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RADIATION DAMAGE OF MYLAR AND H-FILM

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Mylar* is frequently used in nuclear physics apparatus. In the Harvard cyclotron laboratory it is used for vacuum windows and as a container in liquid hydrogen cryostats. Its advantages are its strength and flexibility coupled with the low atomic weight of its constituents [its chemical formula is

$$(COC_6H_4COOCH_2CH_2O)_n].$$

However under severe irradiation it loses its strength and flexibility and so it is sometimes necessary to use metal foils instead. When Du Pont de Nemours and Company announced the production of a new plastic H-film [a polyamide, chemical composition

$$(C_{22}H_{10}N_2O_4)_n]$$

which was thought to be more radiation resistant, we decided to make some comparative tests.

$\frac{1}{4}''$ wide parallel sided specimens of 0.001″ thick Mylar and H-film were irradiated in the 160 MeV external proton beam of the Harvard synchrocyclotron. The Mylar weighed 3.34 mg/cm^2 and the H-film was 3.60 mg/cm^2. The beam was collimated to a $\frac{1}{2}''$ diameter and Polaroid film was exposed in it to determine the beam uniformity. Across the width of the specimen the beam was uniform to 20% but along the length there was a large variation. The proton beam was monitored by a Faraday cup and a calibrated electrometer. The dose was computed using an energy loss in the plastic from the dE/dx tables of Rich and Madey. (We used the value for lucite.) We give the dose in units of the absorbed energy in rad (1 rad = 100 erg/g).

The specimens were tested in an Instron Tensile Tester with a 5 kg load cell. The jaw separation used was 0.25″. A constant increase in strain of 0.1″ per min. i.e. 40% elongation per minute, was used. The dose to the Mylar between the jaws varied as much as a factor three. However there was a central portion $\frac{1}{8}''$ long where the dose was uniform. Since the specimen fails at its weakest point, as long as the plastic loses strength under irradiation the dose to this central area is the one we need to know. Unfortunately H-film gets stronger up to about 5×10^8 rad and therefore would tend to rupture at the least irradiated position. However we have always quoted the maximum dose. It is accurate to 15%.

The results are plotted in fig. 1. We give the ultimate tensile strength (i.e. the stress at failure) against the radiation dose. We have used as the ordinate the fraction of the unirradiated strength. The initial values were 23000 psi for both Mylar and H-film. The values for the unirradiated plastic were an average of six samples. The irradiated values are averages of three samples and the error bars indicate the difference between samples, not the error for an individual sample which is much less. As noted above, H-film becomes stronger up to doses of 5×10^8 rad; the samples with the lowest dose would rupture at the least irradiated position. Because of the three to one dose variation along the length of the sample it might be more meaningful if the first H-film point were moved from 1.9×10^8 to 6×10^7 rad.

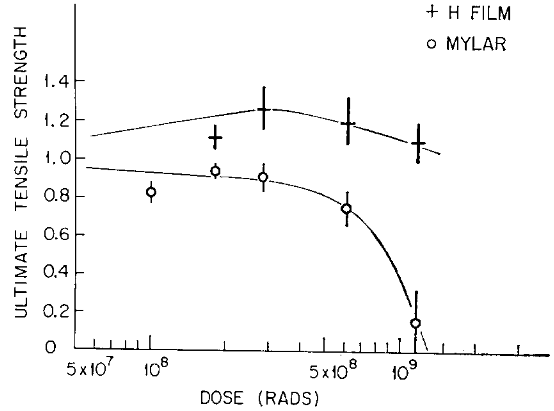

Fig. 1. Comparison of radiation damage to Mylar and H-film.

The samples were irradiated at a rate of 3.5×10^5 rad/minute, which is equivalent to a 160 MeV proton flux of 6.5×10^{10} proton/cm·sec. We thus conclude that at this rate, with the full beam in a focused spot, Mylar will fail before 3×10^3 minutes, i.e. 50 h. We normally try to avoid putting Mylar in such an intense region, but failures after a week or so are not infrequent. The irradiated H-film on the other hand was stronger than the unirradiated and we can conclude that it is at least 10 times less sensitive to radiation

* E. I. Du Pont de Nemours and Company, Inc.

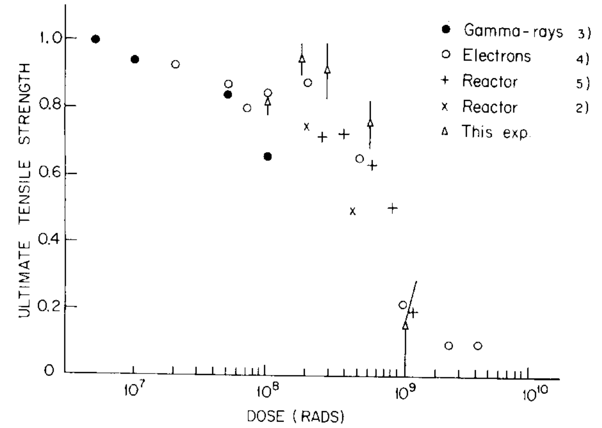

Fig. 2. Effects of different types of radiation on Mylar. The two sets of reactor data are different dose conversions of the same experimental data, (see text).

damage than Mylar. This is confirmed by gamma irradiation to 10^9 rad at Savannah River and an electron irradiation to 6×10^9 rad[1]). These irradiations showed that H-film is about 50 times less sensitive than Mylar.

The target cups in the liquid hydrogen cryostats used in this laboratory are made from H-film sheets glued with Epon 828 resin and V25 hardener (manufactured by the Shell Chemical Company). As Epon 828 weakens at an exposure of 8.5×10^8 rad[2]) we are now limited by the adhesive characteristics. Aromatic-type curing agents have recently been recommended[6]) as giving the best irradiation resistance.

We were also interested in a comparison of the proton irradiations with electron or gamma ray irradiations. Heavy particles such as protons or reactor fast neutrons can displace atoms in the plastic whilst low energy electrons interact mainly by ionizing or breaking the bonds of the molecules. In fig. 2 we have plotted our results with other similar studies on Mylar. The gamma irradiation[3]) was by Co^{60} γ rays on 0.003″ Mylar A. The electron irradiation[4]) was by electrons up to 1.2 MeV in energy on the skin of the Echo II balloon. This skin is made of 0.35 mil Mylar with 0.2 mil aluminum glued on either side. As the aluminum carried only 15% of the ultimate tensile strength in the unirradiated specimen, the damage measured is almost entirely that of the Mylar. The dose conversion factor we used was that 3.2×10^{15} electrons/cm^2 $= 10^8$ rad. The reactor irradiation[5]) was of 0.002″ Mylar in the ORNL graphite reactor. 70% of the dose is from fast neutrons, 30% from gamma radiation. They state that for materials of the composition $(CH_2)_n$ a calorimetric measurement of the energy absorbed gives 1.0×10^9 rep from an exposure of 1.0×10^{18} nvt. Of this is about 70% from fast neutrons, 30% from gamma rays Assuming that the fast neutron dose is proportional to the hydrogen content of the material we calculate that for Mylar the energy absorbed is 0.50×10^9 rad from an exposure of 1.0×10^{18} nvt. A report from the Radiation Effects Information Center[2]) analyzes the same information and uses a conversion factor such that a dose of 0.31×10^9 rad is absorbed from an exposure of 1.0×10^{18} nvt. We give both analyses in fig. 2. We conclude from a comparison of the electron and proton irradiations that heavy particles are neither more nor less efficient at causing radiation damage in Mylar. The reactor data are probably consistent with this. Our data are therefore useful to laboratories where damage from particles other than protons is the concern.

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