation of the SmA molecules) should be aligned along the edge of the wedge. In this geometry, the director field is uniform everywhere. A passive birefringent prism separates the beam into two channels, depending on the beam polariza-

tion. Inside the prism, the beam propagates as ordinary or extraordinary mode. As the ordinary and extraordinary refractive indices are different, the two modes of propagation through the prism result in a different angle of deflection.

The SmA prisms are easier and cheaper to form than solid birefringent crystals, such as yttrium vanadate (YVO₄) or calcite (CaCO₃). The optical axis of SmA prisms can be controlled by surface alignment. They can be prepared as relatively thick prisms (up to 7 mm) or as arrays of micropisms. Light scattering in SmA birefringent prisms can be reduced by proper alignment to levels that are significantly lower than light scattering at the director fluctuations in the nematic samples of the same thickness. As the light scattering is caused mostly by focal conic domains that have a fixed size, it becomes smaller with the increase of the wavelength of light; the infrared (IR) part of the spectrum is less sensitive to these losses. Thus, the SmA prisms are suitable candidates for beam steering not only in the visible part of the spectrum, but in the IR part as well. While SmA prisms can only be used in the temperature range of the SmA phase, it can be expanded significantly by using mixtures.

The TN cells are used to realize the fast switching of the linearly polarized light. The fast switching is achieved be-

cause the dual-frequency nematic is always driven by the operational voltage. To reorient the director along the field, operational voltage is applied at a frequency of 1 kHz. To reorient the director perpendicular to the field, the operational voltage is applied at the higher frequency of 50 kHz. The amplitude of the driving voltage determines the switching time between the states. In regular liquid crystal cells, the field is applied only to reorient the director in one state; the reverse transition is achieved by simply switching the field OFF; the director relaxation is slow in this case as the active reorienting bulk torque is absent. Finally, with their high birefringence, SmA prisms can be constructed in a variety of shapes, including single prisms and prismatic, blazed gratings of different angles and profiles.

This work was done by Oleg Pishnyak, Andrii Golovin, and Oleg Lavrentovich of Kent State University; Liubov Kremenska of Truman State University; Bruce Winker of Rockwell Scientific Company; and John Pouch and Felix Miranda of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18215-1.

Improved Silica Aerogel Composite Materials

Shrinkage and cracking are greatly reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A family of aerogel-matrix composite materials having thermal-stability and mechanical-integrity properties better than those of neat aerogels has been developed. Aerogels are known to be excellent thermal- and acoustic-insulation materials because of their molecular-scale porosity, but heretofore, the use of aerogels has been inhibited by two factors:

- Their brittleness makes processing and handling difficult.
- They shrink during production and shrink more when heated to high temperatures during use. The shrinkage and the consequent cracking make it difficult to use them to encapsulate objects in thermal-insulation materials.

A material in the present family consists of a silica aerogel matrix reinforced with silica fibers and silica powder. The density

of this composite material is typically only about 10 percent greater than the density of the corresponding neat aerogel. The underlying concept of aerogel-matrix composites is not new; the novelty of the present family of materials lies in formulations and processes that result in superior properties, which include (1) much less shrinkage during a supercritical-drying process employed in producing a typical aerogel, (2) much less shrinkage during exposure to high temperatures, and (3) as a result of the reduction in shrinkage, much less or even no cracking.

Synthesis of a composite aerogel of this type is based on a sol-gel process. The first step is to make a silica sol by refluxing and distilling a mixture of silicon alkoxide (tetramethyl ortho silicate, tetraethyl ortho silicate), a suitable sol-

vent (methanol, ethanol), water, and nitric acid. The resultant concentrated sol is then diluted with acetonitrile. The second step is to prepare a solution for casting the composite aerogel: Fumed silica (325-mesh powder having specific surface area of about 200 m²/g) and silica powder (particle sizes between 1 and 2 μm) are suspended in acetonitrile and then the silica sol, water, and ammonium hydroxide base are added to the acetonitrile/powder suspension. The amount of each component can be adjusted to suit a specific application. After thus preparing the aerogel-casting solution, a piece of silica fiber felt (destined to become the fiber reinforcement in the composite) is placed in a mold. Then the aerogel-casting solution is poured into the mold, where it perme-