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Space Radiation Durability of Lithium Fluoride Thin Films

Lithium fluoride (LiF) is a good material for ultraviolet-transmitting windows and lenses that are typically a few millimeters (mm) thick. But these components are known to darken with exposure to space radiation (e.g. ultraviolet, electrons and protons). Recently I was asked whether LiF films ~ 1 micrometer (µm) thick would suffer similar darkening in space satellite applications.

In the case of protons, the only available data were from laboratory exposure of 3-millimeter-thick LiF crystals to protons simulating the expected dose to spectrograph optics on the Hubble Space Telescope [1]. After irradiation with protons of energy 85 MeV and 600 MeV, transmittance at wavelengths between 150 and 200 nanometers was reduced by 50-60% from its pre-irradiation value.

There were three possible outcomes to the thin-film darkening prediction:

1) If the lab protons went clear through the 3-mm test samples with little slowdown, the darkening would be uniform throughout. A 1-µm film probably would maintain its transparency in space.

2) If the lab protons stopped in the first micrometer of the test samples, a 1-µm film would also darken.

3) Something between 1) and 2). This could be handled with appropriate modeling.

Transmission of light through a material layer of thickness z follows a formula known as Beer's Law [2]:

$$T = \frac{I}{I_0} = e^{-\alpha z}$$

where I is the transmitted intensity, I_0 the incident intensity, and z the sample thickness. α is the absorption coefficient (zero for perfect transparency). Radiation exposure increases α by an amount roughly proportional to the amount of energy deposited per cubic centimeter of material.

To see if radiation damage in the 3-mm test samples was uniform throughout their thickness, I used the program SRIM (www.srim.org), to model the passage of 85 MeV and 600 MeV protons through 3 mm of LiF. Results showed that all protons went clear through with little deviation. The average energy transfer to the LiF by one proton, per millimeter of travel, was uniform to within ~ 4% throughout the test sample, and thus would be the same in a 1-µm film.

Beer's Law then predicts that the thin film's transmission loss due to proton irradiation would be approximately <u>0.1%</u>.

I also estimated thin-film darkening using published data on exposure of thick LiF samples to electrons and short-wavelength ultraviolet. These results are also promising.

Thus, LiF thin films are a possible candidate for space applications.

[1] C. S. Reft, J. Becher, and R. L. Kernell, *Proton-induced degradation of VUV transmission of LiF and MgF_2*, Applied Optics Vol. 19, No. 24, 4156-4158 (1980).

[2] Fox, Mark *Optical Properties of Solids*, page 3, Oxford University Press (2001).