Effect of ion implantation on reflection and on surface polaritons of crystal quartz

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The spectra of reflection and of surface polaritons of α-quartz irradiated by 100- and 200-keV nitrogen ions were obtained. It is shown that the calculations using the basic models of the damaged layer are inconsistent with the observed variations of the spectra.

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The variation of the structure (and properties) of different materials as a result of ion implantation at present attracts a large interest. Such structures, for example, are

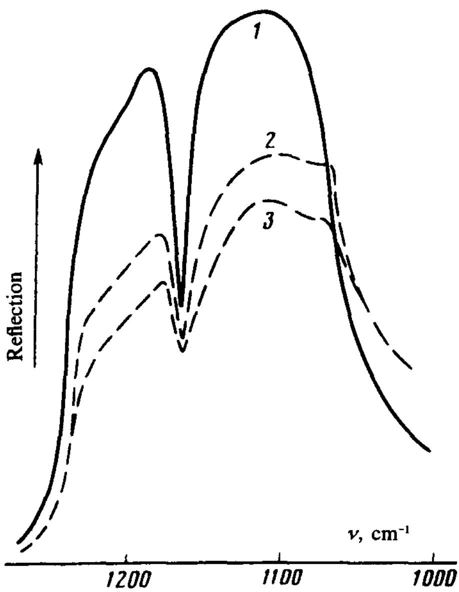

FIG. 1. Variation of the reflection spectrum of crystal quartz (1) as a result of ion implantation with 100-keV (2) and 200-keV (3) nitrogen ions.

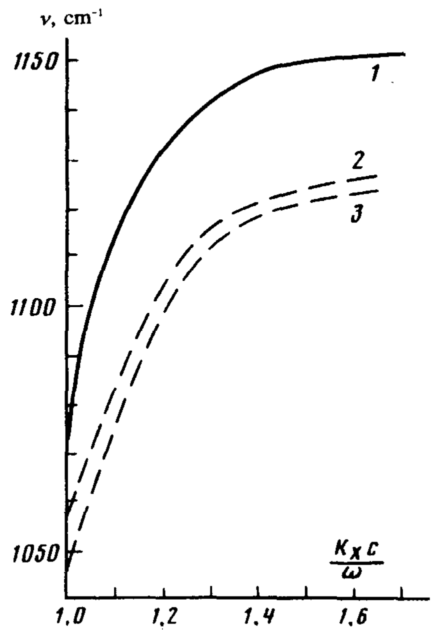

FIG. 2. Variation of the dispersion of the surface polaritons of crystal quartz (1) as a result of ion implantation with 100-keV (2) and 200-keV (3) nitrogen ions.

used as waveguides in integral optics.[1] These systems can be investigated by using the method of infrared spectroscopy, which makes it possible to obtain data on the variation of the spectrum of optical oscillations by modifying the surface. As a result, we can study the spectrum of external reflection in the region of the "residual-ray" bands and the spectra of the surface optical oscillations (surface polaritons),[2] which, because of exponential decrease of their amplitude with increasing distance from the surface, are highly sensitive to the presence of the thin film on the surface. Since the oscillation frequency in the damaged surface layer of the crystal is shifted very slightly, a resonance of the surface polariton of the substrate with film oscillations is likely to occur. The high sensitivity of this method, which was substantiated theoretically in Refs. 2 and 3, was demonstrated in Ref. 4.

Since this situation is expected to occur as a result of ion implantation, we investigated the spectra of reflection and of the surface polaritons of crystal α-quartz whose surface was treated by positively charged 100- and 200-keV nitrogen ions with a density of 10^{15} cm^{-2}. The depth of the damaged layer was $\sim$0.25 and $\sim$0.5 μm, respectively. We used two $15\times15\times3$-mm^3 quartz plates, which were cut out parallel to the optic axis. An area of 10×10 mm^2 on one side of the plate was irradiated with ions while the other side was used for comparison.

An IRS-16 infrared spectrophotometer with an IRA-22 reflector attachment and an attachment for disrupted total internal reflection DTIR-1 was used to record the spectra. The DTIR method was used to investigate the spectra of surface polaritons, since the inhomogneous electromagnetic wave near the "total reflecting prism-air" boundary can excite the surface polariton in the crystal, which is situated a short distance from the boundary. The wave vector of the excitation obtained in this way is determined by the angle of incidence of the light in the prism and the frequency is determined by the optical properties of the crystal and the film on its surface. A detailed description of the DTIR method for excitation of the surface polaritons is given in Refs. 2 and 4 and in their bibliographies.

Figure 1 shows the variation of the reflection spectrum for the high-frequency band of the "residual rays" (the light is polarized perpendicularly to the optic axis) as a result of irradiation by 100- and 200-keV ions. The reflection decreases with increase of the depth of the damaged layer.

The calculation of the reflection spectrum of the system "α-quartz (optical constants were taken from Ref. 5)-film 0.25 and 0.5 μm in thickness" with different optical constants corresponding to different models of the surface layer (including different silicon oxides) showed that the variation of the reflection such as that in Fig. 1 can be obtained by using several models, i.e., the information obtained from the reflection spectrum is insufficient for selecting a single model of a damaged layer.

The spectra of surface polaritons obtained by the DTIR method yield additional information on the system under investigation. Figure 2 shows the experimentally obtained dispersion of the surface polariton (dependence of the frequency on the wave vector) for the original sample and for two, ion-treated samples.

The calculation of the spectra of the DTIR systems described above is inconsistent with the experiment. The systems, which can produce the observed variation of reflection, do not produce a shift of the dispersion curves and a change in the width as observed in the experiment. The line widths in the spectra of the surface polaritons are $\sim$40 cm^{-1}; the lines in the spectra of surface polaritons of fused quartz have such a width, but their dispersion is different.[6] Other models, which can describe the properties of the damaged layer and which are compatible with the reflection and with DTIR, should be developed.

Thus, as a result of ion implantation of α-quartz, we observed a marked change in the reflection spectrum in the region of the high-frequency band of the residual rays and in the spectra of surface polaritons. Although the obtained results have not yet been fully explained, it was shown that the variation of the reflection and of the spectra of surface polaritons must be taken into account in the selection of the model of a damaged layer (as was done by Zhizhin *et al.*[7] for metallic films in quartz).

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