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ABSORPTION OF INFRARED LIGHT ON THE SURFACE OF A SILICON CARBIDE SINGLE CRYSTAL

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It is known that ionic crystals of finite dimensions have surface mode of optical oscillations [1 - 3].

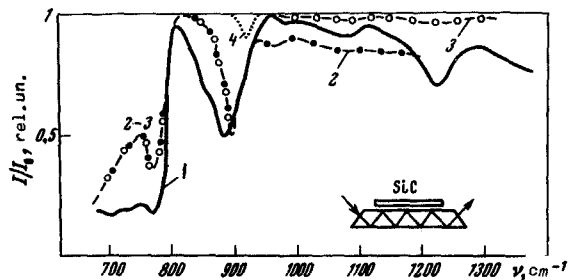
If the crystal dimensions exceed the IR wavelength of that region of the spectrum, then radiative modes of the phonon frequencies of the microcrystals appear in the absorption. These phonons were observed in [4] on β -SiC whisker microcrystals. Thin plates and semi-infinite crystals are characterized by surface nonradiative modes, which do not appear in ordinary absorption and reflection spectra.

Nonradiative surface polaritons in optical spectra were first investigated in NaCl [5] and GaP [6] using a total-internal-reflection method.

In the present study we investigated the absorption of IR light on SiC surfaces by the method of multiple internal reflection (MIR) method. Silicon carbide crystals have a covalent bond between atoms, the fraction of the ionic bond in them is 12%, but the optical volume phonons appear sufficiently clearly in the reflection spectra [7].

The MIR spectra were measured in p-polarized light with an IKS-12 spectrometer with IMEIK-1 attachment in the wave-number range 700 - 1300 cm^{-1} . The presence of a trapezoidal MIR element of gallium arsenide on the surface of the silicon-carbide sample (see the figure) makes the nonradiative surface modes optically active. The influence of interference effects was eliminated in the experiment.

In the investigated frequency region, the IR light causes optical oscillations of the SiC lattice, and also oscillations of the Si-O bonds in the silicon carbide itself and in the oxide film on its surface. We investigated the natural growth surfaces of the crystals β -SiC and α -SiC(6H), and also the surfaces obtained after etching the crystals in HF acid, which removed the oxide from the silicon carbide surface. The figure shows the multiple-reflection spectra for the cubic (curve 1) and hexagonal (curve 2) modifications of silicon carbide.



Spectra of multiple internal reflection of natural silicon-carbide surface: curves 1 and 2 - β -SiC and α -SiC(6H) before etching in HF, 3 - α -SiC(6H) after etching, 4 - β -SiC after etching and $d_3 = 2 - 4 \mu$. $T = 300^\circ\text{K}$, I/I_0 is the ratio of the intensities of the IR light passing through the MIR element with the sample (I) and without it (I_0).

IR absorption appears at frequencies close to 795, 900, 1060 - 1080, and 1150 - 1300 cm^{-1} . The spectrum region near 795 cm^{-1} has been well investigated for its absorption and reflection spectra [7] and characterizes the frequency of the transverse optical phonon. The absorption spectra at 1060 - 1080 and 1150 - 1300 cm^{-1} are typical of fused quartz and are apparently due to light absorption by the amorphous SiO_2 film, the thickness of which is estimated at 60 - 80 Å. Indeed, treatment of the SiC samples with HF decreases the absorption in these bands (curve 3). The removal of the amorphous oxide film ($d_f \leq 5 \text{ Å}$) is evidenced by electron-diffraction data obtained with glancing incidence of the electron beam.

Particularly intense in the MIR spectrum is the 840 - 950 cm^{-1} absorption band, observed only

in p-polarized light. This band is missing from the ordinary reflection spectrum at E C. For the extraordinary ray at E C, weak bands were observed in [8] in the reflection spectra at the frequencies 885 cm^{-1} for $\alpha\text{-SiC}(6\text{H})$ and 858 cm^{-1} for $\alpha\text{-SiC}(15\text{R})$, and were attributed by the authors to the presence of an active axial optical phonon.

In our case, the $840 - 950\text{ cm}^{-1}$ band is observed in the cubic $\beta\text{-SiC}$ (see the figure), in which there are no volume modes connected with the anisotropy of the crystal. The band lies between the transverse and longitudinal optical phonons, where the dielectric constant $\epsilon(\nu)$ is negative, this being a necessary condition for the existence of surface phonons. In this region, the IR light penetrates less than $1 - 2$ microns into the crystal.

The surface nature of the band is favored also by the dependence of its position and of its half-width on the gap d_3 between the sample and the MIR element. The maximum absorption is observed at $d_3 \sim 0.6 - 0.8\text{ }\mu$, which is due in our case to the non-ideal optical contact. Improvement of the contact decreases this peak. When the $\beta\text{-SiC}$ sample is located $2 - 4\text{ }\mu$ away from the prism, an absorption peak is observed at a frequency $\nu_s = 936\text{ cm}^{-1}$, which does not change in the indicated range) and with a half-width $6 - 8\text{ cm}^{-1}$ (curve 4 in the figure).

The appreciable width of the $840 - 950\text{ cm}^{-1}$ band is due apparently to radiative broadening in the presence of a small gap. The value of the limiting frequency of the nonradiative phonons at $\nu_s = 951\text{ cm}^{-1}$ was obtained with the aid of the dispersion relations for the surface optical oscillations [1 - 5] and the expression for the dielectric constant without allowance for the damping. When the IR light passes through the MIR element at an angle $\phi_s = 45^\circ$, the theoretical value of ν_s is 945 cm^{-1} (the refractive index of the prism is $n = 3.3$), in good agreement with the experimental $\nu_s = 936\text{ cm}^{-1}$. This verifies the surface nature of the observed band.

We used in the calculations the data of [9] for the static and high-frequency dielectric constants, $\epsilon_0 = 9.72$ and $\epsilon_\infty = 6.52$, with $\nu_{\text{TO}} = 796\text{ cm}^{-1}$.

Certain differences between the calculated and experimental values of ν_s for $\phi_s = 45^\circ$ may be due to failure to take the damping into account in the $\epsilon(\nu)$ dependence.

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SELF CONSISTENT FIELD METHOD IN THE THEORY OF PARAMETRIC MAGNON EXCITATION

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The Hamiltonian of the spin system of a ferromagnet placed in a high-frequency magnetic field parallel to a chosen axis has the following form in the spin-wave approximation:

$$\mathcal{H} = \sum_k \epsilon_k a_k^+ a_k + \frac{1}{2} \sum_k (V_k a_k a_{-k} e^{i\omega t} + V_k^* a_k^+ a_{-k}^+ e^{-i\omega t}) + \mathcal{H}_{int} \quad (1)$$

$$\epsilon_k = \sqrt{A_k^2 - |B_k|^2}, \quad V_k = \frac{\mu h}{2\epsilon_k} B_k,$$