AFM INVESTIGATION OF HIGHLY ORDERED NANORELIEF FORMATION BY ANODIC TREATMENT OF ALUMINUM SURFACE

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AFM investigation of aluminum surface after anodic treatment was performed. It was shown that electropolishing in $HClO_4$ based solutions and long-time anodic oxidation result in formation of highly ordered nanorelief on the aluminum surface. Applications of such treatments in nano- and optoelectronics are discussed.

1 Introduction

Porous anodic alumina (PAA) films attracts an interest because of possibility of low-cost and short time production of highly ordered nanostructures. Possibility of magnetic [1], semiconducting [2] and photonic [3] nanostructure formation on the basis of PAA was demonstrated last decade. It is known that highly ordered PAA films may be formed on pretextured aluminum surface [4]. There are the two commonly used techniques of ordered nanorelief formation: by electropolishing in perchloric acid ethanolic solution [5] or by two-step anodization [6].

In this paper, we present AFM investigation of the above mentioned processes. An application of PAA for fabrication of magnetic nanocrystals and carbon nanotubes is demonstrated. A possibility of terabit memory production with PAA templates and nanomasks is analyzed.

2 Sample preparation

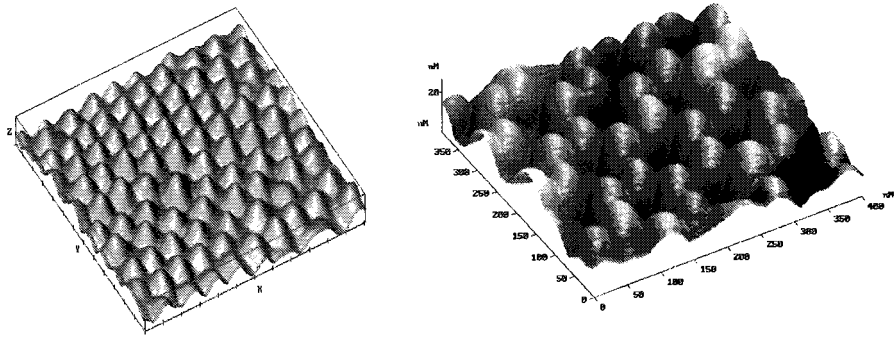
Two types of aluminum were used as a substrate for highly ordered nanostructure formation. (1) Al (99,99%) foil is used for electropolishing and two-step anodization experiments; (2) vacuum deposited Al film of 10 μm thickness is used

for the two-step anodization only. Electropolishing was performed in the solution (vol.%) $HClO_4$:C_2H_5OH:H_2O=6:80:14 at a constant potential 10-70 V during 20-60 s. The two-step anodisation was performed in 40 g/l oxalic acid aqueous solution at 10 mA/cm^2 current density. After both steps of processing the alumina film was etched in CrO_3 and H_3PO_4 mixture at 90 ^{0}C.

AFM investigation of aluminum surface was performed by scannicng probe microscope "Solver P47H" (NT-MDT Co., Russia) in the non-contact mode.

3 Results and discussion

AFM images of Al surface after electropolishing and anodic oxidation are presented in Fig. 1. The best results of electropolishing is obtained at 60 V etching potential for 30 s. As the result of this process 50 μm of Al was dissolved. The period of the nanopattern was about 80 nm independently on electrolyte concentration. Maximum height of the pattern was 4-6 nm.



(a) (b)

Figure 1. AFM images of Al surface produced by electropolishing (a) and anodic oxidation (b) recorded after removal of the oxide.

Long-time anodization of Al in the oxalic acid solution produces the nanorelief with 50 nm period and 20 nm height. An acceptable ordering was achieved during 1 h oxidation when 9 μm of Al was converted into oxide.

Comparison of the above mentioned techniques shows that long-time oxidation allows to form high contrast nanostructures with the lower Al consumption. Therefore, the second technique is more suitable for the formation of ordered nanostructures not only at a foil surface, but also at evaporated Al films.

Further anodization of the pretreated surfaces showed that the ordering degree is much higher at the long-time anodized surface. By our opinion this results from the large height of a nanorelief.

Additionally, we investigated features of nanoimprinted Al surface anodization. Nanoimprinting was performed by indentation of surface with the AFM tip.

Pyramidal pits of 20 nm were formed at the surface of annealed Al. This technique allowed us to form an individual carbon nanotube (CNT) in PAA template. CNT deposition was performed by commonly used PECVD process. Also, we formed the arrays of vertically aligned CNT in PAA with cathodically deposited and evaporated metal catalyst.

The ordered PAA back-side and structured Al surface were used to produce self-organized metal nanoparticles. We used Au or amorphous carbon as add-layer for deposition of Ti or Fe nanostructures. Both these metals have a weak wetting of the add-layer. The deposition was performed by a laser induced plasma deposition technique. In this process the energy of ions was about 20 eV. The highly ordered curved substrate surface defined position of the deposited clusters providing formation of highly ordered arrays of metal nanoclusters. A perspective application of such structures for terabit memory was demonstrated. For example, Ti nanoclusters covered by native oxide demonstrated irreversible transformation of I-V characteristics from barrier-like to the ohmic behavior after the action of current supplied by a tip of conductive AFM.

Thus, the results obtained show the possibility to apply Al for fabrication of large-area highly-ordered nanostructures.

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