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Evolution of Pore Growth in GaAs in Transitory Anodization Regime from One Applied Voltage to Another

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Abstract—The paper reports the results of investigation of the pore growth during anodic etching of (111)-oriented wafers of Si-doped *n*-GaAs in an environmentally friendly NaCl based electrolyte, with switching the applied voltage from a high voltage to lower one and vice-versa. Switching of the applied voltage in the process of anodization was found to cause the formation of layered porous structures with different degrees of porosity. Crystallographically oriented pores shaped as triangular prisms were produced in a stationary regime of anodization, while a more complex morphology of pores was observed at the interface between the two layers with different degrees of porosity, including pores composed of three circular ones. Based on the results of the morphology study using scanning electron microscopy, a possible mechanism of the formation of such kind of pores in the dynamic transitory regime of anodizing is discussed.

Keywords: successive anodization, porous GaAs, crystallographically oriented pores, triangular shape, round shape

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INTRODUCTION

Porous templates with tailored architecture on the submicrometer scale are nowadays widely used in nanofabrication and production of various composite materials [1–4]. Among porous materials, semiconductor compounds provide a wide space for tailored nanofabrication, due to their diversity of compositions, bandgaps, and mechanisms of the pore growth [5]. Over the last two decades, it has been demonstrated that electrochemistry is one of the most accessible and cost-effective approaches for the fabrication of porous semiconductor materials with various morphologies and properties, which open large potential for applications [6–9].

It is worth to mention that semiconductor compounds have some important advantages in comparison with silicon. For example, (i) gallium arsenide has six times higher electron mobility than silicon, which allows a faster operation [7]; (ii) a wider band gap, which allows operation of power devices at higher temperatures and gives a lower thermal noise to low power devices at room temperature [10, 11]; (iii) the direct band gap provides conditions for the occurrence of more pronounced optoelectronic properties in GaAs than in silicon with its indirect band gap; (iv) GaAs can be alloyed to ternary or quaternary compositions adjusting in this way the width of the band gap, thus allowing light emission at chosen wavelengths.

The morphologies and properties of the produced porous semiconductor materials are determined by the mechanisms of the pore growth during electrochemical etching of the bulk semiconductor wafers [5]. Depending on the mechanism of growth, pores with different characteristics are formed in terms of their shape, velocity of growth, etc. On the other hand, the pore growing mechanism depends on the characteristics of the initial bulk semiconductor material and the specific anodizing conditions [12]. Usually pores grow perpendicular to the semiconductor surface. To make the porous nanotemplates perspective for nanofabrication processes, the authors developed methods for the preparation of templates with pores oriented parallel to the top surface of the substrate [13]. Such kind of porous structures are of pronounced interest for the fabrication of two-dimensional and three-dimensional photonic crystals including metallo-dielectric ones, since this geometry allows a wide implementation of structures due to a large surface of samples as compared to the geometry with pores propagating perpendicularly to the surface. Moreover, this approach provides conditions for reaching spectacular porous architectures by applying specially designed masks on the sample surface subjected to anodization [14].