New Possibilities for the Use of Nanostructured Silicon in Micro and Nanoelectronics

M.M. Melnichenko[a], K.V. Svezhentsova[b]
[a]Taras Shevchenko National University of Kyiv, Ukraine
[b]V.E. Lashkarev Institute of Semiconductor Physics NAS of Ukraine, Kyiv, Ukraine
[a]Corresponding author: realcrystallab@univ.kiev.ua

Introduction

In recent years, methods of producing nanostructures based on chemically pure silicon for applications in photonics, photovoltaic devices, energy storage devices, biophotonics, and biosensor technology have been actively developed. At the same time, black silicon is the focus of the research interest of many scientists around the world, both in terms of studying its fundamental properties and in connection with the emerging prospects for wide application. Interest in this material, which has a small (up to 1%) reflection coefficient in the visible range, is associated with the prospects of creating a new generation of efficient photovoltaic current sources on its basis.

Today, the harvesting of unused or wasted energy from our environment and its consequent conversion into usable energy is of considerable scientific interest.

Experimental Results

A method of stain etching of the surface of single-crystal silicon presented in this work allows to obtain homogeneous nanostructured layers of black silicon with thickness from 3 to 60 nm and is a simple way to modify the photonic properties of silicon nanostructures in a wide range. The surface morphology of black nanostructured silicon was investigated using a scanning tunneling microscope. The results of measurements of the photoelectric properties of black silicon layers indicate the possibility of their use in the creation of sensitive photodetectors for the visible and ultraviolet ranges, as well as in solar cell technology to improve the efficiency of the anti-reflective surface of photo converters. In this work, research has been carried out on obtaining energy from room electric lighting for low-power devices such as wireless sensors, portable electronics, and electronic communication. The obtained films of nanostructured black silicon showed a photovoltaic effect (0.2 V, 90 µA under load) under room electric light and sunlight (photocell area - 0.5 cm2).

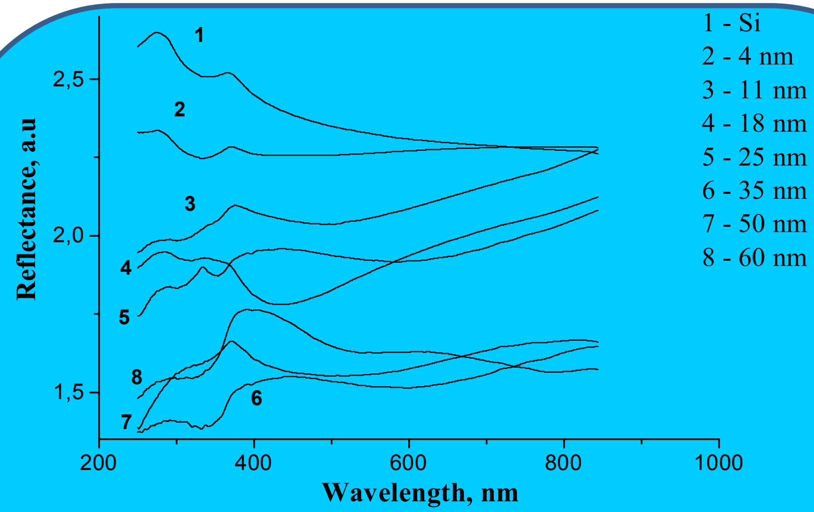
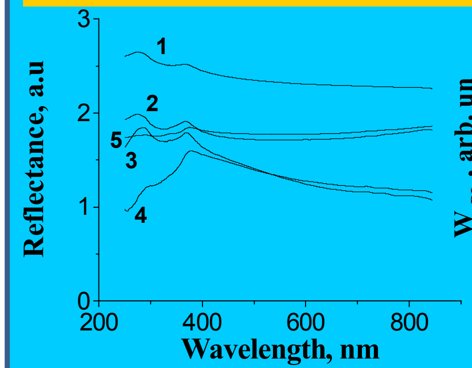


Fig. 1. Dependence of the reflection coefficient on the film thickness of nanostructured silicon.



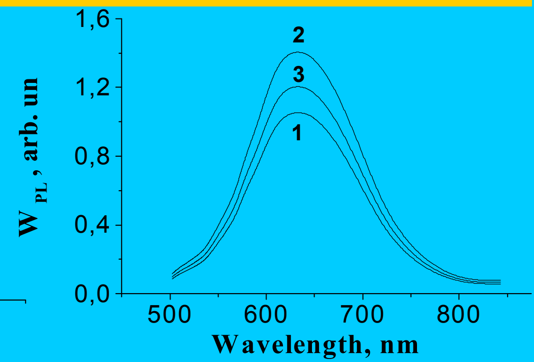


Fig. 2. The spectrums of the reflection of the initial surface of silicon (1), textured surfaces (2), and nanostructured silicon formed on textured surfaces with the time of etching 3 minutes (3), 10 minutes (4), and 30 minutes (5).

Fig. 3. FL spectrums of nanostructured silicon formed on the textured surface of silicon with the time of etching 3 minutes (1)11, 10 minutes (2)50, and 30 minutes (3)60.

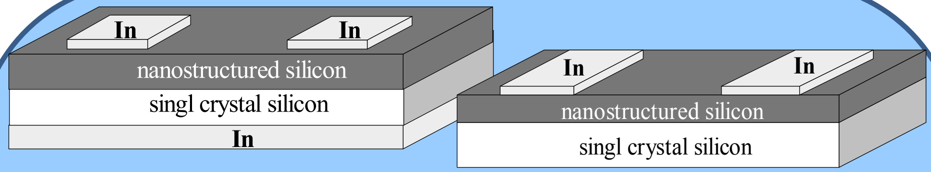


Fig. 4. Structures indium – single-crystal silicon p-type – nanostructured silicon – indium and single-crystal silicon p-type – nanostructured silicon – indium.

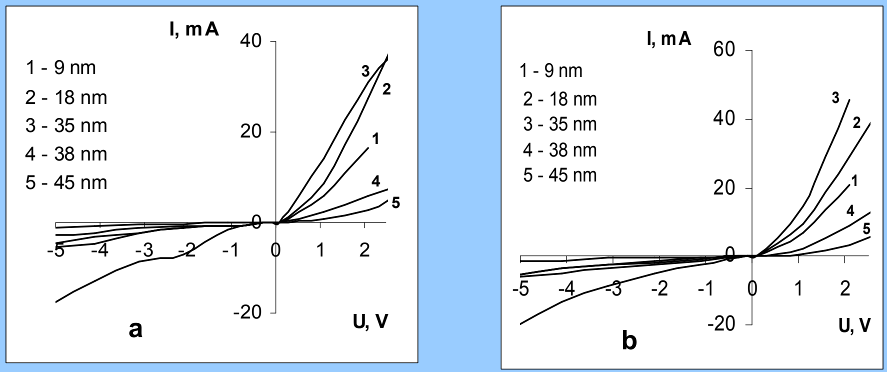


Fig. 5. Volt-ampere characteristics of structures of indium - monocrystalline silicon - black nanostructured silicon - indium in the dark mode(**a**) and under ultraviolet light (**b**).

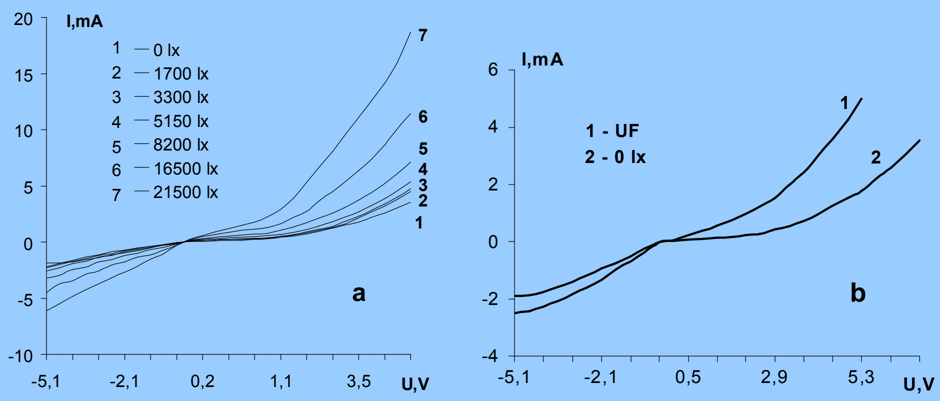


Fig. 6. Light and dark volt-ampere characteristics of the black nanostructured silicon film (**a**) and under ultraviolet light (**b**).

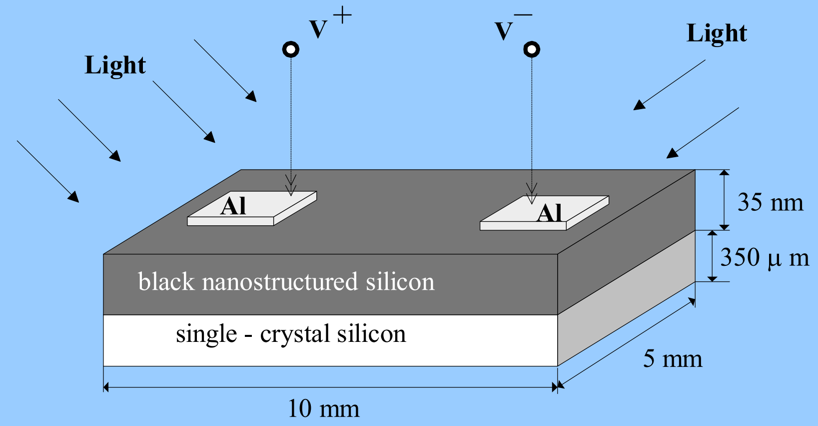


Fig. 7. Schematic representation of the device for harvesting photovoltaic energy in rooms with electric and daylighting (photocell area - 0.5 cm2).

Conclusion

The presented method is an effective and inexpensive way to texture the surface of monocrystalline silicon to obtain black silicon layers with different morphology and distribution of chemical elements while being fully compatible with the silicon planar technology used in the production of semiconductor devices. The influence of nanostructured silicon film thickness on its anti-reflective characteristics was studied. It was found that the best anti-reflective characteristics have samples of black nanostructured silicon with a thickness of 35 nm. The formation of black nanostructured silicon on a textured surface leads to a decrease in the reflective characteristics of the surface and an increase in the conversion efficiency of finished silicon solar cells. The study of volt-ampere characteristics showed that the thickness of black nanostructured silicon affects the electrophysical and photoelectric characteristics of the studied structures. Created mini power converters based on a black nanostructured silicon film and their panels can be integrated into electronic circuits and ready-made chips for various purposes with low power consumption. The latter opens up the possibility of using black nanostructured silicon in photonics, photoelectric devices, biophotonics, and biosensorics.