



ELSEVIER

Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

Optics and Lasers in Engineering 43 (2005) 1322–1329

OPTICS and LASERS
in
ENGINEERING

XRD studies on the femtosecond laser ablated single-crystal germanium in air

Myung-IL Park^{a,b}, Chang Soo Kim^c, Chong-Ook Park^a,
Sae Chae Jeoung^{b,*}

^a*Department of Materials Science and Engineering, Korea Advanced Institute of Science and Technology, Daejeon 305-701, Republic of Korea*

^b*Laser Metrology Lab., Optical Nano Metrology Group, Korea Research Institute of Standards and Science, Daejeon 305-304, Republic of Korea*

^c*Materials Evaluation Group, Korea Research Institute of Standards and Science, Daejeon 305-304, Republic of Korea*

Received 1 September 2004; received in revised form 1 November 2004; accepted 1 December 2004

Available online 7 April 2005

Abstract

Ultrashort laser ablation of single-crystal germanium has been performed in air with femtosecond laser pulses (150 fs, 1 kHz) of 810 nm in the laser fluence range of 0.7–35.4 J/cm². Ablation depth dependence on the laser fluence shows that there are two different processes, which are explained in terms of electronic heating process and the optical penetration one. Structure of ablated region is characterized by means of two different XRD techniques. With increasing the laser fluence higher than 10.2 J/cm², the laser-processed region of germanium exhibits poly-crystalline diffraction peaks in a wide-angle ($\theta/2\theta$) scan and a split of diffraction peak of (400) plane in the rocking curve, which are absent in the lower laser fluence. These observations could be explained in terms of structural changes induced by ultrashort laser irradiation at the higher laser fluence.

© 2005 Elsevier Ltd. All rights reserved.

Keywords: Femtosecond laser; Ablation; XRD; Germanium

*Corresponding author. Tel.: +82 42 868 5211; fax: +82 42 868 5188.

E-mail address: scjeoung@kriss.re.kr (S.C. Jeoung).

1. Introduction

The rapid advances in the generation and amplification of ultrashort laser pulses (≤ 1 ps) have opened up many new possibilities in materials processing [1,2]. The extreme short pulse width makes it easy to achieve very high peak laser intensity with low average power. The distinctive features of ultrashort laser ablation have further stimulated much interest on ultrafast laser–matter interactions [3,4]. Much attention has been paid to investigate the laser-induced damage after irradiation in order to develop a better quality in the laser processing. In particular, several studies led us to have deeper understandings on the structural transformation in semiconductor surfaces using scanning electron microscope (SEM) and pump-probe technique with comparatively longer duration pulses [5–7]. Recently, it has been reported that the damage morphology of germanium (Ge) surface demonstrates recrystallization through ultrafast cooling [8]. However, there has been no attempt to analyze the crystal structure of damaged surfaces of Ge as a function of laser fluence.

Ablation characteristics as a function of the laser fluence show that there are two different ablation regimes, which are explained in terms of the thermal diffusion length of the electrons and the penetration depth of the laser light. These phenomena are frequently invoked for other solid materials [9–11], where the two-temperature diffusion model for the electrons and lattice is used to explain the observation.

In this work, we present the results of the ablation depth measurement and the structural changes of Ge (100) single crystal as a function of laser fluence. Two X-ray diffraction (XRD) methods including $\theta/2\theta$ scan and rocking curve (ω -scan) were used to examine the structural properties of Ge samples irradiated by femtosecond laser. While it is often claimed that femtosecond processing of material is characterized by energy localization after laser deposition, we found that this effect might not be generally true for Ge in the extremely high fluence region.

2. Experimental

The ablation of Ge (100) single crystal with diamond cubic structure was conducted by irradiation of Ti:sapphire laser (Quantronics, USA) in air. This laser delivers pulses with energy of up to 1 mJ at 800 nm and a repetition rate of 1 kHz. The fundamental output of the laser was delivered to the galvanometer scanner (Scanlab AG, Germany), which is connected to the IBM compatible PC. Fast optical shutter with a rising time less than 0.5 ms was interfaced to the same PC in order to control the laser exposure. A variable neutral density filter was used to attenuate laser fluence from 0.7 to 35.4 J/cm². The relative error of the fluence determination amounts to $\pm 5\%$. A telecentric lens (Sill Optics, Germany) with a focal length of 85 mm was employed to focus the laser beam on the substrate. A Gaussian spatial beam profile with a radius ($1/e^2$) of ~ 40 μm in the spot was achieved. The pulse width of 160 fs observed after passing a focusing optics was almost equal to that of the fundamental output of about 150 fs [12].

Download English Version:

<https://daneshyari.com/en/article/10408839>

Download Persian Version:

<https://daneshyari.com/article/10408839>

[Daneshyari.com](https://daneshyari.com)