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GLASS AS A RADIATION DETECTOR (~10^9 rads)

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Glass plates have been developed as high exposure dosimeters. They can be utilized in measuring absorbed dose in the range about 10^9 and 10^{10} rads. The principle of operation is based on the relationship between the absorbed dose and the increased loss of mass from the glass surface when it is etched in a 6% HF solution from 5 to 50 minutes. The advantages of the technique are the low price of the dosimeter, reproducibility and possibility of working with a dose that saturates other dosimeters.

INTRODUCTION

In recent years a number of dosimeters for high dose measurements (Megarad region) have been developed. This is due mainly to the fact that ionizing radiations are used not only in physics research but also in medicine and food sterilization where high dose rates are necessary.

These dosimeters are based on optical density measurements as Perspex HX,[1] on the thermoluminescence phenomena as lithium fluoride[2] and on the chemical reactivity as polycarbonates[3] or glass plates.

In general, saturation effects are seen in these dosimeters at doses whose order of magnitude are 10^7 or 10^8 rads; among them, the detectors based on the chemical reactivity principle are the ones which support higher doses.

Pieces of glass have been used by several authors[4] for the detection of fission fragments which produce along their path a damage equivalent to 10^9 rads or more. After irradiation the pieces of glass are etched in hydrofluoric acid and the tracks produced by the fission fragments become visible in an optical microscope.

Due to this fact, we decided to investigate the behaviour of pieces of glass as a dosimeter, using the loss of weight to measure the amount of dose received.

The advantages of this detection technique are the low price of the detector, simplicity of the measurements, reproducibility and possibility of working in a region where other detectors present saturation effects.

2 EXPERIMENTAL TECHNIQUE

Glass plates with a fairly uniform thickness such as the ones used in photographic plates are cut in pieces of 2 cm x 1 cm x 0.1 cm and submitted to different radiation doses.

In the absence of a gamma source that could produce 10^9 rads or more, the radiation of a 2 MW reactor was used. The irradiation times varied from 2 to 72 hours and the reactor flux was monitored by metallic tantalum samples.

There are some difficulties in determining the reactor gamma doses, because the gamma spectrum is continuous up to energies of 3 MeV and not known with sufficient precision in order to determine the electronic equilibrium. Beside this fact, the neutrons produce reactions in any dosimeter that could be used and although these reactions have low cross section, they will produce disturbations on the dosimeter employed. Our interest in this experiment was to show the behaviour of the glass as a dosimeter and not to make absolute calibration so this was not considered a disturbing effect.

After irradiation the glass plates were cleaned and weighted before being etched in a 6% HF solution at room temperature for different times. All the samples were put in the hydrofluoric acid simultaneously in order to avoid any influence of temperature or acid concentration changing. We have observed that temperature variations of the order of 5°C around room temperature do not change the results.

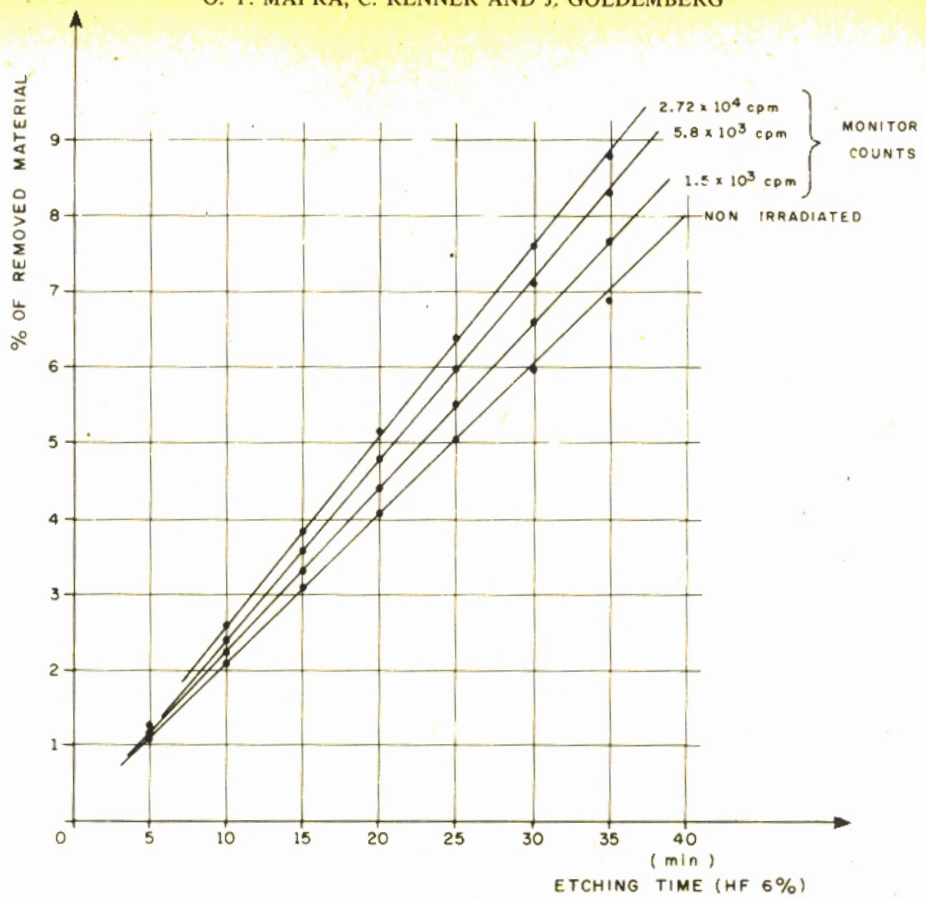

FIGURE 1 Average surface thickness removed from irradiated glass by etching for various times in a 6% HF solutic

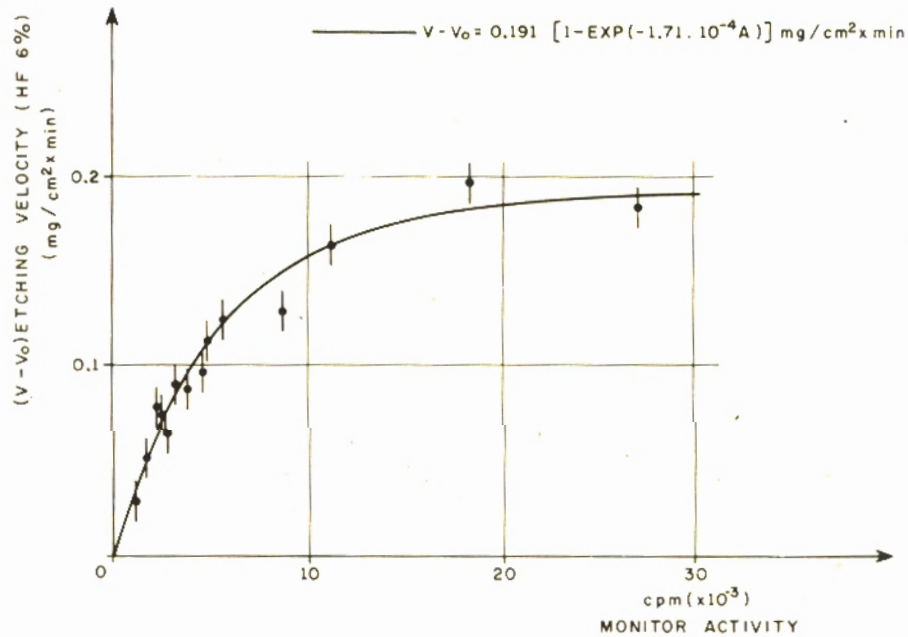

FIGURE 2 Etching velocity in glass etched by 6% HF for different monitor activities (proportional to dose).

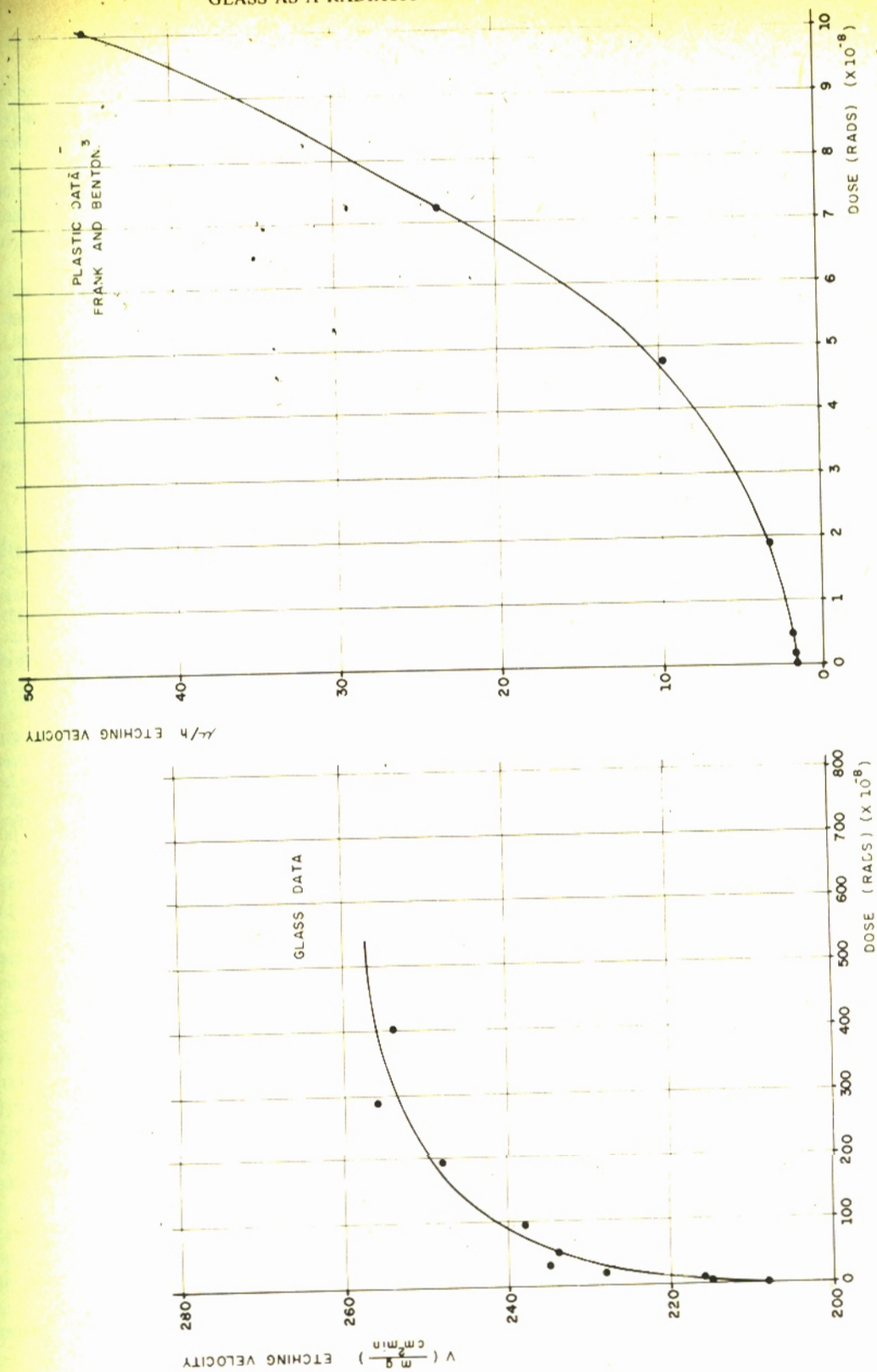

FIGURE 3 Etching velocities in glass and plastic for different absorbed dose.

After an etching time of 5 minutes the samples were washed, dried and weighted and then etched again for another 5 minutes. The process was repeated several times (10 or more); it was thus possible to obtain the loss of mass for any etching time.

Even without being irradiated the glass presents a loss of mass when etched by HF; for this reason some unirradiated samples were etched together with the irradiated ones giving the lower limit of the method sensibility.

In Figure 1 we can see the variation of loss of mass or thickness (in mg/cm^2) as a function of the etching time (in minutes). The different straight lines correspond to different doses obtained by different irradiation times. The angular coefficient of each straight line, which is the etching velocity (mg/cm^2/min) is seen in Figure 2 as a function of irradiation time (doses). The solid curve was the best adjustment to the experimental data and in the region described is given by the equation

$$v - v_0 = 0.191\ [1 - \exp(-1.71 \times 10^{-4} A)]$$

The etching velocity v_0 for unirradiated glass is 0.648 mg/cm^2/min, and A is the monitor activity proportional to the irradiation time or doses.

Even knowing the difficulties in measuring the gamma ray intensity at the irradiation position, some measurements were performed to give the order of magnitude of the dose. These measurements were made using calibrated Perspex HX[1] and lithium fluoride dosimeters; the result was approximately 2×10^8 rads/h. It is known that this dose is not accurate because both dosimeters employed present variations when irradiated in a gamma field where neutrons are also present.

In Figure 3 we can see a comparison of our data with the results of Frank *et al.*[3] who has used plastic dosimeters based on the same chemical reactivity principle.

The etching speed in the plastic has a behaviour of the form $v = v_0 e^{Kx}$. It can be used as a good discriminator between ionizing ions as carbon, nitrogen, oxygen and has been extensively used in this way.[5]

The glass supports higher doses and has a much higher threshold. So it can be used to discriminate between two types of radiation when the ionization produced by one of them is outside the sensibility interval. It is the case of, fission fragments which produce a damage equivalent to 10^9 rads along the track, detected in the presence of gamma fields of 10^7 rads.

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