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Study of Thermal Conductivity of Porous Silicon Using the Micro-Raman Method

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ABSTRACT

In this work, we are interesting in the measurement of thermal conductivity (on the surface and in-depth) of Porous silicon by the micro-Raman spectroscopy. This direct method (micro-Raman spectroscopy) enabled us to develop a systematic means of investigation of the morphology and the thermal conductivity of Porous silicon oxidized or no. The thermal conductivity is studied according to the parameters of anodization and fraction of silicon oxidized. Thermal transport in the porous silicon layers is limited by its porous nature and the blocking of transport in the silicon skeleton what supports its use in the thermal sensors.

Keywords: Mono-Crystal Silicon; Porous Silicon; Thermal Conductivity; Micro-Raman Spectroscopy

1. Introduction

Porous silicon (PS) is obtained by electrochemical attack of single crystalline silicon [1]. PS is a tuneable material in respect of its pore size distributions depending on its formation conditions. From the macro-porous silicon (with thickness bigger than 0.1 µm or 0.1 nm) to the meso-porous silicon (about 2 to 100 nm of thickness) to the nano-porous silicon (thickness smaller than 10 nm), the range of its applications varies. This material is used in photonics and optoelectronics [2], quantum electronics [3], silicon-on insulator technology [4] and very recently in sensors [5]. Since the last decade, PS has also been investigated in the area of photovoltaic [6] as an antireflection coating and as a sacrificial layer for the layer transfer process (LTP) [7,8].

This material presents a thermal conductivity near to thermal conductivity of silicon dioxide [9]. This material is an excellent candidate to ensure the thermal insulation for the micro sensors on silicon because it ensures the mechanical stability of the microstructure [10]. For this reason, PS layers have been effectively used as material for local thermal isolation on bulk silicon [11,12] and as material for the fabrication of micro-hotplates for low-power thermal sensors [13,14]. Nevertheless, before implementing the PS sensor, it is necessary to understand the thermal transport in such nanostructure and the experimental study of its thermal conductivity, according to its characteristic parameters.

In this work, we are interesting in anodization of silicon to release the principal factors, acting on the morphology in-depth of the layer. We expose a direct method of measurement of the thermal conductivity for PS layers. This parameter is founded on their micro-Raman response to a laser excitation producing a thermal gradient in material. This latter is evaluated by the micro-Raman spectroscopy. The analysis of surface and indepth distribution of the crystallites composing the material is presented.

2. Experimental Procedure

The PS samples were prepared by electrochemical anodic etching of *p*-type, (100)-oriented, 0.01 - 0.025 $\Omega\cdot cm^{-1}$ silicon wafers, in a solution of HF (48%):C_2HÖH of 1:1. Current densities range were 5 and 75 mA/cm² during 10 min. The current density and the time attack selected permit to obtain different layers with different porosities and different thicknesses. After the electrochemical treatment, samples were rinsed in deionized water and were dried under nitrogen flow.

Samples prepared in this study are described in **Table 1**.

Table 1. Anodization parameters of the samples prepared with two current densities.

Curent density (j) (mA/cm)²	time (min)	Porosity (P) (%)	Thicknes (e) (µm)
5	10	20	5
75	10	48	40

