e-J. Surf. Sci. Nanotech. Vol. 7 (2009) 772-776 Conference - ISSS-5 -

Nanofabrication of Three-Dimensional Imprint Diamond Molds by ECR Oxygen Ion Beams Using Polysiloxane*

Shuji Kiyohara† and Tomoyuki Kashiwagi
Electric and Control System Engineering Course, Faculty of Advanced Engineering, Maizuru National College of Technology, 234 Aza Shiroya, Maizuru, Kyoto 625-8511, Japan

Hirofumi Takikawa
Department of Electrical and Electronic Engineering, Toyohashi University of Technology, Toyohashi, Aichi 441-8580, Japan

Yuichi Kurashima
Department of Mechanical Systems Engineering, University of Yamanashi, 4-3-11 Takeda, Kofu, Yamanashi 400-8511, Japan

Yoshio Taguchi and Yoshinari Sugiyama
Application and Technical Section, ELIONIX INC., 3-7-6 Motoyokoyama, Hachioji, Tokyo 192-0063, Japan

(Received 2 October 2008; Accepted 26 May 2009; Published 18 July 2009)

We have investigated the nanofabrication of three-dimensional (3D) chemical vapor deposited (CVD) diamond molds in Electron Cyclotron Resonance (ECR) oxygen ion beam etching technologies using polysiloxane $[\text{-R}_2\text{SiO-}]_n$ as an electron beam (EB) mask and a room-temperature (RT)-imprint resist material. The polysiloxane exhibited a negative-exposure characteristic and its sensitivity was 5.5×10^{-5} C/cm^2. The maximum etching selectivity of polysiloxane film against diamond film was 4.7, which was obtained under the following ECR oxygen ion etching conditions: ion energy of 400 eV, ion incidence angle of 0°, microwave power of 100 W, gas pressure of 1.4×10^{-2} Pa and stage temperature of 24°C. The diamond molds of cone and tetragonal pyramid dots were fabricated with polysiloxane mask in EB lithography technology using the RT-nanoimprint lithography (NIL) process. The dots are 500, 600, 700, 800, 900 nm in diameter and width respectively. The pitch between the dots is 2 μm, and each dot has a height of about 1 μm. It was found that the optimum imprinting pressure and its depth obtained after the press for 5 min were 0.5 MPa and 0.5 μm respectively. The resulting diameter of each imprinted polysiloxane pattern was in good agreement with that of the 3D-diamond mold. We carried out the RT-NIL process for the fabrication of diamond nanopatterns, using the 3D-diamond molds that we developed. [DOI: 10.1380/ejssnt.2009.772]

Keywords: Diamond; Nanofabrication; Ion etching; Lithography; Atomic force microscopy; Room-temperature imprint; Three-dimensional mold

I. INTRODUCTION

The nanopatterning technique of a diamond is essential to the fabrication of diamond-based micro/nano electronic, optical and mechanical devices. We have investigated the nanopatterning of chemical vapor deposited (CVD) diamond films in room-temperature nanoimprint lithography (RT-NIL), using a diamond mold. The diamond mold has a lifetime about 100 times longer than that of silicon dioxide (SiO_2) mold or that of silicon (Si) mold, both using a conventional NIL process. The reason for the longer lifetime is that diamond has many unique properties such as hardness, high thermal conductivity and low thermal expansion [1–3]. The diamond mold has been fabricated by radio frequency (RF) oxygen plasma with $Bi_4Ti_3O_{12}$ octylate mask in the electron beam (EB) lithography technology that we developed [4, 5]. However, the maximum etching selectivity (diamond/$Bi_4Ti_3O_{12}$ octylate films) of 3 is very small. To overcome this problem, we have proposed the use of polysiloxane $[\text{-R}_2\text{SiO-}]_n$ (Hitachi Chemical Co., Ltd., Japan, HSG-R7-13), which has resistance to oxygen ion beams, as EB mask and RT-imprint resist materials in order to form an oxide film on surface and high viscosity. Compared to the conventional NIL process using PMMA [poly(methyl methacrylate)] which requires a thermal cycle, the RT-NIL process using polysiloxane has certain advantages, including short steps, high throughput and low cost [6–8].

Here we shall report the nanofabrication of three-dimensional (3D) diamond molds in EB lithography technology using polysiloxane and the electron cyclotron resonance (ECR) oxygen ion beam etching resistance of a polysiloxane film. We have investigated the optimum conditions for RT-NIL using fabricated 3D diamond molds.

II. EXPERIMENTAL APPARATUS AND PROCEDURE

A. Nanofabrication of 3D diamond molds

A polished polycrystalline diamond film (thickness, 12 μm; surface roughness R_a, 1.5 nm) synthesized by CVD method on Si substrate ($10 \times 10 \times 3.2$ mm^3) was used as

* This paper was presented at International Symposium on Surface Science and Nanotechnology (ISSS-5), Waseda University, Japan, 9-13 November, 2008.

†Corresponding author: kiyohara@maizuru-ct.ac.jp

