Conference Paper

Preparation of Silcon Nanoparticles and Films By Pulsed Laser Deposition

S. V. Antonenko[1], S. I. Derzhavin[1,2], and S. M. Klimentov[1,2]

[1]National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse 31, Moscow, 115409, Russia
[2]Prokhorov General Physics Institute of RAS, 38, Vavilova st., Moscow, Russia

Abstract

Silicon films and nanoparticles were prepared by pulsed laser deposition under irradiation of crystalline silicon targets in residual inert gas atmosphere. Properties the prepared samples were investigated by means of the scanning probe microscopy.

Keywords: pulsed laser deposition, scanning probe microscopy, silicon film, nanoparticles.

Corresponding Author:
S. V. Antonenko
SVAntonenko@MEPHI.RU

Received: 17 January 2018
Accepted: 25 March 2018
Published: 17 April 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the PhysBioSymp17 Conference Committee.

1. Introduction

Recently, laser-synthesized silicon (Si) nanoparticles (NPs) are of a great interest because they can be used in biomedicine, e.g. theranostics of cancer [1]. A method of the pulsed lased deposition under ablation of a solid target in inert gas atmosphere allows us to control both the morphology and photoluminescent properties of Si NPs [2]. Laser-ablated Si NPs are dispersible in aqueous media and they can act as PL labels in bioimaging [3]. Our present work is devoted to a search of the optimal conditions to prepare Si NPs by using laser ablation of solid targets in inert gas atmosphere.

2. Materials and methods

Samples of Si Np films were prepared by using a PVD PLD/MBE-2000 integrated pulsed laser deposition tool. An electro-polished 304 SS cylindrical chamber was used with internal removable SS shields. A Coherent/Lambda Physik COMPex PRO 110 excimer laser will be mounted on top of the electronic rack system at the correct height for the optical train. Nominal angle of incidence of the laser beam on target: 60°. The laser comes with ceramic tube technology and operates at repetition rate 15 Hz at 150 – 250 mJ per pulse (248-nm, KrF), pulse duration 20 ns. Focal spot beam dimensions were 1 x 4 mm^2 on the target and radiation intensity of about 2.5 x 10^8 W/cm^2. Targets were single crystalline Si wafers (c-Si) with surface orientation (100), specific resistivity of 20 Ohm*cm. The system can handle c-Si substrates up to 2-inch in diameter. The chamber with samples and targets was pumped to residual pressure about $5 \cdot 10^{-10}$ Torr and then it was filled with 1 Torr inert gas (He, Ar) to deposit Si NP films.

Films of Si NPs were deposited on c-Si and quartz substrates. Atomic force microscopy (AFM) studies were done by using a "Nanoeducator" scanning probe microscope NT-MDT.

3. Results and Discussion

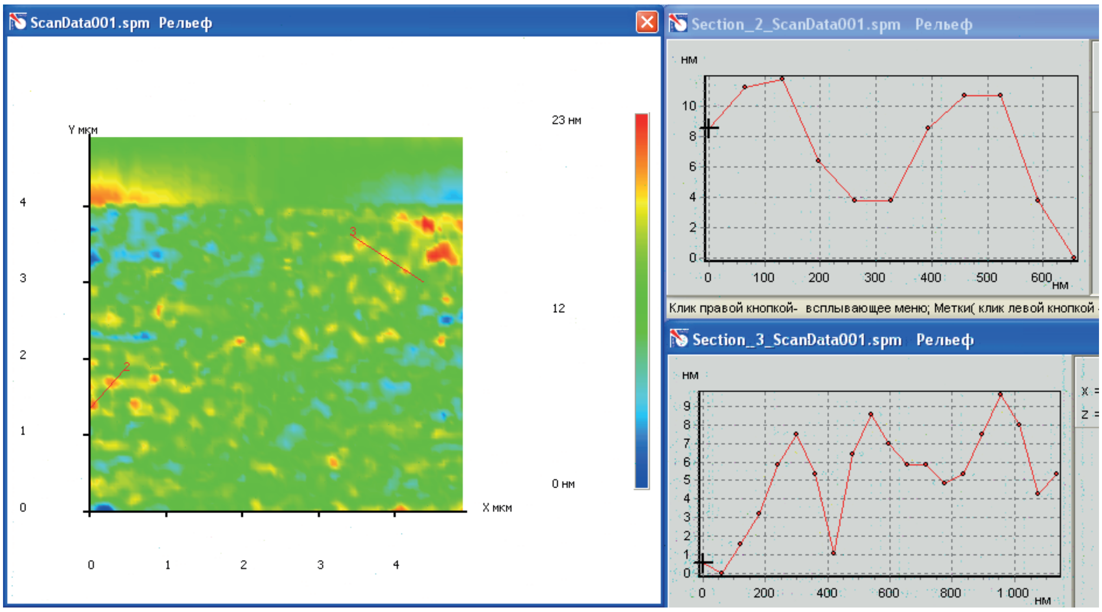
Fig.1a shows typical AFM image of a region of the deposited film. The corresponding profile cross-section 2 (above) and 3 (below) with height of the particles was about 3 – 7 nm and their lateral dimensions were 50 – 200 nm are shown in Fig.1b. One can see that minimal height and lateral dimensions of Si NPs are 2 – 4 nm and 20 – 30 nm, respectively. While the latter can be overestimated because of the real size of AFM tip, the former one are typical for Si NPs obtained by laser ablation in inert gas [2]. Our experiments have revealed that the total thickness of Si NP film was nearly linearly dependent on the deposition time varied from 1 min to 1.5 h. The obtained films were porous and the porosity can be controlled by the inert gas pressure in agreement with results of Ref.[2].

4. Conclusions

Films of Si nano particles with minimal sizes of 2-4 nm were prepared by nanosecond laser ablation of c-Si targets. Our results indicate that Si NPs with desired size and porosity can be efficiently created in laser-plasma conditions during pulse laser deposition. Because of the porous morphology of the prepared films they can be easily disassembled to obtain Si NPs, which can be used in biomedical applications as theranostics of cancer.

Acknowledgments

S.V.A. acknowledges the financial support of the Ministry of Education and Science Russian Federation, contract № 3.8542.2017/7.8. S.I.D. and S.M.K. are grateful for the



a) b)

Figure 1: a) Scanning probe microscopy scan size 5×5 μm^2, b) profile section 2 (above) and profile section 3 (below).

financial support of the Ministry of Education and Science Russian Federation, contract №16.2969.2017/4.6.

References

[1] A. V. Kabashin, V. Yu. Timoshenko. What theranostic applications could ultrapure laser-synthesized Si nanoparticles have in cancer? Nanomedicine, 11 (17), 2247-2250 (2016).

[2] A.V. Kabashin, J.-P. Sylvestre, S. Patskovsky, M. Meunier. Correlation between photoluminescence properties and morphology of laser-ablated Si/SiO$_x$nanostructured films, Journal of Applied Physics, 91, No. 5, pp. 3248–3253 (2002).

[3] M. B. Gongalsky, L. A. Osminkina, A. Pereira, A. A. Manankov, A. A. Fedorenko, A.N. Vasiliev, V. V. Soloviev, A. A. Kaudryavtsev, M. Sentis, A. V. Kabashin, V. Yu. Timoshenko. Laser-synthesized oxide-passivated bright Si quantum dots for bioimaging, Sci. Rep., 6, 24732 (2016).