High-resolution X-ray diffraction and grazing incidence X-ray reflectivity analyses of nanostructured porous silicon

P.G. Abramof [1,2], A.F. Beloto [2], U.A. Mengui [2], A.Y. Ueta [2] and N.G. Ferreira [2]

[1] Centro de Desenvolvimento de Tecnologia e Recursos Humanos - CDT, CEP 12242-800 SJC, SP, Brazil

[2] Instituto Nacional de Pesquisas Espaciais INPE/LAS, CP 515, CEP 122245-970 SJC, SP, Brazil

SUBJECT AND OBJECTIVES

- Porous silicon layer (PSL) formation by stain etching and its structure control as a function of doping level, p-type and crystalline orientation.
- Structural characterization of PSL by grazing incidence X-ray reflectivity as a function of etching time.
- Study of the nanoporosity as a function of etching parameters.
- Characterization of PSL by X-ray diffraction as a function of etching time.
- Study of the strain in PSL a function of etching parameters.
- Structural characterization of PSL by high-resolution X-ray diffraction .

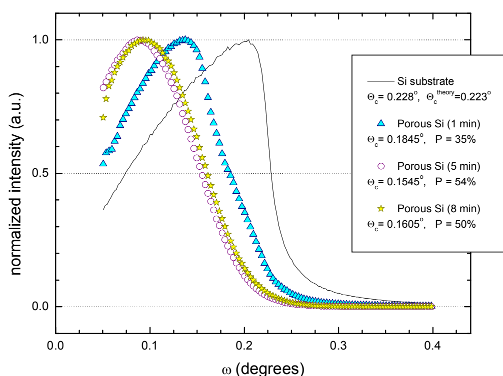
SAMPLE PREPARATION

POROUS SILICON LAYER

- Silicon p^+ (100), boron doped, 10^{18} atoms/cm^3, resistivity of 0.01 to 0.02 W.cm.
- Stain etching HNO_3: HF (500:1) + $NaNO_2$ (0.1 g/L).
- Etching time varying at 1 t0 10 minutes

CHARACTERIZATION BY GRAZING INCIDENCE X-RAY REFLECTIVITY

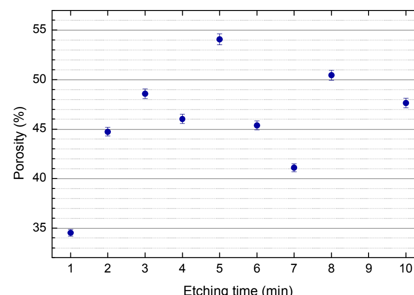
The X-ray reflectivity spectra



The porosity of the porous material can be determined by the following relation:

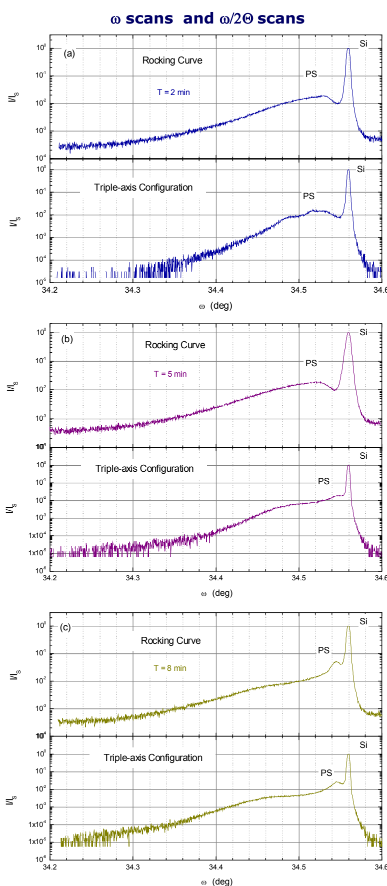
$$P_0 = 1 - \left(\frac{\omega_{c,PS}}{\omega_{c,Si}} \right)^2$$

where $\omega_{c,PS}$ is the critical angle of the PS layer and $\omega_{c,Si}$ is the critical angle of bulk silicon (0.223º for the $CuK_{\alpha 1}$ radiation).



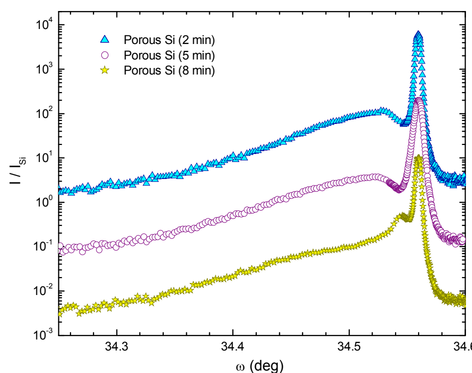
Porosity obtained from the value of the PS critical angle versus the etching time.

ω scans and ω/2Θ scans

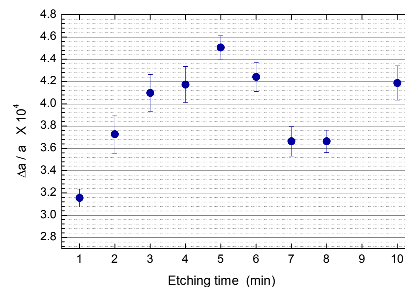


CHARACTERIZATION BY HIGH-RESOLUTION X-RAY DIFFRACTION

The Rocking curve (ω scans)



The strain obtained by the lattice mismatch for PS layer



The relative expansion $\Delta a/a$, where Δa is the difference between the porous layer and the silicon bulk lattice parameter, is directly proportional to the angular splitting $\Delta\omega$ between both peaks:

$$\frac{\Delta a}{a} = -\frac{\Delta \omega}{\tan \Theta_{Si}}$$

where Θ_{Si} is the (004) Bragg angle of the bulk Si.

CONCLUSIONS

- The results showed that the porosity and the compressive stress increase for etching time up to 5 min and then this tendency is replaced by an oscillatory behavior.
- The results showed also that the variation in the porosity and in the stress is directly correlated with the crystallite size distribution in the PS layers as a function of etching time.
- The observed morphology is directly correlated with the lattice mismatch controlled by the solution concentration and the etching time.
- Stain etching can be to guarantee the use of PS layer as substrate for growing epitaxial narrow gap semiconductor films.

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