Optical characterization of anisotropic porous silicon structures

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1. Introduction

Porous silicon has attracted a great deal of attention because it makes it possible to produce a new generation of both active and passive optoelectronic devices [1]. This material can be obtained by HF electrochemical etching of silicon, which generates a range of refractive indices by changing the current density during anodization process. The thickness is determined by the time for which the current is applied [2]. It has excellent mechanical and thermal properties and is obviously compatible with silicon-based microelectronics. The anisotropy of Porous silicon has been reported in the literature [3] therefore in order to perform a good characterization of this kind of structures, an anisotropic numerical method must to be employed.

In this work we characterize by the transfer matrix method (TMM) [4] the dimensions and dispersion properties of two anisotropic porous silicon structures. From a previous analysis of the dimensions by mean of scanning electron microscopy (SEM) we fit these dimensions comparing the reflectance obtained by a Fourier transform infrared spectroscopy (FTIR) and the reflectance simulated by the TMM.

2. Results and discussion

The two structures analyzed in this work are composed by the stacking of two kinds of monolayers. The ordinary and extraordinary refraction index of these monolayers has been obtained by spectroscopic ellipsometry. The reflectance data has been obtained at an incident angle of 12º for the wavelength range of 1-4 μm at 5 nm intervals. The dispersive refractive index of the silicon substrate is obtained from [5].

The first structure is composed of two different layers, A and B. Table 1 summarizes the dimensions and refractive indexes obtained with SEM and ellipsometry and adjusted by TMM. Fig. 1 shows the three spectra, the experimental spectrum (square marker), the spectrum simulated by TMM considering the previous dimensions (doted line) and the spectrum obtained by fitting the dimensions and dispersion (solid line). As it can be seen, a good adjustment can be obtained and only one of the features of the spectra is not matching with the experimental and simulated spectrum. The mismatch between the dimensions estimated by SEM and those estimated by fitting are 2,42% for the A layer and 6,20% for the B layer.

The second structure is composed of four layers, where the stacking is BABA. Table 2 summarizes the dimensions and refractive indexes obtained with SEM and ellipsometry and fitted by TMM. Fig. 2 shows the three spectra, the experimental spectrum (square marker), the spectrum simulated by TMM considering the previous dimensions (doted line) and the spectrum obtained by fitting the dimensions and dispersion (solid line). As can be seen, again a good agreement between experimental and simulated spectrum is obtained. The differences between the dimensions obtained by SEM and our simulation are 3,42% for the first layer, 1,05% for the second layer, 4,95% for the third layer, and 8,84% for the fourth layer.

References

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4. Acknowledgements

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Figures and tables

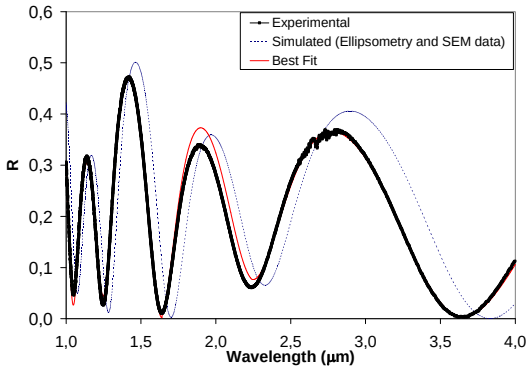

Figure 1. Experimental (square marker), simulated considering previous data (doted line) and TMM fitting (solid line) reflectance for structure 1.

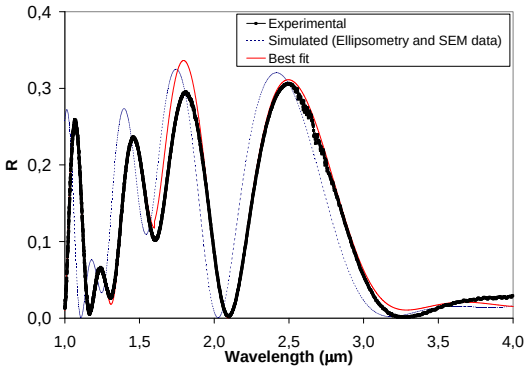

Figure 2. Experimental (square marker), simulated considering previous data (doted line) and TMM fitting (solid line) reflectance for structure 2.

	Wavelength (μm)	A			B		
		n_o	n_e	d (μm)	n_o	n_e	d (μm)
Previous	1-4	1,41	1,55	0,62	1,83	2,02	1,29
TMM fitting	1-1,64	1,41	1,55		1,83	2,02	
	1,64-2,24	1,41	1,55	0,635	1,8	2	1,21
	2,24-4	1,4	1,53		1,79	1,98	

Table 1. Refraction index and length of the structure 1.

	Wavelength (μm)	B			A			B			A		
		n_o	n_e	d (μm)	n_o	n_e	d (μm)	n_o	n_e	d(μm)	n_o	n_e	d (μm)
Previous	1-4	1,83	2,02	1,29	1,41	1,55	0,62	1,83	2,02	1,29	1,41	1,55	0,62
TMM fitting	1-1,3	1,84	2,02		1,41	1,55		1,84	2,02		1,41	1,55	
	1,3-1,6	1,83	2,02	0,725	1,41	1,55	0,385	1,83	2,02	0,785	1,41	1,55	0,48
	1,6-4	1,79	1,98		1,4	1,53		1,79	1,98		1,4	1,53	

Table 2. Refraction index and length of the structure 2.