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Substrate surface polariton splitting due to thin zinc oxide and aluminum nitride films presence

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ABSTRACT

Surface polariton (SP) is the non-radiative interface electromagnetic mode, propagating along the interface between two media, if one of them is absorbing (metal, semiconductor or dielectric with the strong absorption bands) and exponentially decaying out of the interface. The introduction of a transition layer at this interface results in the shift and broadening of SP. This effect can be used to obtain film parameters (thickness and optical constants) in the region of SP existence. Zinc oxide (ZnO) films (100–300 nm thick) have been prepared on the LiF and CaF_2 substrates and aluminum nitride films (40 and 400 nm thick) have been prepared on sapphire substrates. The SP spectra have been measured by attenuated total reflection (ATR) technique. IFS66v (BRUKER) infrared Fourier-transform spectrometer was used for ATR and near normal incidence external reflection spectral measurements. Angular dependencies of the absorption bands positions in the ATR spectra give the dispersion of SP. The measured SP dispersion is compared with one calculated using the film parameters obtained by dispersion analysis of the external reflectivity spectra. The splitting of the dispersion curves of substrate SP was found. It is due to the resonance interaction of substrate SP with the film optical phonons. This splitting is proportional to the square root of the film thickness. For ZnO films on CaF_2 "long range" SPs were observed. These effects allow estimate film complex dielectric function in the region under consideration.

1. Introduction

Zinc oxide (ZnO) thin films and nanowires have received increasing research focus last years due to their interesting applications properties. ZnO is a promising material for photonic devices in ultraviolet to blue wavelength range. The excitonic-stimulated emission and optically pumped laser action in high-quality ZnO films and nano-wires [1,2] have just been observed at room temperature. As a versatile material with excellent properties, it is also highly useful in various applications such as catalysts, solar cells, sensors, photovoltaic and surface acoustic wave devices. Aluminum nitride (AlN) is also very interesting for similar applications.

One of the promising techniques of the surface, interface and thin film characterization is the surface polariton spectroscopy [3,4]. Surface polariton (SP) is the non-radiative electromagnetic mode, propagating along the interface between two media, if one of them is strongly absorbing. SP electromagnetic field decays exponentially out of the interface. The introduction of a transition layer at this interface results in the shift and broadening of SP. This effect depends on the film and the substrate parameters (optical constants and film thickness) in the region of SP existence and can be used to obtain them. We have used SP spectroscopy to characterize ZnO and AlN thin films.

2. Experiment

ZnO films (100 and 300 nm thickness) on the LiF and CaF_2 substrates have been prepared by using the radio frequency magnetron sputtering system (A500 Edwards) with a power of 200 W. Two wurtzite AlN epilayers were grown on sapphire substrates by using the Veeco Gen II molecular beam epitaxy system with subsequent etching of one of them in alkali and acid solutions to remove back side metal coating. More details of the 40 nm and 400 nm thick AlN films preparation on sapphire can be seen in [5].

The attenuated total reflection (ATR) measurements in Otto configuration [3] and the measurements of external reflectivity have been done using IFS66v (BRUKER) infrared Fourier-transform spectrometer. The reflectivity unit (IPO-22, LOMO) was used for the external reflectivity spectra at near normal incidence. The ATR unit (NPVO-1, LOMO) with KRS-5 prism was used for various angles of incidence (20–60° in the prism) in p-polarized light to study transverse magnetic SP. Grid polarizer on KRS-5 substrate was used. The spectral resolution was $2\,cm^{-1}$. The gap between the prism and the sample (varying from a few microns to dozens microns) was

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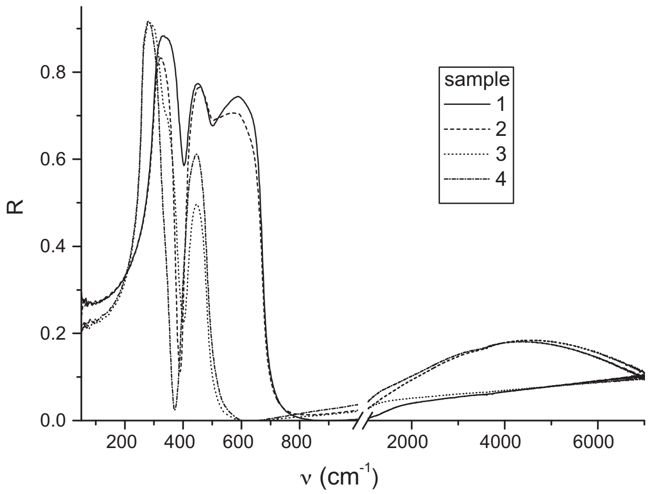

Fig. 1. Reflectivity spectra of the ZnO samples under study.

Table 1
Parameters for the calculation of the ZnO film dielectric function ε.

Sample	1	2	3	4
Substrate	LiF	CaF_2	LiF	CaF_2
d, nm	102	104	303	287
ε_{oo}	3.9	2.3	3.7	3.3
ν_{TO}, cm^{-1}	406.5	407	408.5	409.7
Δ	3.41	2.6	4	4.23
ν_{LO}, cm^{-1}	557	594	589	618
Width, cm^{-1}	44	40	33	26

adjusted by the mylar strips or by the dust particles in the gap to optimize the SP excitation.

3. Results and discussion

The ZnO films external reflectivity s-polarized spectra measured at near normal incidence are presented in Fig. 1. In the high frequency region the interference maxima are clearly seen for thicker samples (2 and 4). It allows estimate the film optical thickness. For thinner samples (1 and 3) the corresponding maxima are out of the measured spectral region. In the low frequency

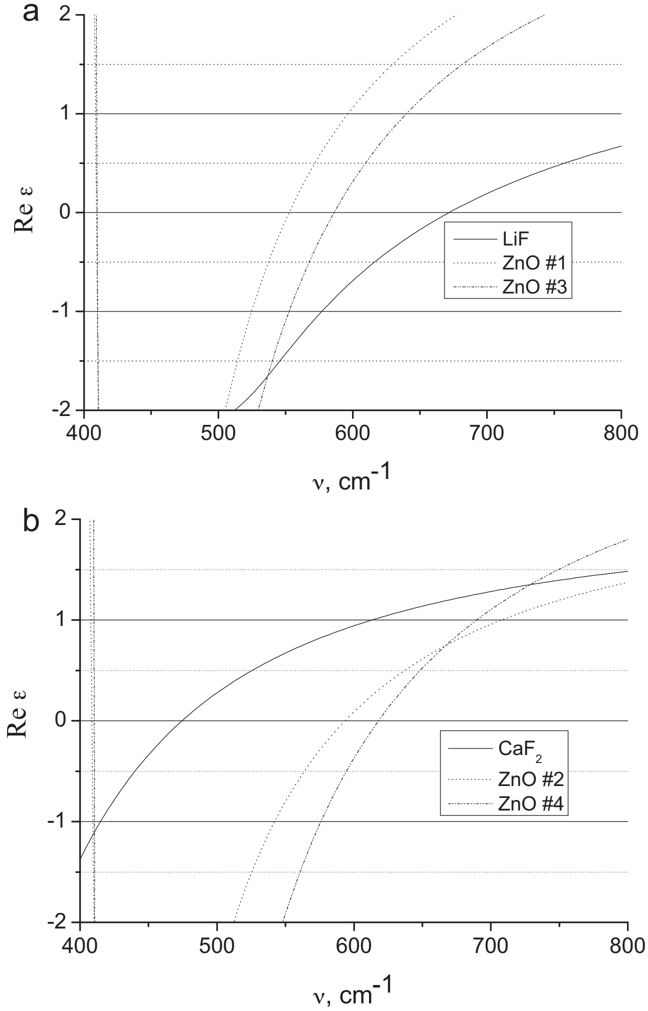

Fig. 2. Frequency dependencies of the real parts of film and substrate dielectric functions for ZnO films on LiF (a) and CaF_2 (b) substrates.

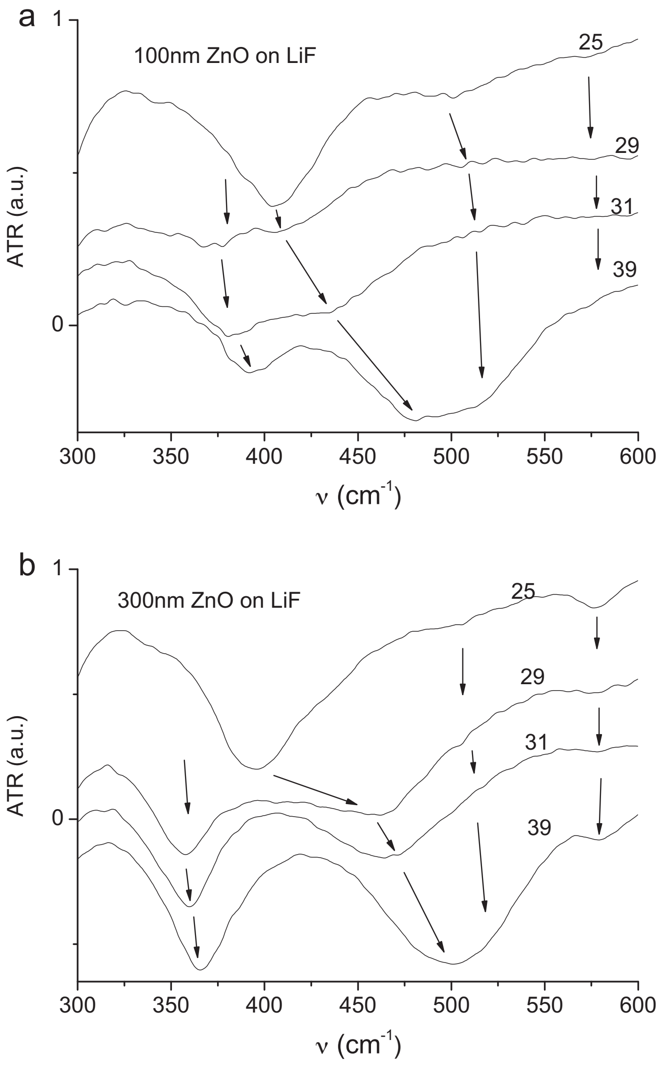

Fig. 3. ATR spectra of 100 nm (a) and 300 nm (b) thick ZnO films on LiF. The angles of the incidence in the prim are shown near spectra. The arrows indicate the minima positions shift (SP bands). Y-scale is shown for the angle 25°. Other curves are shifted down along y-axis to avoid their overlapping.