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CHARACTERIZATION OF THE SURFACE OF SILVER ION-IMPLANTED SILICON BY OPTICAL REFLECTANCE

A. L. Stepanov,[a,b]* V. V. Vorobev,[b] V. I. Nuzhdin,[a] V. F. Valeev,[a] and Yu. N. Osin[b]

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The optical reflection of the surface of silicon implanted with Ag^+ ions at low energy of 30 keV in a wide dosage range of $5.0\cdot10^{14}$–$1.5\cdot10^{17}$ ion/cm^2 was studied in parallel with electron microscopy observation of the samples. It was found that with increasing ion dose of irradiation, the reflection intensity in the UV range of the Si spectrum decreases monotonically due to amorphization and macrostructuring of Si near-surface layer. In the long-wavelength region of the reflection spectra, a selective band with a maximum near 830 nm is recorded due to the plasmon resonance of ion-synthesized Ag nanoparticles.

Keywords: *optical reflectance, ion implantation, plasmon resonance.*

Introduction. Optical reflection is one of the most important characteristics that is used in practice to describe the spectroscopic absorptive properties of solar cell elements. In order to increase the absorptivity of silicon solar cells, an approach has recently been proposed that involves the use within the Si-structure of silver nanoparticles (NP) of small dimensions (<30 nm) [1, 2], in which localized plasmon resonance arises under the action of light. Plasmon resonance manifests itself in intense absorption of light by metallic NPs in the visible spectral range [3, 4], which provides a total contribution to the increased absorption of a thin semiconductor layer containing localized plasmon regions [5]. Moreover, the local electromagnetic field arising near the NP due to plasmon resonance can generate the appearance of electron-hole pairs in semiconductors [1]. The use of noble metal nanoparticles in the structure of solar cells opens up additional possibilities for using the nonlinear optical properties of metallic NPs [6].

At present, the methods of vacuum deposition, electron lithography, various chemical approaches, etc. are used to form composite layers with Ag NPs. The ion implantation technology, which is actively used in industrial Si-microelectronics, is of particular interest. However, studies on the synthesis of Ag NPs in a Si matrix in the process of ion implantation for applications in solar energy have not been carried out previously. In the present work, a new technology is proposed for the formation of thin layers of porous Si with Ag NPs (Ag:Si) at low-energy high-dose (> 10^{16} ion/cm^2) implantation of *c*-Si with Ag^+ ions (Ag:Si) [7, 8]. Later, ellipsometric measurements were carried out in parallel with the observation of the diffraction of reflected electrons for the Ag:Si surface obtained by low-dose implantation at (< 10^{16} ion/cm^2) [9].

In the present study, to determine the optical characteristics of Ag:Si layers, the visible reflection spectra for composites obtained in a wide range of ion doses of $5.0\cdot10^{14}$–$1.5\cdot10^{17}$ ion/cm^2 have been studied.

Experiment. Plates of *c*-Si with a polished *p*-type conductivity surface with the crystallographic orientation (100) and a thickness of 0.5 mm, opaque in the visible spectral range, were used as the substrate. *c*-Si was implanted with singly charged Ag^+ ions with an energy of 30 keV with a current density in the ion beam of 8 microamps/cm^2 and doses of $5.0\cdot10^{14}$–$1.5\cdot10^{17}$ ion/cm^2 using the ILU-3 ion accelerator at room temperature. Optical reflection spectra were measured on an AvaSpec 2048 (Avantes) spectrometer at a normal angle of incidence of the probing and reflected light beams to the surface of the samples through a parallel plate waveguide in the 220–1100 nm range at room temperature. Local morphology and surface structure of implanted Si were studied by scanning electron microscopy (SEM) using a Merlin (Carl Zeiss) SEM microscope equipped with an HKL NordLys (Oxford Instruments) reflection electron diffraction detector.

*To whom correspondence should be addressed.

[a]Kazan Physical-Technical Institute Kazan Scientific Center, Russian Academy of Sciences, Kazan, 420029, Russia; [b]Kazan Federal University, 18 Kremlevskaya Str., Kazan, 420008, Russia; email: aanstep@gmail.com. Translated from Zhurnal Prikladnoi Spektroskopii, Vol. 84, No. 5, pp. 726–730, September–October, 2017. Original article submitted April 17, 2017.