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Artificial birefringence introduced by porosity in GaP

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Abstract
Porosity-induced birefringence in a GaP membrane is studied using a method based on the analysis of beats in unpolarized and polarized transmittance spectra as well as in angular dependence of optical spectra. Birefringence as high as $n_e - n_o = 0.25$ was measured in a porous GaP membrane with the degree of porosity close to 40%. The measured values of n_e and n_o are compared with those calculated in the frame of effective medium theory for a GaP membrane with appropriate morphology.

1. Introduction

Over the past few years, increasing attention has been paid to porous GaP layers due to their strongly enhanced photoresponse, ability to support Fröhlich-type surface vibrations and enhanced nonlinear optical properties [1–4]. GaP is considered as prospective material for manufacturing photonic crystals for the visible spectral range [5, 6]. It is well known that III–V compounds possess second-order nonlinear optical coefficients several orders of magnitude higher than those of KDP, ADP and other materials used in frequency upconversion. However, the utilization of large nonlinear susceptibilities of III–V compounds has not been possible due to high dispersion and lack of birefringence necessary for phase matching [7, 8]. Electrochemistry proved to be a powerful tool for introducing the necessary optical anisotropy in Si [9]. In Si the pores grow predominantly in the [1 0 0] crystallographic directions. Therefore, the porous layers prepared on (1 0 0) substrates are optically isotropic at normal incidence and exhibit birefringence at oblique incidence. On the other hand, the mesoporous silicon layers prepared on low-symmetry (2 1 1) or (1 1 0) surfaces show strong birefringence at normal incidence, since the optical axis is located in the surface plane [10–12].

Anodization of (1 1 1)-oriented GaP substrates results in the formation of an array of pores stretching perpendicularly to the initial surface [2]. In this paper, we present results of a study of birefringence in porous GaP layers prepared on (1 1 1)-oriented substrates. Unpolarized and polarized optical transmittance spectra as well as angular dependence of optical spectra are analysed.

2. Experimental details

Free-standing membranes of porous GaP were fabricated by anodic etching of (1 1 1)-oriented wafers cut from *n*-GaP:Te Czochralski grown ingots. The free carrier concentration in as-grown samples was $n = 10^{18}$ cm^{-3} at 300 K. The anodic etching was carried out in H_2SO_4 aqueous electrolyte as described elsewhere [2]. A configuration with four electrodes was used: a Pt reference electrode in the electrolyte, a Pt sense electrode on the sample, a Pt counter electrode and a Pt working electrode. The electrodes were connected to a specially designed potentiostat/galvanostat. All the equipment used in the experiments were computer controlled. The morphology of the porous layers was analysed with a scanning electron microscope (SEM). SEM image taken from a porous GaP membrane is illustrated in figure 1. One can see that the transverse size of pores is between 50 and 100 nm.

The optical transmittance spectra were measured using a MDR-2 spectrometer equipped with a halogen lamp and a FEU-62 photomultiplier. The spectral resolution was better than 0.5 nm.

3. Results and discussion

Figure 2(*a*) shows the unpolarized transmittance spectrum of an 8 μm thick porous GaP layer measured at normal incidence.

