Surface polaritons in amorphous bodies

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Many present studies are devoted to the surfaces of solids. In particular, investigations were made of surface phonons in crystals and of plasmons in metals and semiconductors.[1] So far, however, despite the numerous investigations of surface states, no surface polaritons (SP) have been observed in disordered systems although the phenomenological theory[2] does not exclude in principle the existence of SP in such compounds. We report here an attempt to observe SP in bodies in which there is no long-range order.

The measurements were performed in p-polarized light at room temperature by the method of attenuated total internal reflection (ATIR)[3] with a DS-403G spectrophotometer with an NPVO-1 attachment and a semicylindrical KRS-5 prism. The gaps d were fixed with the aid of liners.

Quartz was chosen for investigation because it exists in both the crystalline and in the amorphous state. We registered two bands in the ATIR spectrum of fused quartz (Fig. 1, curves 1 and 1′). The figure shows also, for comparison, the SP spectra of crystalline quartz (curves 2 and 2′) at an orientation that excludes the effect of the optical anisotropy. It is seen from the figure that in the case of fused quartz the minima of the bands occur at the same frequencies as the minima of the corresponding SP bands of α quartz. It should be noted that in the ATIR spectrum of fused quartz the band 1′ is asymmetrical on the high-frequency side, where a doublet component is distinctly resolved in crystalline quartz. In addition, the bands 1 and 1′ in fused quartz become broader: $2\Delta\gamma_1 = 15$ cm^{-1} and $2\Delta\gamma_1' = 28$ cm^{-1} (as against $2\Delta\gamma_2 = 6$ cm^{-1} and $2\Delta\gamma_2' = 10$ or 11 cm^{-1} in crystalline quartz). We propose that the changes in the shapes and half-widths of the bands are due to disorders in the structure of the fused quartz. However, to ascertain that the observed bands correspond to surface polaritons, it is necessary to carry out a more detailed study of the observed oscillations.

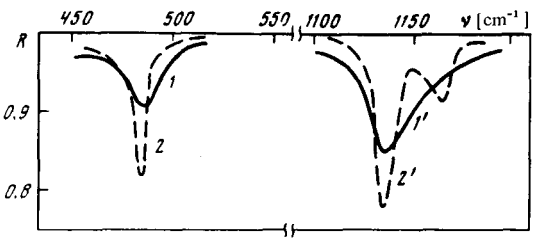

FIG. 1. ATIR spectra at $\phi = 34°30'$: 1, 1′—for fused quartz ($d = 6$ μ, $d' = 2$ μ); 2, 2′—for crystalline α quartz ($d = 6$ μ, $d' = 2$ μ).

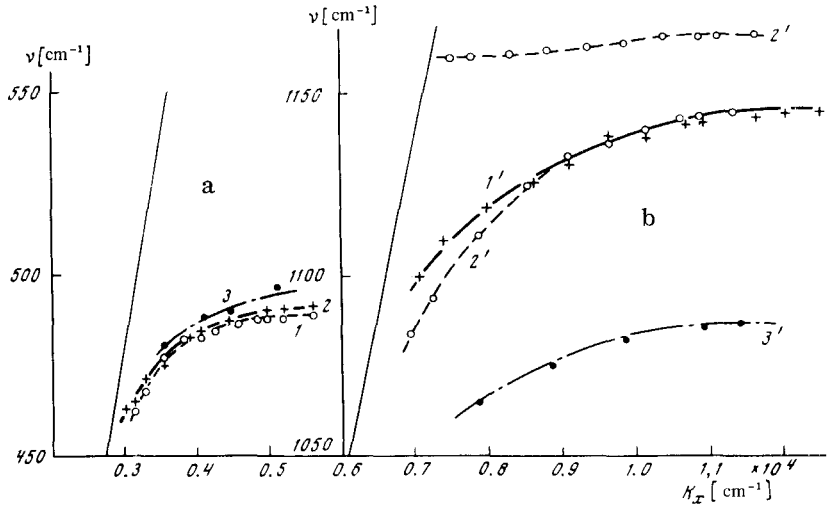

FIG. 2(a,b). Dispersion curves: +—fused quartz (1, 1′), ○—crystalline α quartz (2, 2′), ●—glass (3, 3′).

Figure 2 shows plots of the frequencies in the ATIR spectra as functions of the projection of the wave vector K_x for fused quartz (curves 1 and 1′) and α quartz (curves 2 and 2′). The values of K_x were calculated in accordance with the formula

$$K_x = \frac{\omega}{c}\sqrt{\epsilon}\sin\phi\,,$$

where ϕ is the angle of incidence of the light in the prism, ϵ is the dielectric constant of the prism material, and $\omega = 2\pi\nu_c$. At low frequencies, Fig. 2(a), the dispersion of the oscillations in the fused quartz coincides with the dispersion of the SP in crystalline quartz. An analysis of the curves of Fig. 2(b) shows that the dispersion curves of fused quartz (1′) coincide with the dispersion curves of crystalline quartz (2′) at the large K_x and differ somewhat in the initial sections.

To check that the regularities observed in fused quartz are general for the amorphous state, the measurements were performed also on silicate glass. Indeed, it has turned out (see Fig. 3) that, under the same photography conditions, the ATIR spectrum of glass reveals also broad bands with $\nu_3 = 480$ cm^{-1} and $\nu_3' = 1082$ cm^{-1} (half widths $2\Delta\gamma_3 = 120$ cm^{-1} and $2\Delta\gamma_3' = 115$ cm^{-1}). The dispersion curves observed for these bands were of the same type as for quartz (Fig. 2, curves 3 and 3′).

Thus, the observed oscillations in fused quartz and in glass have the following properties: the oscillations are p-polarized and radiative smearing of the bands is observed as $d \to 0$ (at zero gap), with dispersion of the frequencies in the region of the total reflection. According to[4], these are properties of surface polaritons. Consequently, the observed minima in the ATIR spectra of fused quartz and glass correspond to surface polaritons. This circumstance un-

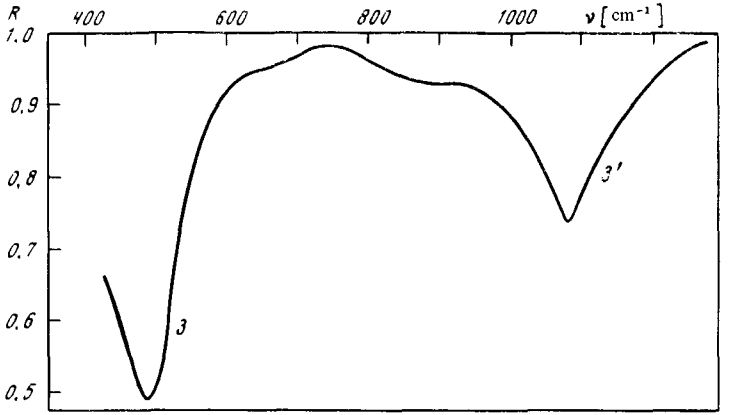

FIG. 3. ATIR spectrum of glass at $\phi = 34°30'$ and $d = 2\ \mu$.

covers new possibilities of using the ATIR method to study the properties of the surfaces of solids in which translational symmetry is violated.

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