IR surface polariton spectroscopy as a method for studying the optical properties of ultra thin films

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Abstract. Experimental results of investigation of optical properties of MgO thin films (thickness 10, 30, 100 и 300 nm) and AlN films (thickness 40 и 400 nm) on sapphire substrate are discussed. The optical phonon frequencies of these films are located in frequency region of surface polariton of sapphire. Due to the resonance between them the splitting and the shift of absorption spectra of sapphire surface polariton appear. From these experimental data it is possible to reconstruct all constants of the permittivity of both the film and substrate, the film thickness, and to specify its structure.

To use thin semiconductor films in a variety of applications, including optoelectronics, need to know their physical properties. In most cases the film properties are very different from the properties of bulk materials from which they are made. To study the physical (optical) properties of ultrafine (nanometer) films still no spectrometers required photometric accuracy. In some cases, to determine the physical parameters of nanofilms useful surface polariton spectroscopy.

Surface polaritons (SP) are nonradiative electromagnetic excitations at the interface of two media, propagating along the interface, if the dielectric constant of the contacting materials have different signs [1-4]. Electromagnetic field of SP focuses directly from the media interface, and decreases exponentially with distance from the interface (near field), so that the SP is very sensitive to the characteristics of the interface. If the frequency of the optical phonons of the film lies in the region of existence of SP substrate, then, by the resonance between them, there is a splitting of the bands and a shift of the absorption spectra of SP substrate. From these experimental data can be restored all constant permittivity and the thickness of the film, and thus to characterize the film properties. The resulting gap in this dispersion curves of SP substrate is proportional to the square root of the thickness of the film that allows you to measure the thickness of very thin films [1, 5-9]. The report discusses the experimental results on the optical properties of the films of MgO (thickness 10, 30, 100 and 300 nm) [5, 7, 9] and films of AlN (thickness of 40 nm and 400 nm) on sapphire [6-9]. SP spectra were measured in attenuated total internal reflection

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mode (ATR) on the FT-IR spectrometer IFS66v (Bruker), and range of external (in the far field) reflection at angles close to normal incidence. The external reflection spectra of MgO film thickness of 10 nm and 30 are not visible, and the spectra of the film thickness of 100 nm and 300 nm appear only at low frequencies (near 400 cm^{-1}) due to resonance TO phonon of the film with low frequency TO phonon sapphire. By measuring the ATR spectra of film on sapphire at different angles of incidence of light in the prism ATR can restore dispersion SP sapphire with the film. MgO film radically changes the spectrum of sapphire SP due to the resonance of sapphire SP with an optical phonon of MgO film. This interaction leads to splitting of the high branches of SP sapphire near the frequency of 700 cm^{-1}. From the angular dependence of the reflectance spectra in ATR mode dispersion of SP sapphire with the film was reconstructed. It was compared with a dispersion of SP, calculated using the parameters of the dielectric constants of sapphire (found from the analysis of variance external reflection spectra) in the fitting parameters of the dielectric constant of the film, which determines the best agreement between the calculated variance of SP with experimental frequency-angular spectrum. Fig. 1 shows the dispersion curves of SP 10 nm MgO film on sapphire, which the spectra of the far-field was not visible at all.

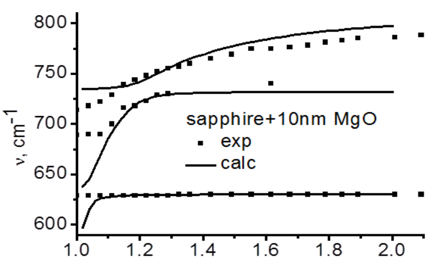

Fig. 1. The dispersion of surface polaritons of "MgO film 10 nm thick on sapphire." The solid curves are calculated using the optical constants of bulk MgO [5], and sapphire.

Surprisingly, studies have shown that the optical constants of MgO film thickness of 10 and 300 nm were very close to those of bulk MgO crystals, in contrast to the film thickness of 30 and 100 nm.

Thus, the example of MgO films on sapphire shows that due to the resonance of SP sapphire substrate with optical phonons even very thin (nm) film, it is possible to restore the dispersion curves of the surface polaritons.

As a result, the calculated dispersion curves fit to the experimental, varying the dielectric constant of the film permeability, it can be determined not only all these constants, but also to receive information about modifying the optical constants of the substrate material on the nanometer thickness [5-9].

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