SCIENCE NEWS of the week

Shine Dims on Protective Space Films

For three decades, researchers have coated ground-based and space-borne optical instruments — including the Hubble Space Telescope's primary and secondary mirrors — with magnesium fluoride, a compound that reduces unwanted reflections and acts as a barrier to oxidation. But a new laboratory study suggests that thin layers of magnesium fluoride might undergo significantly more long-term radiation damage in space than previously thought.

While NASA researchers maintain that the cumulative dose of radiation in the laboratory experiments would not occur until years after the expected 15-year lifetime of the well-shielded Hubble mirrors, optics experts say the new data may prompt them to reexamine the wisdom of routinely coating solar cells, mirrors and other spacecraft materials with magnesium fluoride.

Aluminum-coated mirrors designed to reflect optical and ultraviolet light carry a thin final coat of magnesium fluoride because this material acts like a transparent blanket. It prevents a light-absorbing film of aluminum oxide from forming on the mirror's surface, while allowing ultraviolet radiation to reach the aluminum unimpeded. After testing by researchers nearly two decades ago, "the coatings were taken for granted, they were considered history," says Robert A. Weller, a materials scientist at Vanderbilt University in Nashville, Tenn.

Questioning that assumption, he and Marcus H. Mendenhall undertook their own investigation under ultrahigh-vacuum conditions that emulated the space environment. The Vanderbilt researchers deposited a thin (170-angstrom) layer of magnesium fluoride onto a mirror-quality bed of beryllium and then bombarded the coating with medium-energy (150-kilo-electron-volt) helium ions.

The coatings sustained exposures of 10^{17} particles per square centimeter (a value that NASA researchers say far exceeds the dose an orbiting spacecraft would encounter over 15 years or so). The radiation stripped all but 20 percent of the fluorine from the thin film, leaving behind largely metallic magnesium. This dramatically reduced the system's ability to reflect light, the Vanderbilt scientists found. "The effect of this change on the reflectivity of the surface was catastrophic," they report in the Oct. 22 APPLIED PHYSICS LETTERS.

Weller speculates that several studies conducted during the late 1960s and 1970s by NASA and other groups may not have detected radiation damage because these studies took place in poorer vacuum conditions, which allowed a film of surface contaminants to build up on the coatings. Weller notes that these coatings showed contamination with an ultrathin (20- to 100-angstrom) layer of hydrocarbons, a phenomenon that dramatically alters the interaction between radiation and the magnesium fluoride surface, he says.

However, John F. Osantowski of NASA's Goddard Space Flight Center in Greenbelt, Md., who conducted some of the early tests, says he doubts the thin hydrocarbon layer could have masked or prevented radiation damage.

The studies he and Goddard colleague James B. Heaney conducted more than a decade ago used photons, electrons and protons — the predominant forms of radiation encountered in low-Earth orbits, such as Hubble's — to bombard the coatings. The Vanderbilt researchers, by contrast, relied on helium ions, which occur in only low concentrations in near-Earth space. The Vanderbilt work "is good, but I don't see how it's relevant to space," Heaney told SCIENCE NEWS. Mendenhall says he plans to include other types of radiation in further studies.

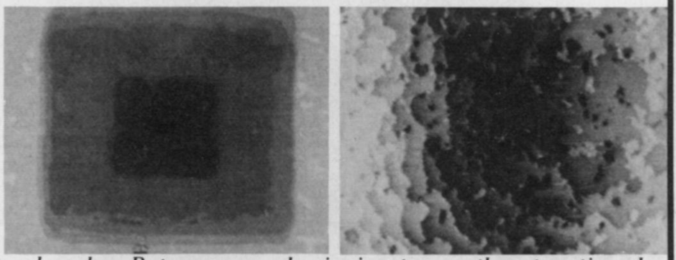
Osantowski also observes that magnesium fluoride has maintained an apparently strong track record in space: No such coating has yet been found significantly degraded, including any on the 12-year-old International Ultraviolet Explorer, he says. The NASA researcher notes that magnesium fluoride coatings exposed to natural radiation in space during 10 months of the five-year Long-Duration Exposure Facility (LDEF) mission (SN: 11/11/89, p.314) showed only minor degradation — consistent with micrometeorite and atmospheric contaminants but not with instrinsic radiation damage, he says.

But Terry M. Trumble of the Wright-Patterson Air Force Base in Dayton, Ohio, told SCIENCE NEWS that magnesium-fluoride coatings on LDEF's most oxygen-exposed edge — irradiated throughout the mission — appear to have suffered radiation damage. Thomas H. Allen, a physicist at Optical Coating Laboratory, Inc., in Santa Rosa, Calif., says his company will begin an optical analysis of the LDEF coatings this month to explore initial reports that radiation stripped fluoride atoms from the coatings' surface, an effect possibly similar to that seen by Mendenhall and Weller.

"What they [Mendenhall and Weller] did is not exactly what's going on in space," says Allen, "but it's close enough that it's forcing us to rethink our use of all space-borne fluoride coatings."

— R. Cowen

Digging ditches in molecular strata


Parkinson/JACS

Most researchers use the scanning tunneling microscope (STM) to probe molecular and atomic landscapes and to image materials at these smallest of structural scales. But some are beginning to use the atom-tipped instrument to sculpt or even rearrange the diminutive landscapes.

One recent afternoon, Bruce Parkinson of E.I duPont de Nemours & Co. in Wilmington, Del., used his STM to etch a three-tiered pit of squares (left) into a tin diselenide crystal — a stack of orderly molecular sheets, each separated by slightly more than 0.6 nanometers. A million of the inscribed micropits might fill a flattened sesame seed. Each side of the smallest and deepest square, lying six molecular sheets below the surface, measures 200 nanometers. The medium-sized tier, two sheets thick, has a square hole measuring 500 nanometers per side. The largest, uppermost tier includes three sheets and has a square hole 1,000 nanometers (1 micron) to a side. To date, the smallest pit Parkinson has etched measures 25 x 25 x 1.2 nanometers.

On another afternoon, he used his STM to etch the less orderly pit shown on the right. Parkinson suggests in the Oct. 10 JOURNAL OF THE AMERICAN CHEMICAL SOCIETY that this flaky topography might emerge from crystalline defects and impurities in the tin diselenide, which would enable underlying sheets to begin eroding before overlying layers have completely disappeared.

Because the STM tip itself rarely scratches the crystal surface, Parkinson says he suspects the etching process involves additional mechanisms, including heating and electrical field effects.