Formation of the nanoporous Si structure of solar cell with using a model representation

Information about the authors

***Valeriy Yerokhov, Anatoly Druzhinin, Stepan Nichkalo**

Department of Semiconductor Electronics, Lviv Polytechnic National University

12 S. Bandera Str., Lviv-79013, Ukraine

****Corresponding author: v.yerokhov@gmail.com***

Introduction

The study of all stages of formation of porous structure on the basis of the selected model and identification of patterns that affect the characteristics of the resulting nano-, meso-, macropores are very important because most parameters of porous layers are laid at the stage of formation of nucleation (or seed) centers. The mechanism of pore formation can be described only by a few known models. Among the selected and used by us, which can be used in the creation of SC front surfaces and considered to be the most promising, are Lehmann's model [1] and Zhang's model [2]. In fact, the use of these models will contribute to the creation of an efficient and cost-effective nanocoating based on PSi for solar cells. The use of a multilayer PSi, obtained on the basis of model representation, will simplify the technological cycle, reduce the cost of the product and increase performance, i.e. will increase the efficiency of SC manufacturing technology.

►The ***aim*** of this work was to develop frontal functional nanolayers of SC (SC) by electrochemical and chemical technologies of porous silicon (PSi) to obtain efficient and cost-effective technological processes in the production of photovoltaic converters of sunlight, which should be adapted to the fabrication processes of silicon SC. In this study, to obtain frontal functional nanolayers of solar cells, a deep analysis of existing models of PSi was made. The described models are suitable for creating an efficient and cost-effective coating based on nanoporous silicon, as well as maximally adapted to the solar cell fabrication processes.

The most effective models for creating an efficient and cost-effective nanocoating

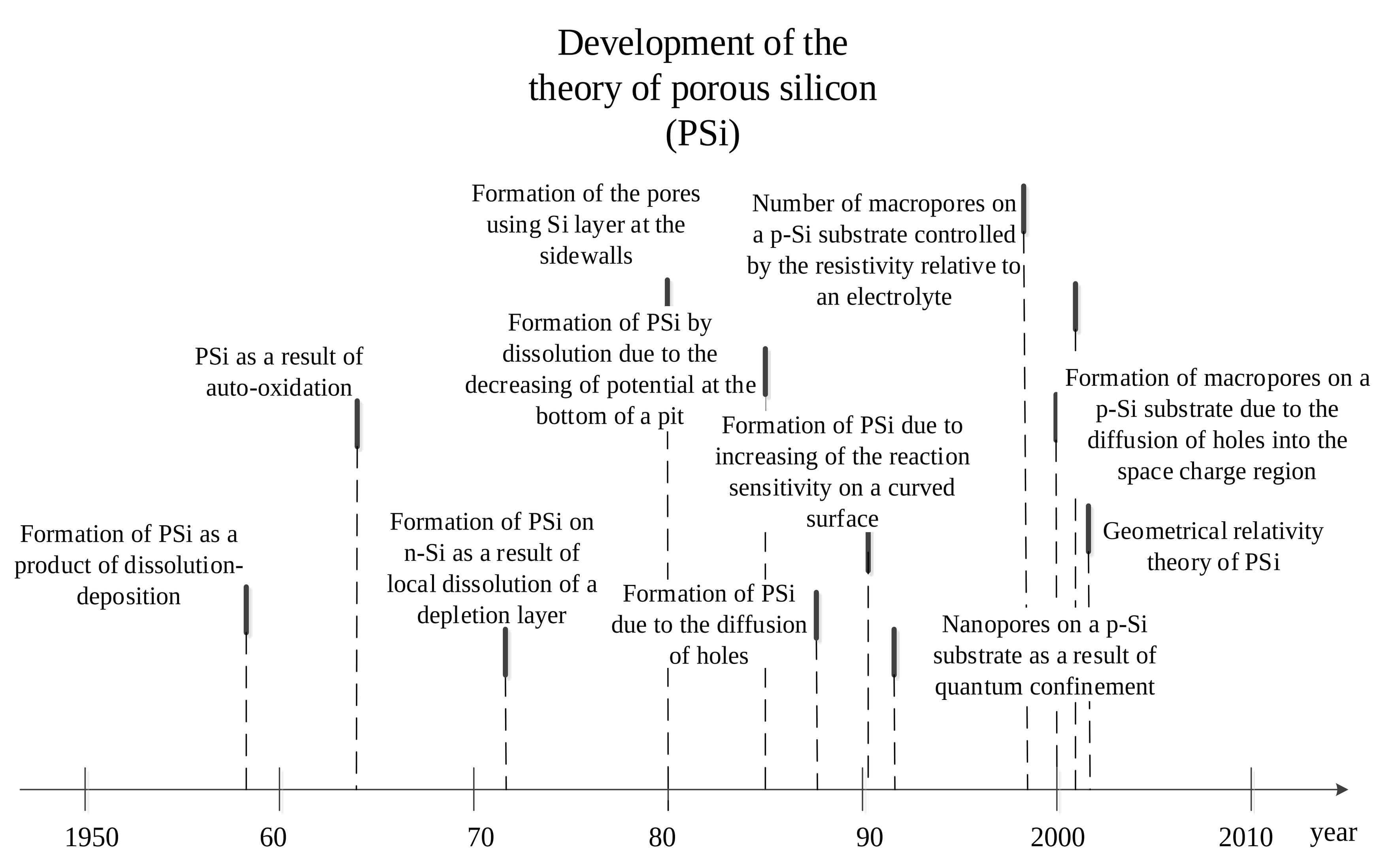

Fig. 1. Development of the threory of porous silicon over the past 50 years

To explain the properties of PSi, a number of models that describe the possible mechanisms of pore formation in the layers of PSi can be considered. These models can be divided into several groups:

a) models describing the quantum confinement of charge carriers in Si crystallites of nanoscale size;
b) models describing localized emission caused by Si polysilanes or hydrides formed on the surface of PSi during its growth due to passivation of dangling bonds on the surface;
c) models describing the formation of a specific class of Si-O-H compounds (siloxanes);
d) models that combine theories of quantum confinement of carriers and the existence of areas with local defects on the surface, the so-called hybrid models, which better describe the optical properties of the porous film.

Over the last few decades, many reviews have been found in the literature on the problem of PSi, as well as PSi production technology and the formation mechanism of porous structures. The main milestones in the development of PSi are schematically shown in Fig. 1. This can provide a huge basis for analysis and future modeling, which we used. Naturally, the authors classified different reviews using different approaches, such as mathematical, chemical or physical, later works were classified regarding the pores dimension (micropores, mesopores, macropores), and used universal model approaches.

Technological aspects of the PSi formation and the development of a porous structure model

Fig. 2 shows a classic coral-like model of porous Si and Fig. 3 shows a model of nanoporous Si, which were created by a conventional electrochemical method. Fig. 4 is a schematical representation of chemical cell which was used in our work for anode etching process. Such parameters of PSi layers as porosity and thickness, and for the technological process - growth rate and electrolyte composition, we considered as the main for development of a PSi technology. When creating a model of the technological process, the most important are the dependence of these parameters on temperature, anode current density, electrolyte concentration, duration of anode treatment and a number of other conditions for electrochemical etching.

Fig. 5 shows the cut model of PSi together with the model of the approximate band gap width, from the solid matrix of the substrate crystal, through the whole PSi. Here the band gap varies from 1.12 eV to 1.6 eV (bulk Si – E_g=1.12 eV, porous silicon - E_g=1,6 eV at 273 K). The influence of electrolyte components and its physicochemical properties on the results of etching of silicon should be considered separately. This is important for studying the technological process formation of PSi layers. In this aspect, the following list of electrolyte parameters can be considered as the main: concentration of hydrofluoric acid; type and concentration of other components of the etching solution; oxidizing ability; pH; electrolyte resistivity; viscosity; wettability.

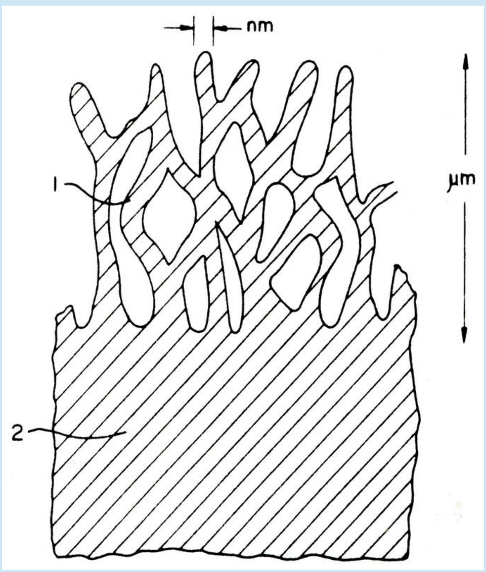

Fig. 2. Coral-like structure of PSi

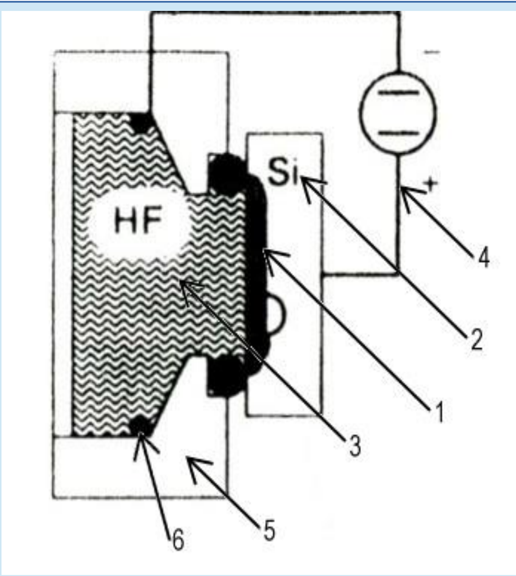

Fig. 4. Schematical view of chemical cell used for obtaining PSi: 1 – sealant between the HF containing electrolyte and Si sample; 2 – Si sample; 3 – electrolyte based on HF acid; 4 – anodizing line; 5 – teflon dish of electrochemical bath cell; 6 – part of the counter electrode

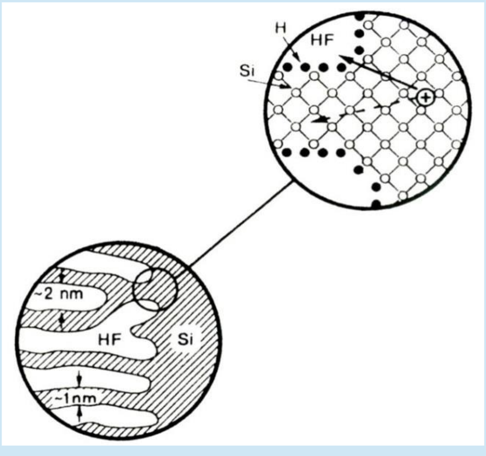

Fig. 3. Model of PSi with nanopores: (a) nanoporous Si; (b) the view of an electrolyte inside the pore and the motion of charge in the Si lattice

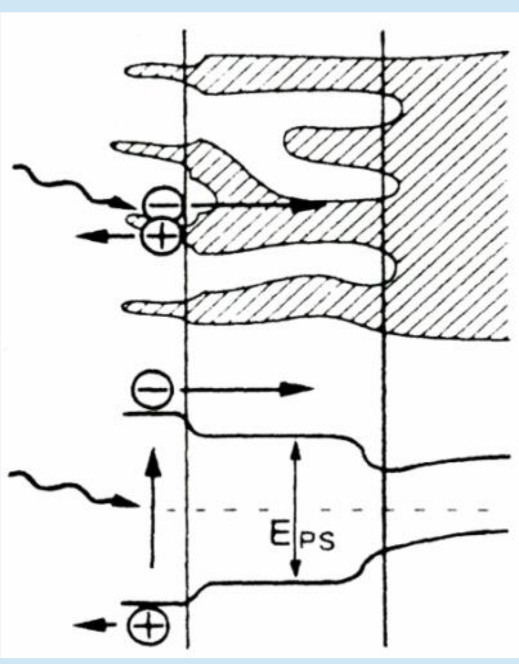

Fig. 5. The cut model of PSi together with the model of the approximate band gap width, from the solid matrix of the substrate crystal, through the whole PSi. The band gap varies from 1.12 eV to 1.6 eV

Conclusions

The frontal Si nanolayers made by electrochemical and chemical methods allow to obtain efficient and cost-effective coating for solar cells. In this study, to obtain frontal functional nanolayers of solar cells, a deep analysis of existing models of PSi was made. The developed models are suitable for creating an efficient and cost-effective coating based on nanoporous silicon, as well as maximally adapted to the solar cell fabrication processes.

References:

[1] Lehmann V., Ronnebeck S. The physics of macropore formation in low-doped p-type silicon, *Journal of The Electrochemical Society*, 146, pp. 2968-2975 (2004).

[2] Zhang X.G. Morphology and formation mechanisms of porous silicon, *Journal of The Electrochemical Society,* 151, pp. 69-80 (2004).