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INVESTIGATION OF PROPERTIES OF YTTRIUM VANADATE YVO_4 FILMS

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Abstract. Films of yttrium vanadate oxide were obtained on a silicon substrate by way of high-frequency (13 kHz) multi-pulse laser evaporation of a ceramic target in vacuum. The morphology of the films was studied using an atomic force microscope. Transmission spectra in the visible, near and middle IR regions, photoluminescence spectra, as well as volt-ampere and volt-farad characteristics were studied.

1. INTRODUCTION

Yttrium vanadate is widely used in the manufacture of birefringent crystals in laser technology. Nanostructured films of yttrium vanadate can be useful in the development of new photoactive systems for photovoltaic devices [1]. High-frequency laser action on a ceramic sprayed target [2] is capable of providing effective film production. The aim of the work is to obtain and comprehensively study laser-deposited yttrium vanadate films.

2. EXPERIMENT AND RESULTS

The experimental installation based on a neodymium laser (λ = 1.06 microns) included an optical system for transporting laser radiation to a sprayed target, a vacuum chamber, and a measuring and diagnostic complex. To obtain a multi-pulse laser generation mode with a high pulse repetition rate, a passive optical shutter made of radiation-irradiated lithium fluoride, LiF, with $F2^-$ color centers was installed inside the resonator. The repetition frequency of laser pulses was varied by changing the level of laser pumping and the optical density of the shutter; the duration of the laser pulses at half-height was ~ 85 ns. Effective deposition of thin films was achieved at a laser radiation power density, q = 64 MW/cm2, and a pulse repetition rate f ~ 13 kHz. The films were deposited at a pressure of 3 Pa. Ceramic targets were obtained by molding and subsequent sintering at a temperature of T = 1500°C in air.

Morphology of the sample surface was studied using a Solver P47-Pro scanning probe microscope (NT-MDT, Russia) in a semi-contact mode. The volt-ampere characteristics (VAC) at room temperature were measured on an automated basic laser test complex with a multispectral laser radiation source (a set of laser diodes with wavelengths of 405, 450, 520, 660, 780, 808, 905, 980, and 1064 nm with a common fiber-optic output and calibrated radiation power). The transmission of optical radiation by thin films in the near infrared (IR) range of the spectrum was measured using a Carry 500 Scan spectrophotometer. Transmission spectra in the far infrared region were recorded using the NEXUS Infrared Fourier spectrometer (Thermo Nicolet) in the range of 400–4000 cm-1 with a resolution of 2 cm-1 after 128 scans.

The AFM images of the surface of the yttrium vanadate films on the KDB-12 (100) silicon substrate are shown in Fig.1, 2. Using the atomic force microscopy method, it is found that deposition of the films on the silicon substrate results in the formation of a developed surface with a droplet phase of various sizes. The lateral size of large droplets on the film surface ranges from 0.5 to 2.5 microns (Fig. 1a, b), whith the height of the droplets not exceeding 350 nm. The fraction of the large droplet phase is found to be 2% of the total surface area of the films. The YVO4 film consists of fine particles with a lateral size from 20 to 250 nm (Fig. 2), while the average height difference does not exceed 50 nm and the average arithmetic roughness is 17 nm.

The transmission (a) and reflection (b) spectra of the yttrium vanadate film on a silicon substrate in the visible and near-infrared regions are shown in Fig. 3. The transmission reaches 2.9% at a wavelength of λ = 1192 nm and decreases to T = 2.1% at λ = 2793 nm. In the reflection spectrum, two minima (R1min = 11.2% at 242 nm and R2min = 1.2 % at 603 nm) and one maximum R1max = 41% at 358 nm are observed.

The luminescence (1) and luminescence excitation (2) spectra of the YVO4 film on silicon are shown in Fig. 4, a. The wavelength of luminescence excitation is 350 nm, and the maxima in the luminescence spectrum are located in the region between 413 and 438 nm, which is most likely due to the introduction of yttrium or its complex with oxygen.

The volt-ampere characteristics (VAC) of the studied films on the silicon substrate are shown in Fig. 4, b. The photoelectric effect of the YVO4/Si structures is observed at both the negative polarity of the voltage at the YVO4 and the action of laser radiation at 450 nm and 905 nm wavelengths (at the voltage offset of more than -15 V). At other wavelengths of laser radiation, the photoelectric effect is insignificant.

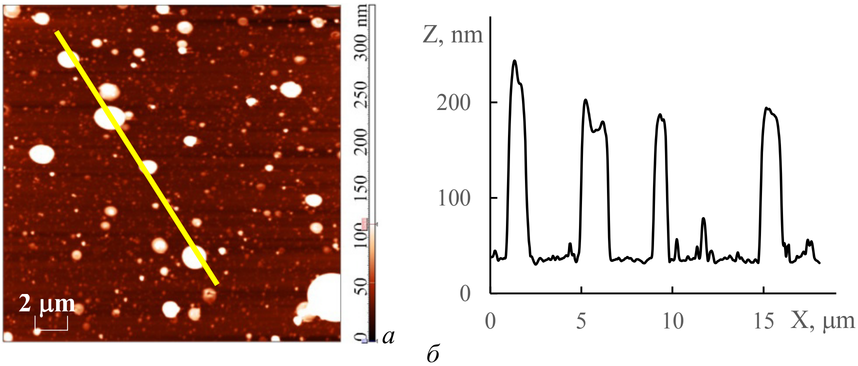

Figure 1: Surface morphology (a) and a cross-section profile along the selected line (b) of the laser-deposited thin film of yttrium vanadate on silicon.

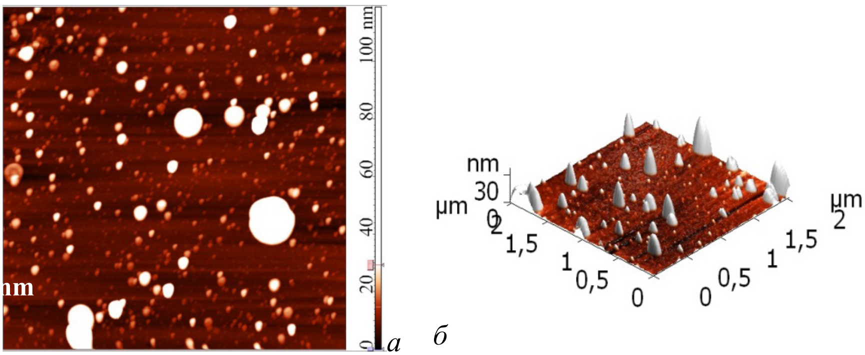

Figure 2: AFM images of the surface of yttrium vanadate thin film on silicon.

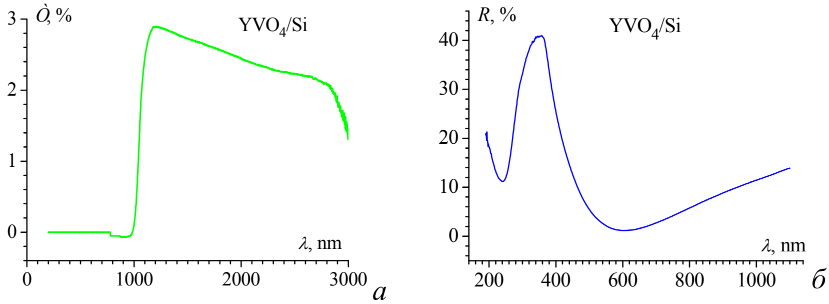

Figure 3: Transmission (a) and reflection (b) spectra of the yttrium vanadate film in the visible and near-infrared regions.

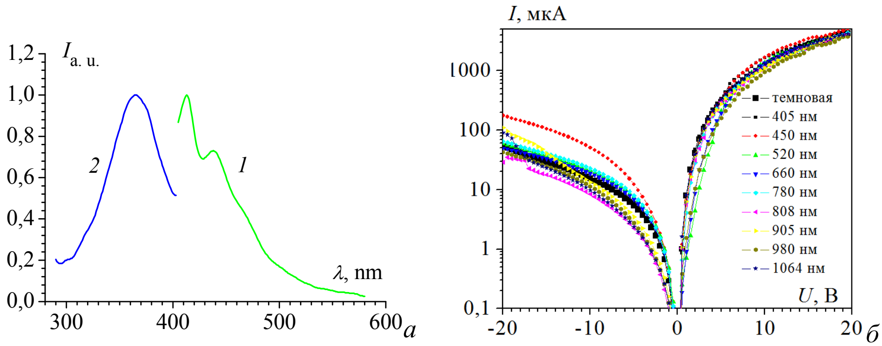

Figure 4: Spectra of luminescence (1) and luminescence excitation (2) of the YVO4 film on the silicon substrate (a). Volt-ampere characteristic of the yttrium vanadate thin film (b).

3. CONCLUSIONS

Films of yttrium vanadate oxide on a silicon substrate are obtained using high-frequency pulsed laser deposition and studied by different methods. The obtained films are characterized by both a finely dispersed structure with an average roughness of 50 nm and the presence of an insignificant number of large particles on the surface with a lateral size from 0.5 to 2.5 microns. Two minima are observed in the reflection spectrum (R1min = 11.2% at λ = 242 nm and R2min = 1.2 % at λ = 603 nm) and one maximum R1max = 41% at λ = 358 nm. At the wavelength of luminescence excitation, λ = 350 nm, the observed maxima in the luminescence spectrum are located in the region between 413 and 438 nm. The photoelectric effect and photoluminescence are caused by the introduction of yttrium or its complexes with oxygen into the film.

References

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