national accelerator laboratory

TM-183
1100

THE EFFECT OF RADIATION ON ELECTRICAL INSULATING MATERIALS*

Miguel Awschalom and Thomas Borak

August 8, 1969

Attached is an abstract of a study conducted by the Radiation Effects Information Center. Notice the weakness of teflon compared to the strength of polystyrene, phenolics, and aromatic cured epoxies against damage by nuclear radiation Lucite (polymethyl methacrylate is more resistant to damage than teflon, but not as resistant as polystyrene).

Figures 1 and 2 give "ballpark" information. Further details are available on file at the Radiation Physics Section.

---

*C. L. Hanks, D. J. Hamman, REIC Report No. 46, Battelle Memorial Institute, Columbus, Ohio.

Operated by Universities Research Association Inc. Under Contract with the United States Atomic Energy Commission

Radiation damage to dielectric and insulating materials is a function of temperature and atomospheric conditions as well as the radiation environment. Many materials are more resistant to radiation in the absence of oxygen or moisture and at lower temperatures. Because of this influence of environmental conditions it is impractical to attempt to compile detailed information that would be directly applicable to all circuit requirements and environmental conditions. The fabrication method used by the manufacturer can also be a factor in the amount of damage that occurs from radiation.

Organic Materials

Both temporary and permanent changes occur in the characteristics of organic insulating and dielectric materials as a result of exposure to a radiation environment. Enhancement of the electrical conductivity is the most important of the temporary effects with increases of several orders of magnitude being observed. The conductivity increases exponentially in response to ionizing radiation until it reaches equilibrium at a value that is determined by the rate of exposure and ambient temperature for a specific material. Following the termination of the irradiation the induced conductivity gradually decreases.

Other temporary effects, in addition to the enhanced conductivity, are a reduction in breakdown and flashover voltages, increases in a-c loss characteristics, and variations in dielectric constants. These changes in electrical characteristics, however, are often not large enough to prevent the use of the insulators in a radiation environment, particularly if allowances are made to minimize their effect on the circuits performance.

Permanent effects of radiation on organic insulating materials are normally associated with chemical changes, the most important of which are molecular scission and cross-linkage. The latter leads to hardening and embrittlement; increased strength, density, and melting point; and a decrease in solubility. Chain scission produces almost the opposite change in physical characteristics including decreases in hardness, tensile strength and melting point, and greater solubility. This physical degradation in the advanced stages is disastrous in that the insulating material breaks, crumbles, or powders thus losing structural integrity and causing failure. Changes in dissipation factor and insulation resistance have also occurred as permanent effects, but they are normally quite small and offer few problems except in the most uncommon applications.

A comparison of the relative radiation resistance of organic insulating materials to permanent effects is presented in Figure 1.

Gas evolution, a secondary reaction that occurs when organic insulators are irradiated, is also a problem because of pressure buildup in confined enclosures. Some of these gas species are corrosive and can be detrimental to electrical contacts, etc., especially in sealed parts such as miniature relays.

Inorganic Materials

In general, the inorganic insulating or dielectric materials are more resistant to radiation damage than the organics. Atomic displacement is responsible for permanent damage in the inorganic insulators and is manifested by changes in density, strength, and electrical properties. The density of crystalline insulators decreases while that of amorphous insulators increases from exposure to fast neutrons. The predominant effect on electrical properties is a change in resistivity. A comparison of the relative radiation resistance of inorganic insulators to permanent damage is presented in Figure 2.

Inorganics experience a strong photoconductive effect from the energy of incident radiation which is absorbed through ionization and electronic excitation. Transient changes of several orders of magnitude are normally tolerable, however, because of the high resistivity of inorganic insulators.

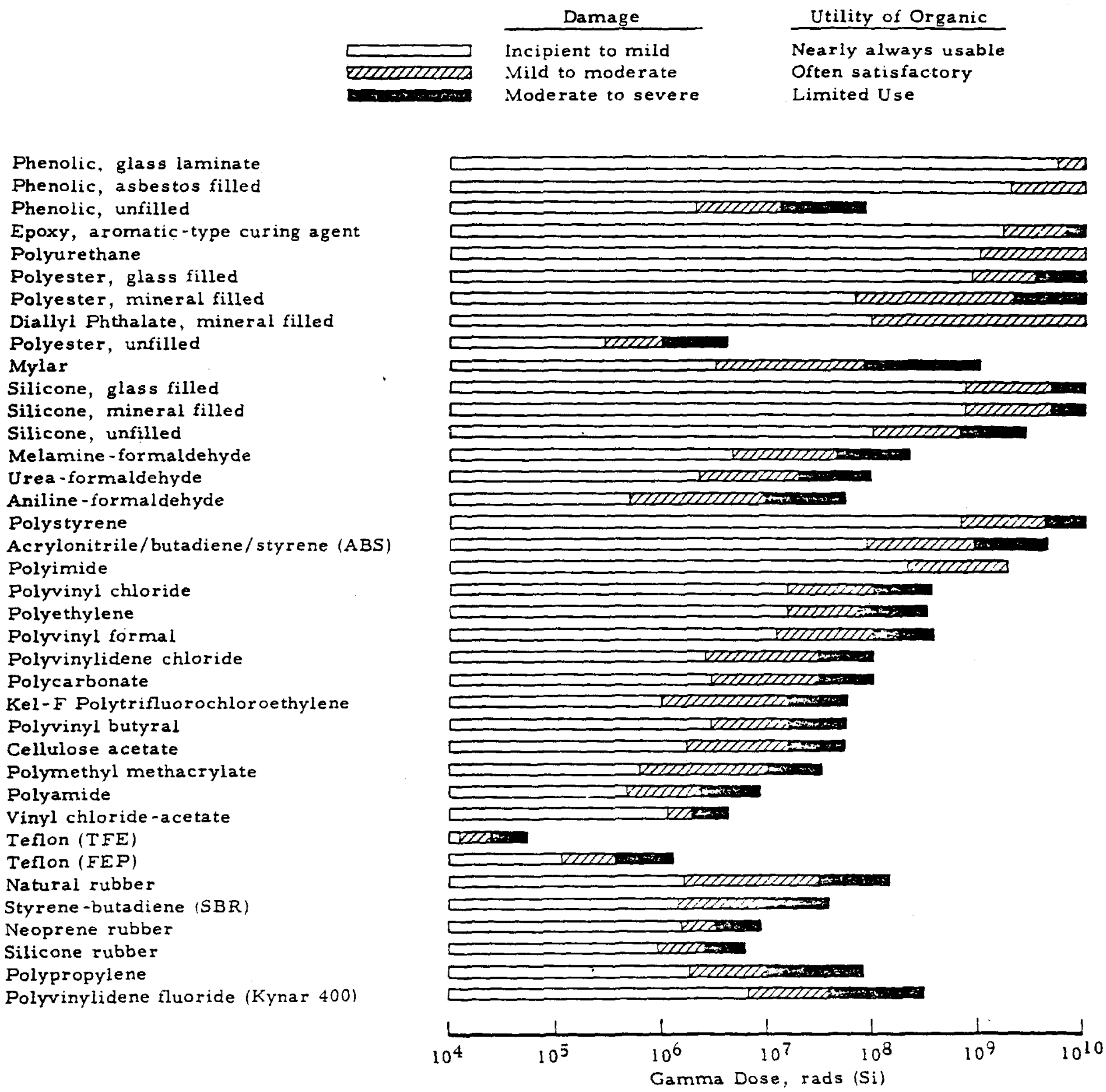

FIGURE 1. RELATIVE RADIATION RESISTANCE OF ORGANIC INSULATING MATERIALS

Based upon changes in physical properties.

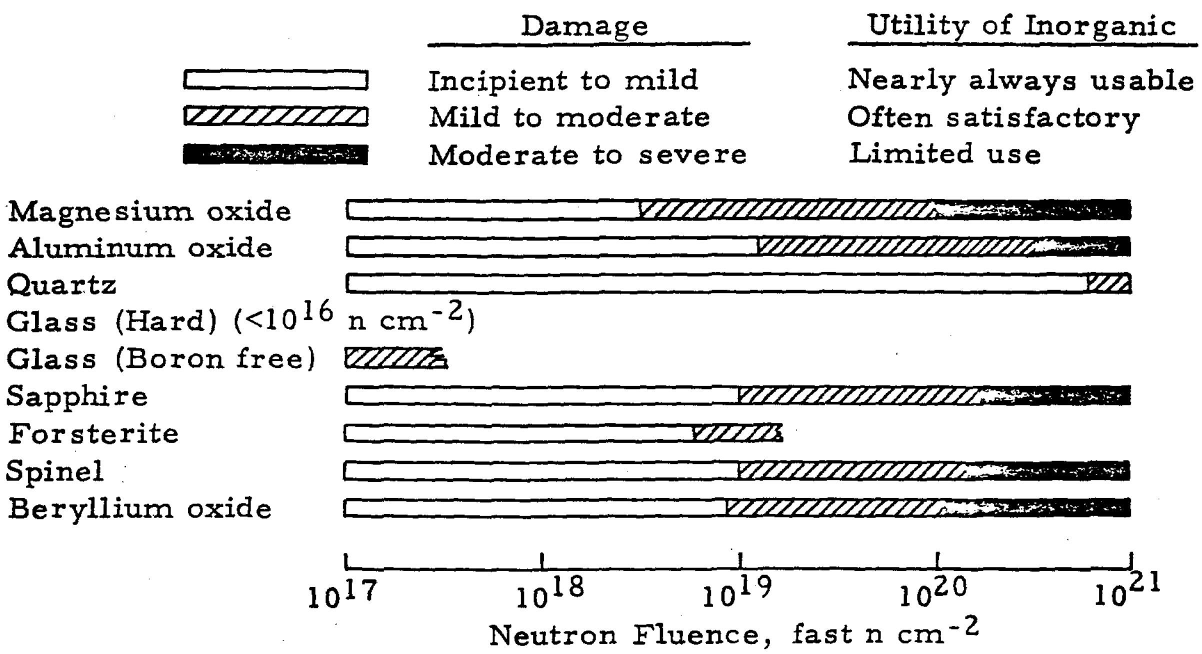

FIGURE 2. RELATIVE RADIATION RESISTANCE* OF INORGANIC INSULATING MATERIALS. BASED UPON CHANGES IN PHYSICAL PROPERTIES

*Varies greatly with temperature.