Anisotropic Texturing Amorphous Silicon Thin Films by Femtosecond Laser Irradiation

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Abstract— Femtosecond laser treatment allows to fabricate periodic structures at amorphous hydrogenated silicon surfaces on areas more than a square millimeter. The period of the structures is near the laser wavelength and determines by the nonequilibrium electrons concentration at high power laser excitation. The obtained structures possess a pronounced electrophysical anisotropy.

Keywords— amorphous silicon; femtosecond laser treatment; surface plasmon-polaritons; laser-induced periodic surface structures; nanocrystallization; artificial anisotropy

I. Introduction

Direct laser writing is an effective technique to fabricate surface structures with wavelength and subwavelength accuracy. One of realizations of such approach is the laser-induced periodic surface structures (LIPSS) formation via femtosecond laser irradiation where intensive surface photoexcitation results to surface plasmon-polariton generation not only in metals but also in semiconductors due to electron-hole plasma generation [1, 2]. Such surface electromagnetic waves give a contribution to the periodical relief modulation and corresponding ripple formation at the irradiated surfaces. In particular, because of femtosecond laser pulses irradiation of amorphous silicon films and corresponding LIPSS formation, strong optical [3] and electrophysical anisotropy [4] may emerge in plane of a sample. Thus, it is a promising way to fabricate compact devices of optical memory and photovoltaic which are polarization and applied current sensitive, respectively.

II. Results and Discussion

The present work describes main features of the LIPPS texturing at hydrogenated amorphous silicon surfaces under femtosecond laser action with the wavelength of 1030 nm or 1250 nm when the pulses number are varied in the range of 50–1000 at different energy fluences. It allows to fabricate ripples with the period from 880 to 1250 nm and the orientation perpendicular or parallel relative to the laser radiation polarization. Using mechanical translators and a galvanometric scanner we obtained relatively large areas (1 mm x 1 mm and more) with LIPSS and a good quality for the applications.

To explain the observed ripple evolution, we used the model proposed by J.E. Sipe [5] where the efficacy factor depends on the real and imaginary parts of the dielectric constant and determines the LIPSS wave vector on the irradiated surface [2]. In turn, according to the Drude model the dielectric constant complex value is varied due to concentration change for the nonequilibrium electrons excited by different number of high-power femtosecond laser pulses.

The modified surfaces are characterized by the high level of nanocrystallization. According to Raman spectra analysis the volume fraction of nanocrystals in the irradiated films ranges from 17% to 70% depending on the treatment conditions. The silicon nanocrystal presence leads to growth of the specific conductivity up to 3 orders for the irradiated samples in comparison with non-irradiated ones. The in-plane conductivity anisotropy was revealed too [4]. This result is in a good agreement with the Bruggeman model [6] and spectra of absorption for the surface possessing artificial anisotropy.

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