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ЛАЗЕРНАЯ МОДИФИКАЦИЯ И ОБРАЗОВАНИЕ ПЕРИОДИЧЕСКИХ ПОВЕРХНОСТНЫХ СТРУКТУР В АМОРФНЫХ МАТЕРИАЛАХ ФАЗОВОЙ ПАМЯТИ $Ge_2Sb_2Te_5$

LASER-INDUCED MODIFICATION AND FORMATION OF PERIODIC SURFACE STRUCTURES OF AMORPHOUS $Ge_2Sb_2Te_5$ PCM MATERIALS

Козюхин С.А.[1,2], Лазаренко П.И.[3], Смаев М.[4,5], Воробьев Ю.[6], Глухенькая В.[3], Зыбина Ю.[3], Козик В.В.[2], Сигаев В.Н.[4]

Kozyukhin S.A.[1,2], Lazarenko P.I.[3], Smayev M.[4,5], Vorobyov Yu.[6], Glukhenkaya V.[3], Sybina Yu.[3], Kozik V.V.[2], Sigaev V.N.[4]

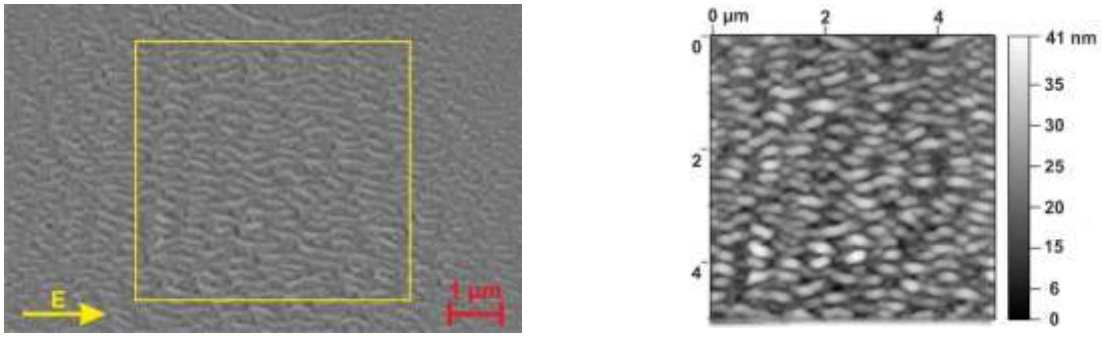
[1]Kurnakov Institute of General and Inorganic Chemistry, RAS, Moscow, Russia.
[2]National Research Tomsk State University, Tomsk, Russia
[3]National Research University of Electronic Technology, Zelenograd, Moscow, Russia
[4]Mendeleev University of Chemical Technology of Russia, Moscow, Russia
[5]Lebedev Physical Institute, RAS, Moscow, Russia
[6]Ryazan State Radio Engineering University, Ryazan, Russia,
e-mail: sergkoz@igic.ras.ru

В работе представлены результаты по модификации аморфных пленок материалов фазовой памяти состава $Ge_2Sb_2Te_5$ (GST225) с использованием лазерных импульсов фемто-и наносекундной длительности. Показано, что в режиме предабляционного облучения на поверхности аморфной пленки возможно образование периодических структур типа рипплов, имеющих двухфазную (аморфную и кристаллическую) структуру. Установлены характеристики данных структур и их зависимость от параметров лазерного облучения – числа импульсов, поляризации светового луча, плотности энергии лазерного импульса; предложена теоретическая модель для объяснения эффекта появления двухфазных структур в рипплах.

Ultrashort laser irradiation is proven as an alternative to lithography to nano-structure surfaces of various materials via formation of laser-induced periodic surface structures (LIPSS) or ripples [1]. In this work, our efforts were focused on the study of LIPSS formation with the periodicity of the order of laser wavelength on surfaces of $Ge_2Sb_2Te_5$ (GST225) amorphous thin films. GST225 composition is one of the extensively investigated phase change memory (PCM) materials, which is currently used for rewritable data storage applications based on structural phase transitions. In addition, we studied the processes of laser crystallization and laser amorphization of GST225 thin films under ultrashort pulsed irradiation.

The GST225 amorphous thin films have been prepared by *dc* magnetron sputtering. We used a Yb:KGW femtosecond laser with wavelengths λ=515 and 1030 nm, pulse duration of 600 fs, and repetition rate of 200 kHz to study surface modification. We used such methods as XRD, EDX, SEMS to perform a phase and elemental analyses for as-deposited films; Raman spectroscopy and transmission/scanning electron microscopes (TEM/SEM) were utilized to study the LIPSS.

It is shown that, with specially selected parameters of the laser irradiation (laser pulse fluence *F*, number of pulses *N*, and light polarization), it is possible to realize LIPSS formation with the periodicity of the order of laser wavelength in the pre-ablation regime. The characteristic feature of the surface nano-structures is the presence after the laser action of the periodic modulation of the refractive index of the ridges and valleys of the gratings due to different phase states whose dielectric constants differ greatly from one another (Fig.1). The formation of LIPSS originates from the interference of the incident light with surface electromagnetic wave excited by irradiation. We used the model of heterogeneous crystallization for objects with different surface curvatures to explain the observed effect of the phase transformation in laser-induced periodic surface structures.



a b

Fig. 1. Images of the illuminated mark for F = 5 mJ/cm^2, N = 10^4: a – SEM image of LIPSS; b – AFM scan image

We obtained LIPSS in the form of near-subwavelength ripples (NSRs) of two types: *i*) ripples that are formed parallel to the light field polarization with Λ/λ=0,45 and H ~10 nm at "low" energy fluence, N=10^4 pulses, and *ii*) ripples that are oriented perpendicular to the electric field of the incident beam with Λ / λ ~ 1 and H ~15 nm at "high" fluence, N=10^2 pulses. The specific LIPSS and ripple orientation with respect to the optical field depends on the irradiation conditions. It was found with use of HRTEM that the fraction of the crystalline phase is higher in the ridges of the ripples compared to the valleys. We identified the crystalline phase using Fourier transformation. The results of qualitative analysis lead us to the conclusion that crystallization practically did not occur in the valley of LIPSSs under laser influence. We used the model of heterogeneous crystallization for bodies with different curvatures of the boundary surface to explain the observed effect of the phase transformation in LIPSSs.

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СУПЕРГИДРОФОБНЫЕ МЕЗОПОРИСТЫЕ КОМПОЗИТЫ Fe_2O_3 –SiO_2: СИНТЕЗ И СВОЙСТВА
SUPERHYDROPHOBIC MESOPOROUS COMPOSITES OF Fe_2O_3 –SiO_2: SYNTHESIS AND PROPERTIES

Кондрашова Н.Б., Шамсутдинов А.Ш.
Kondrashova N.B., Shamsutdinov A.Sh.
Пермский федеральный исследовательский центр Уральского отделения Российской академии наук, Пермь, Россия
e-mail: Kondrashova_n_b@mail.ru

Methods for obtaining iron-containing silica composites Fe_2O_3 – SiO_2 with an organized mesoporous structure (MCM-41) and high specific surface area (up to 1476 m^2 · g^{-1}) are considered. The influence of the method of synthesis of materials on their structure, particle size, textural and magnetic characteristics was studied. The effect of processing the obtained composites with a solution of polymethylsiloxane on their hydrophobic properties is shown.