Superlattices and Microstructures 38 (2005) 130–141

Superlattices and Microstructures

www.elsevier.com/locate/superlattices

Self-assembling of metal nanoparticles on patterned semiconductor surfaces (Au/GaAs)

T.R. Barlas*, N.L. Dmitruk, N.V. Kotova, O.I. Mayeva, V.R. Romanyuk

Institute for Physics of Semiconductors of NAS of Ukraine, Prospect Nauki 41, Kyiv 03028, Ukraine

Received 24 November 2004; received in revised form 15 March 2005; accepted 6 April 2005
Available online 15 June 2005

Abstract

The fabrication of selectively deposited arrays of metal nanoparticles on textured semiconductor surfaces is reported. Gold nanoparticles were grown on previously textured surfaces using photostimulated chemical deposition from an aqueous solution of $AuCl_3$ salt. Surfaces with random and periodic microreliefs were used as templates of sites for nanoparticle deposition. Dendrite-like and quasi-grating-like microreliefs were produced by anisotropic etching of GaAs (100) substrates. Periodic reliefs (diffraction gratings and bi-gratings) were fabricated by the holographic photochemical etching of the same substrates. Our results from AFM, SEM and EDX show that gold predominantly locates on the tops of the microreliefs. Since the surface relief strongly affects the topology of metal deposition, the use of microprofiling of semiconductor surfaces allows designing nanostructure deposition.

Keywords: Microrelief; Metal nanoparticles; Metal–semiconductor interface; Electroless deposition; Diffusion layer

* Corresponding author. Tel.: +38 044 5256546; fax: +38 044 5256486.
E-mail address: barlas@isp.kiev.ua (T.R. Barlas).

0749-6036/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.spmi.2005.04.003

1. Introduction

The formation of small metal particles on surfaces of various materials and self-assembling of them into a desired surface (2D) pattern has been the subject of many studies during recent years [1–3]. Highly ordered arrays of nanodots and nanorods [4] have attracted considerable attention, because these nanostructures show novel, size- and shape-dependent physical properties with potential applications in electronic and optical devices, biological labels, catalysts, sensors, etc. One of the perspective routes for the formation of linked nanoparticles structures is the use of templates onto which the particles can assemble in a pre-determined fashion. This approach, for example, allowed the obtaining of carbon nanotubes decorated by gold nanoparticles in [5], a system of aligned gold nanoparticles along friction transferred lines of PTFE on glass substrate [6], or pearl-necklace-type arrays of silver nanoparticles in polyethylene [7]. A possible way of forming self-organized nanostructures is the employment of high-index surfaces of single crystals with regular atomic steps as templates [8].

From a practical point of view regular 2D arrays of quantum dots and quantum wires are interesting for applications in some photonic devices. Recently the effect of electromagnetic coupling between the localized particle surface plasmon modes in nanolithography produced planar arrays of metal nanoparticles with subwavelength periods and evanescent surface plasmon polariton modes at the metal-dielectric interface was observed [9,10].

In this work photostimulated chemical (electroless) deposition [11] of Au from an aqueous solution of $AuCl_3$ salt for gold nanoparticle fabrication on semiconductor surfaces of different relief morphologies is reported. Self-organized formation of uniform surface structures of metal nanoparticles opens an elegant and efficient route towards the fabrication of large-scale arrays of uniform metal–semiconductor nanostructures. Our purpose was to affect the deposition process with the help of substrate surface relief and thus to control the shape and localization of the deposited assemblies of Au nanoparticles.

2. Experimental

The preparation of microrelief textured surfaces is a very important stage before nanoparticle deposition because the created microrelief serves as a matrix of sites for preferable nanoparticle localization on the semiconductor surface. As textured semiconductor surfaces we used both surfaces with periodical relief such as diffraction gratings and surfaces with random or pseudorandom surface roughness. In particular for textured surface fabrication the wet chemical anisotropic etching was used, when local removal of a single-crystalline material occurs due to the anisotropy of the dissolution rate in different crystallographic directions [12]. The advantage of an anisotropically etched surface lies in the formation of a controlled geometrical relief of the semiconductor surface without a subsurface damaged layer [13]. By using different etchants and varying the conditions of etching we gave the possibility to fabricate reliefs with essentially different morphologies on a semiconductor (GaAs) surface.