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Special issue on surfaces patterned by ion sputtering

J Muñoz-García[1], R Cuerno[1], M Castro[2,3], L Vázquez[4], R Gago[4], A Redondo-Cubero[5]

[1] Departamento de Matemáticas and Grupo Interdisciplinar de Sistemas Complejos (GISC), Universidad Carlos III de Madrid, 28911 Leganés, Spain

[2] GISC and Grupo de Dinámica No Lineal (DNL), Escuela Técnica Superior de Ingeniería (ICAI), Universidad Pontificia Comillas, 28015 Madrid, Spain

[3] School of Mathematics, University of Leeds, UK

[4] Instituto de Ciencia de Materiales de Madrid (CSIC), 28049, Madrid, Spain

[5] Electronics and Semiconductors Group, Departamento de Física Aplicada, Universidad Autónoma de Madrid, 28049 Madrid, Spain

The production of self-organized nanostructures by ion beam sputtering (IBS) at low and intermediate energies (1–100 keV) has proved an efficient bottom-up technique suitable for many different types of materials. This remarkable universal tool is expected to be applicable in many fields of materials research such as optics, magnetism, or microelectronics, and different technological applications including biomedicine. Ever since the first reports on the ability of IBS to induce surface submicrostructures by Navez et al [1], a lot of work has been devoted to control the capabilities of this technique to produce surface nanopatterns and to understand the physical mechanisms involved in the process. Different experimental studies have revealed the formation of various types of patterns with wavelengths in the submicrometer scale [2, 3]. From the theoretical point of view, one should mention the crucial work by Bradley and Harper [4] which has just turned 30 years old and represented a pioneering effort in the modelling of this phenomenon. This work described the process mathematically through an evolution equation for the height of the irradiated target, which reflects the interplay between diffusive relaxation and a surface instability due to ion erosion, bringing IBS ripple formation into the general context of modern pattern formation theory. Another relevant landmark that represented a turning point on this topic was the observation of the key role played by metal incorporation in silicon (Si) and the absence of patterns for small incidence angles [5, 6, 7]. In order to convey a representative view of the state of the art at that time, a previous collection of research articles was published in this journal [8]. It is almost 10 years since that first special issue and there has been a large amount of novel and original results which have represented substantial further progress in this topic. Hence, it seemed convenient to repeat that experience and group together a number of international teams and some of the main current results on this topic. This collection contains a number of representative experimental and theoretical studies which indicate the main research lines towards which this field is directed. In some of these works theory and experiments are combined to gain further insight into the basic mechanisms operating in IBS, such as in [9] and [10]. In these cases Ar^+ ions with low energies are employed to study patterns formed on SiO_2 [9] and Si [10]. The experimental results are compared with predictions based on analytical descriptions and binary collision simulations in the initial linear stages [9], and with a nonlinear partial differential equation in the nonlinear stage [10], respectively. The mechanisms acting during IBS are also explored theoretically in [11]. Specifically, the suppression of pattern formation for all incidence angles at high energies under suitable conditions in the keV range is studied here using a viscous flow model, suggesting the stabilization of the surface for large dwell times (defined as the ratio between the ion induced fluid thickness and the erosion rate). Regarding the more purely experimental works contained in this collection, most of these articles extend the classical configuration of a single elemental target which is irradiated using noble gas ions, with the final aim to obtain reliable data on IBS patterning under different experimental conditions. Thus, different ion/target combinations have been explored. Likewise, the ion energy range considered spans from 200 eV up to 1 MeV. Also, different ion species have been used. Finally, various geometries and ion beam configurations have been studied. For example, in [12] and [13] semiconductor targets have been bombarded using metallic ions at medium energies. In [12] the morphology of germanium surfaces irradiated with 26 keV gold ions is studied, and in [13] Si targets are bombarded with iron ions. In both works, interesting results are reported on the existence of a threshold incidence angle for ripple patterning. The behavior of binary compounds at low energies using noble gas ions has been studied in [14] and [15] for the cases of molybdenum silicides and A_{III}-B_V semiconductors, respectively. Alternative irradiation setups are analyzed in [16], where the effects of two simultaneous ion beams or of altering the substrate orientation are studied. Other interesting expansions of pattern formation by IBS are explored in [17], where a polycarbonated target was irradiated with 40 keV Ar^+ ions, or in [18], which investigates the formation of ripples with large wavelengths, approximately from 4 μm to 8 μm, on SiO_2 with implanted Si^+ ions at high energies (1 MeV). Finally, some of the applications of IBS are also covered in this special issue. For example, in [19] self-organized ripple structures obtained by IBS are employed as templates for organic thin film growth. In this work the authors prove how altering the morphology of TiO_2 (110) surfaces the growth of conjugated molecules can be tuned. We consider that the articles included in this collection provide a representative view of the current status of the field and illustrate the way in which extended surface areas of very different materials can be nanostructured and modulated by IBS, altering some of their functional properties. However, much work has still to be done in order to completely unveil the potential and possible applications of IBS surface patterning and fully control and understand this process.

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