ISSN 1027-4510, Journal of Surface Investigation: X-ray, Synchrotron and Neutron Techniques, 2024, Vol. 18, No. 2, pp. 333–347.

Development of Submicrometer Conical Surface Morphology on Nanometer-Thick Al–Fe Alloy Films under Various Conditions of Ion-Assisted Deposition onto Glass

I. I. Tashlykova-Bushkevich*

Belarusian State University of Informatics and Radioelectronics, Minsk, 220013 Belarus

**e-mail: iya.itb@bsuir.by*

Received August 28, 2023; revised October 25, 2023; accepted October 25, 2023

Abstract—The morphology, topography, and wettability with distilled water of Al–1.5 at % Fe alloy films with thicknesses of 25–90 nm are investigated. These films are formed on glass by ion-assisted deposition using a resonance ion source of vacuum arc plasma. Scanning probe microscopy reveals that the longitudinal and transverse roughness parameters, as well as dimensionless complexes, vary depending on the deposition mode and time. Measurement of these dimensionless parameters yields a quantitative description of cone formation processes in the Al–Fe/glass system. The mean roughness of the films increases in the range of 20–40 nm within the duration of deposition. Under self-irradiation conditions, the transition from island growth of the films to layered growth is observed. The effect of the substrate relief on the longitudinal step parameters of the film topography is found. Scanning electron microscopy is employed to examine the size and surface density of microdroplet-fraction particles. The size-frequency distributions of the microdroplet fraction are satisfactorily approximated by a lognormal distribution. Under self-ion irradiation conditions, 60–70% of particles comprising the microdroplet fraction are up to 0.8 μm in size. For the first time, a double Gaussian function is employed to approximate histograms of the distribution of relief features in the films, improving the accuracy in the description compared to a normal distribution law. The effectiveness of this approach in analyzing the structural formation of nanoscale films at various growth stages is demonstrated. By employing a bi-Gaussian model of the surface, the role of topographic characteristics in controlling the wetting of modified coatings is determined. The mechanism of the heterogeneous wetting of hydrophilic films in the Cassie state with contact edge angles of 50°–80° is discussed. In the potential mode, with an increase in deposition duration up to 10 h, the relief distribution of the films approximates a normal distribution, and the development of a submicrometer conical morphology on the surface leads to mixed wetting.

Keywords: ion-assisted deposition, scanning probe microscopy, scanning electron microscopy, roughness, wettability, hydrophilicity, Al–Fe alloys

DOI: 10.1134/S1027451024020198

INTRODUCTION

Optical films of metals on dielectric substrates, synthesized by ion-beam coating methods, find wide applications in technology, including solar photovoltaic devices, as well as nanoelectronics, microelectronics, and optoelectronics [1, 2]. Thin-film structures based on aluminum are employed as optical films and front contacts in solar cells [3–5]. A significant challenge is the exploration of ways to modify the characteristics of surfaces of thin metal coatings deposited under conditions of nonequilibrium solidification, to control their physical–chemical and service properties. Therefore, considerable attention is currently directed towards understanding the impact of deposition conditions on nanometer- and micrometer-scale heterogeneities in the surface relief of the coating–substrate system [6, 7]. In practical structural–morphological studies of sample surfaces, amplitude roughness parameters are often used, despite lacking information about the profile shape. At the same time, insufficient attention is given to the step parameters. Therefore, the determination of a universal set of discrete and integral parameters that accurately describe the nanostructure of real rough surface reliefs is relevant for studying the physical processes involved in the formation of the morphology of nanoscale films, as well as the operational behavior of products [8–10].

With a wide range of metal materials in use, the primary trends in industry currently focus on modifying known materials and improving synthesis processes rather than on developing new alloy compositions. The production of thin metal films using ion beams under nonequilibrium conditions at super-high cooling rates in the range of 10^{12}–10^{13} K/s enables the synthesis of structurally unique materials. The properties