

FEASIBILITY OF AN OPTICAL BIOSENSOR BASED ON POROUS SILICON

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ABSTRACT: Porous Silicon thin films, obtained by p-type silicon, have been used for developing an optical interferometric biosensor. Its surface has been modified using a bromine oxidation to prepare porous silicon for DNA attachment. Optical characterization has been made either for as prepared samples and for oxidized ones. Modelling shows that large reflectance variations can be expected when such a treated PS surface is exposed to even small quantities of DNA.

Keywords: Porous Silicon, Biosensor

INTRODUCTION

Porous Silicon (PS) is obtained by an electrochemical etching of a silicon substrate. This material consists of a network of silicon nanocrystallites. Since the discovery of its strong room temperature visible photoluminescence (PL) PS has stimulated considerable interest

in view of its possible use in silicon based optoelectronics. In addition the high surface to volume ratio (even $500 \text{ m}^2/\text{cm}^3$) and the compatibility of the PS fabrication process with the usual silicon technology make this material a very interesting candidate in sensor field. Particularly, its surface is very reactive to various gases and liquids and then can be used as a good "active" layer. Recently, thin films of PS have been used as an optical interferometric transducer for detecting small molecules, short DNA oligonucleotides and proteins. In Fig. 1 the change in effective optical thickness in a DNA modified porous silicon layer as a function of DNA concentration, measured by Harper et al [1] is reported.

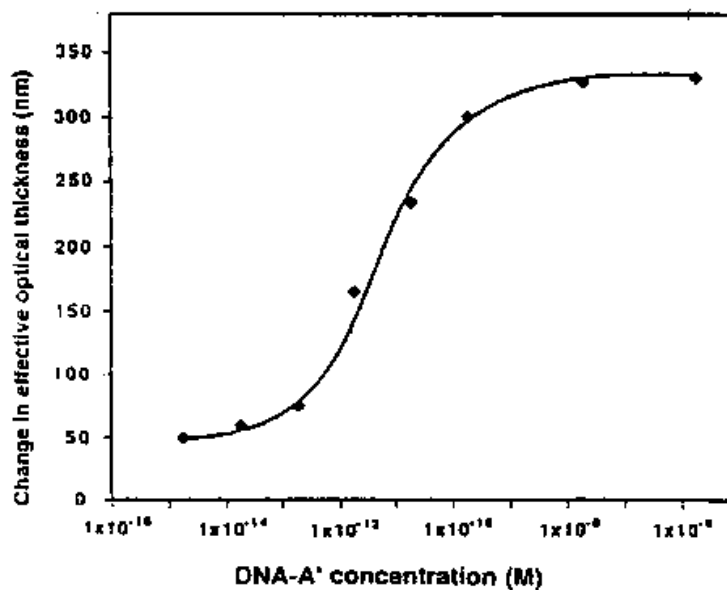


Figure 1 Change in effective optical thickness in DNA modified PS layer as a function of DNA-A' (cDNA sequence). The sensor is responsive to femtomolar DNA concentrations.

In this work we present results obtained using thin films of PS as an optical interferometric biosensor. In order to prepare PS for DNA

attachment we have modified its surface using Br oxidation in liquid phase and we have reported optical changes after this treatment.

EXPERIMENTAL

Samples (about 300 nm in thickness) have been fabricated electrochemically starting from 0.1 Ω cm p-type CZ silicon wafers, in a solution HF:IPA=1:1 with a current density 1 mA/cm². After formation, PS has been rinsed in isopropyl alcohol and optically characterized. PL measurements have been carried out using as excitation source the 442 nm line of a HeCd laser. Incident power on the sample was always 1 mW/cm². A monochromator blazed at 500 nm and a charge coupled device (CCD) detector have been used to collect the PL spectra. In addition, interferometric reflectance measurements have been carried out by a spectrophotometer. The typical p-type morphology resulting by the above process is shown in Fig. 2.

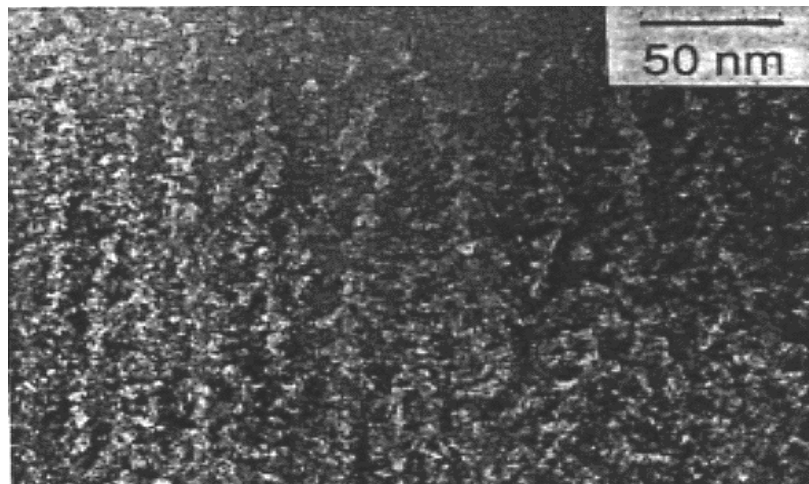


Figure 2: p+- type porous silicon XTEM [2]

RESULTS

In Fig. 3 the measured PS interference fringes are reported.

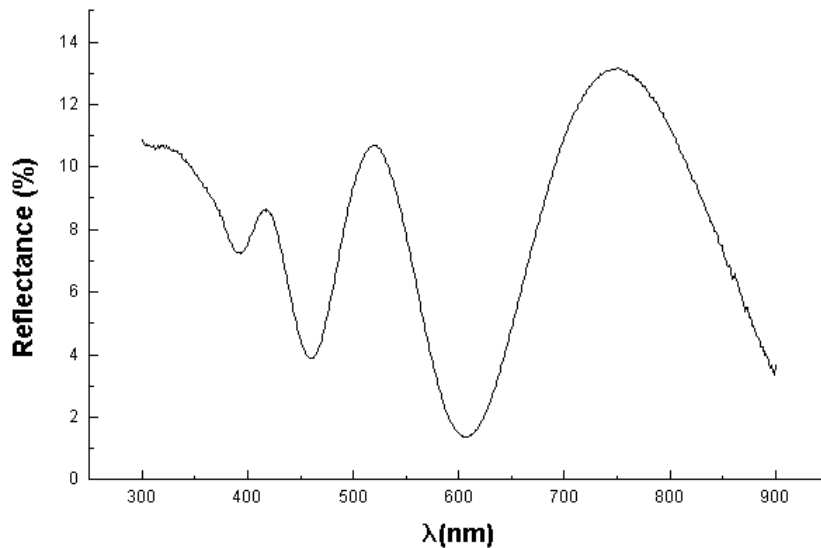


Figure 3: as prepared PS reflectance

For modelling data we have considered reflectance as due to two porous silicon layers of different porosities on silicon substrate. For each layer refractive index has been calculated using an effective medium approximation:

$$n = n_s * (1-p) + n_a * p \quad (1)$$

where n_s is the silicon complex index, p is the porosity and n_a is air refractive index. In Fig. 4 the reflectance expected relative variation is reported as a function of wavelength, for a 2% variation of the refractive index. Modelling shows that reflectance strongly depends on the changes of the refractive index itself, due to interactions of the

molecular species (such as oligonucleotides, biotin or antibodies) with PS surface producing a wavelength shift in the fringe pattern.

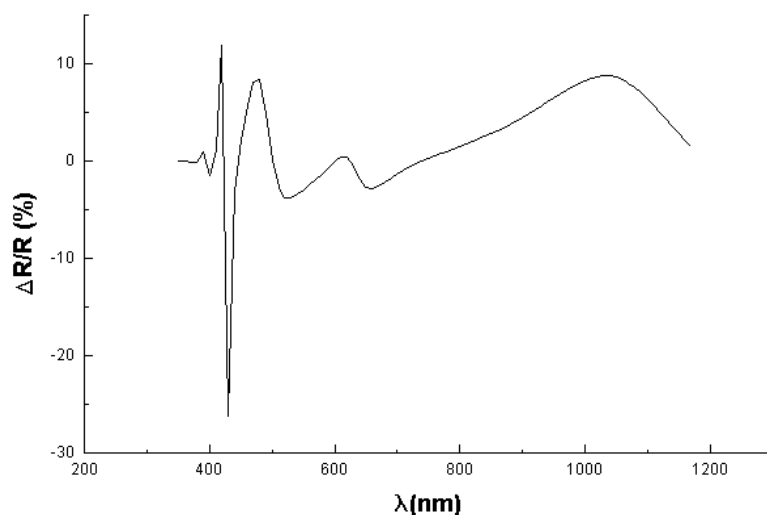


Figure 4: Relative refractive variation as a function of wavelength

PL spectra are recorded either for as prepared samples or for samples after Br oxidation (Fig. 5). It is evident an irreversible quenching of photoluminescence, confirmed by the surface modifications observed by FTIR characterization.

Work is in progress to develop the optical interferometric transducer. After oxidation, PS samples will be treated using a toluene diluted linker solution. The linker molecules will allow the attachment of 5' phosphoate group of DNA to brominate surface of PS. The linker derivatized PS chip so obtained will be exposed to a DNA denaturing solution, using a 5' phosphoate oligonucleotide 16 mer, HPLC purified (5'-pGC CAG AAC CCA GTA GT-3'). The real attachment of DNA will be detected by a modification of interferometric index of PS matrix. The

effect of different concentration of complementary DNA (cDNA) will be finally tested.

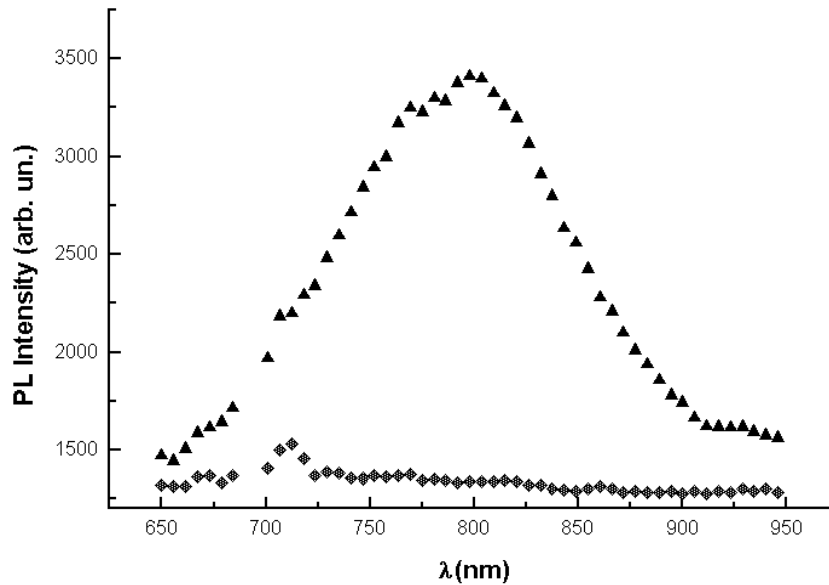


Figure 5: PL spectra of as prepared PS samples (triangle) and after Br oxidation

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