UDC 621.315.592

MORPHOLOGICAL FEATURES OF ALD TiO_2 COATED POROUS SILICON SURFACE

N. Pavlenko[1], PhD I. Iatsunskyi[1,2], Prof. V. Smyntyna[1]

[1]Odessa I. I. Mechnikov National University
Odessa, Ukraine
[2]NanoBioMedical Center, Adam Mickiewicz University
Poznan, Poland
yatsunskiy@gmail.com

In the present work, we report on the use of atomic layer deposition (ALD) technique to achieve TiO_2 films deposition on porous silicon (PSi) obtained by metal-assisted chemical etching (MACE) presenting different porosity level and morphology. Structural and compositional properties of TiO_2—PSi are studied. It was found that depending on initial structure of PSi the layer of TiO_2 has various structures and size of nanocrystallites.

Keywords: atomic layer deposition, porous silicon, titanium dioxide.

Recent interest has been paid by researchers to the nano-scale metal oxides, especially TiO_2, which has highly active surface area and demonstrates new properties, induced by quantum-size effects, such as UV shift of absorption edge and room temperature photoluminescence. It is expected that metal oxide (TiO_2) coatings of such nanostructures as porous Si (por-Si) will form nanostructures possessing novel optical, structural and electrical properties that can be used for development of new devices. It is no doubt that the investigation of morphological features of such structures allows one to develop more stable and effective devices based on TiO_2 – por-Si. However, the main publications have been devoted to the ALD TiO_2 films on planar silicon substrates [1—3]. There is no information on how the morphology and chemical composition of initial nano-silicon will affect the structure of dioxide titanium. Recent articles devoted to this topic do not reveal morphology of fabricated TiO_2 structures. Thus, the aim of this study was to reveal morphological features of obtained por-Si–TiO_2.structures. The results obtained are very promising for the improved use of por-Si–TiO_2 structures in photocatalysts, photovoltaic and sensor application where it is important to tune their physical properties by the morphology of por-Si–TiO_2.

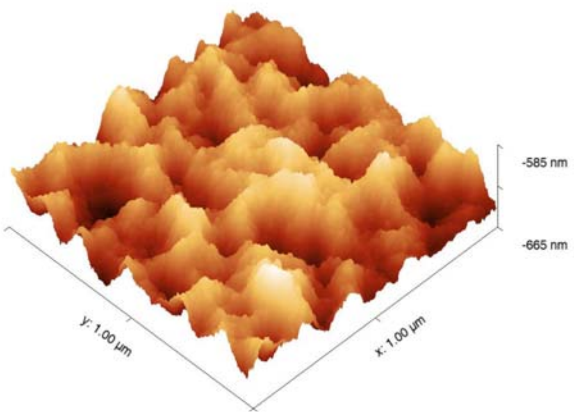

Fig. 1. 3D AFM image of TiO_2–por–Si surface (150 cycles of ALD)

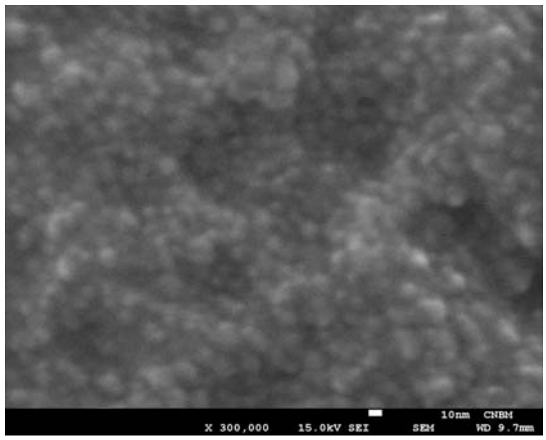

Fig. 2. Plane view of scanning electron microscope (SEM) image of TiO_2–por–Si surface (150 cycles of ALD)

The procedure used to prepare the TiO_2 – por-Si samples involves three main steps:

1. Fabrication of porous silicon by metal-assisted chemical etching [4]. We obtained various porous samples having direct or branched structure with different sizes of the pores.
2. ALD deposition. Varying the number of cycles we could regulate the approximate thickness of TiO_2 layer (100 cycles — 10 nm thickness of TiO_2 for the plane sample);
3. Some samples were annealed in the air at 400°C for an hour.

We found that depending on the structure of initial porous silicon the dioxide titanium layers get different morphology (for instance, granular nanocrystallites having approximate diameter of 12 nm) (Fig. 1, 2). More frequently titanium dioxide penetrated and filled pores than grew up on the porous silicon surface. Investigating the penetration depth of TiO_2 into porous silicon, we found that its concentration decreases for all samples but its stoichiometry is retained. For samples having branched porous structure, the concentration of titanium dioxide was the lowest. Methods of X-ray structural analysis and Raman spectroscopy allowed us to establish the structural and phase transformations occurring in the samples before and after annealing. It was found that annealing of this structure leads to partial transformation of anatase phase into rutile and it cause mechanical deformations of por-Si and TiO_2. Analyzing X-Ray and Raman spectrum we also calculated the average size of nanocrystallites (TiO_2 and Si) and mechanical deformations occurring before and after annealing. Calculations will allow us to estimate the possible mechanism of degradation of these structures. The experimental results allow us to propose the optimal procedures and conditions for obtaining more stable and sensitive samples.

REFERENCES

1. P. Dhivya, K. Prasad and M. Sridharan, Nanostructured TiO_2 films: Enhanced NH3 detection at room temperature // Ceramics International.— 2014.— 40.— P. 409—415.

2. Li Jianline and M. Sailor, Synthesis and characterization of a stable, label-free optical biosensor from TiO_2-coated porous silicon // Biosensors and Bioelectronics.— 2014.— 55.— P. 372—378.

3. V. M. Arakelyan et. al., Hydrogen sensitive gas sensor based on porous silicon/TiO2_x structure // Physica E. 2007.— 38.— P. 219—221.

4. V.C. Chartier, S. Bastide, C. Lervy-Clerment, Metal-assisted chemical etching of silicon in HF–H_2O_2 // Electrochimica Acta.— 2008.— 53.— P. 5509—5516.

Н. Павленко, И. Яцунский, В. Смынтына

Морфологические особенности атомного послойного осаждения диоксида титана на поверхности пористого кремния.

Показана возможность использования метода атомного послойного осаждения для получения пленок TiO_2 на пористом кремнии. Изучены структурные и химические свойства структурі «TiO_2 – пористый кремний». Показано, что в зависимости от исходной морфологии пористого кремния слой TiO_2 имеет различные фазовые структуры и размер кристаллитов.

Ключевые слова: *атомное послойное осаждение, пористый кремний, диоксид титана.*
