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ULTRASONIC ATTENUATION IN GAMMA IRRADIATED VITREOUS SILICA

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Abstract - Longitudinal ultrasonic attenuation measurements in four types of gamma irradiated vitreous silicas have been carried out for frequencies between 30 and 90 MHz over the temperature range from 1 to 300 K. The magnitude and temperature dependence of the low- and high-temperature ultrasonic relaxations characteristic of glasses were found to be independent of the degree of room temperature gamma irradiation to a dose of 10 MRads. The results indicate that the low activation energy dielectric center created by gamma rays in impure silicas is not acoustically active.

I - INTRODUCTION

On the basis of production processes fused silica is commercially available in four types. Table I lists some of the reasonably well defined characteristics of the different silica glasses /1,2/ which make them useful for comparative studies of their properties. Dielectric measurements in fused silicas /2,3/ have established that the magnitude of the low frequency dielectric losses is sensitive to metallic and polar impurities. Type I and to some extent Type II fused silicas show a 240K relaxation which is unnoticeable in Types III and IV, whereas high-OH content silicas show a He-temperature loss whose magnitude increases with OH-content. In addition, all types of fused silica show a 40K relaxation which appears to be only weakly influenced by the overall impurity content. Upon irradiation with gamma rays no dielectric loss changes are observed in either Type III or Type IV silicas. However, for Infrasil samples the 240K relaxation is destroyed by gamma irradiation and a lower activation energy relaxation is created in the region around the 40K relaxation /2/. This radiation response suggested a specific model for the origin of the high temperature and the gamma-ray induced relaxations in Types I and II fused silicas /2/. On the other hand, it is known that the same thermally activated relaxation process is responsible for the acoustic and dielectric losses in silica glasses around 40K. Thus, it can be reasonably expected that ultrasonic attenuation measurements in the four types of fused silica may provide meaningful

results to compare with their dielectric behavior under gamma irradiation.

TABLE I. - Characteristics of commercially available fused silicas^(a)

	Type I	Type II	Type III	Type IV
Production process	Electric Fusion	Flame Fusion	Flame hydrolysis	Plasma oxidation
Starting material	Natural or re-fined quartz	Selected natural or re-fined rock quartz	SiCl ₄ , etc., vapor	SiCl ₄ , etc., vapor
Purity	≈Rock quartz 50-100 ppm impurities	>Rock quartz	Extremely high 50 ppm Cl	Extremely high 200 ppm Cl
Water content (wt.%)	0.001	0.015-0.04	0.08-0.14	0.001
Samples used in this work	Infrasil	Ultrasil Homosil	Suprasil	Suprasil W

(a) After Ref. /2/.

II - EXPERIMENTS AND DISCUSSION

The attenuation of longitudinal ultrasonic waves of the as-received samples /4/ was measured from 1 to 300K by conventional pulse-echo techniques in the frequency range from 30 to 90 MHz. PVF₂ transducers bonded with No-Naq grease were used in all experiments. The samples were surrounded by either liquid or gaseous Helium and their temperature determined by calibrated Ge-thermometers. Since the same transducer bonding agent was used throughout a wide temperature range phase effects limit the accuracy of the attenuation magnitude to about 15%.

The acoustic properties of Suprasil before and after gamma irradiation have been reported in the literature /5/ thus, the present experiments are limited to samples of Infrasil, Ultrasil, Homosil and Suprasil W. The attenuation of the irradiated samples was measured after each irradiation at room temperature in a Co-60 source to a maximum dose of 10 MRads. The observed (optical) radiation hardness of the four types of silica was found to increase with purity as previously reported /6/. We observed however, that our samples of Type II silica did not colored homogeneously: a circular sector in the periphery of the rods of Ultrasil and all but a globular zone tangent to the periphery of the Homosil rods remained almost colorless up to the maximum gamma dose.

The ultrasonic attenuation of the as-received samples as a function of temperature for 60 MHz is shown in Fig. 1 after subtracting the attenuation at 1.3 K. Similar curves were obtained at 30 and 90 MHz except that their amplitudes scale roughly linearly with frequency. As has been observed for other transport properties of amorphous silica and in contrast to the low frequency dielectric losses, the ultrasonic attenuation curves have the same shape and nearly the same magnitude for the different types of fused silica studied in this work.

It was found that room temperature gamma irradiation of the samples to a dose of 10 MRads did not produce any discernible change in the ultrasonic attenuation or its temperature dependence (Fig. 2). This is a known fact for high purity silicas (Types III and IV) but it is somewhat surprising for the less pure ones (Types I and II) in view of the reported radiation induced excess dielectric loss which is

quite noticeable at temperatures as low as 20K. Since our measurements included one Type I and two Type II silicas it may be concluded that the new gamma-ray induced dielectric center in silica with metallic impurities does not couple to longitudinal sound waves.

Fig. 1 - Attenuation of longitudinal waves in as-received samples of fused silica.

Fig. 2 - Attenuation of longitudinal waves in gamma irradiated fused silica.

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