The Features of Photolithography Process Based on Reversible Photostructural Changes in Germanium Chalcogenides

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Photoinduced structural transformations of chalcogenide glasses (ChGs), which lead to changes of their properties (optical characteristics, conductivity, solubility in selective etchants, and even mechanical characteristics), are a basis for wide practical use of GhG films, glasses and fibers. For example, the use of GhG films as a photoresist was based on irreversible change that observed in the thermally deposited films only. In annealed ChG films transient photostimulated structural changes, which exist during illumination, and a small reversible changes after the exposure are observed.

Recently we reported that both the reversible and the transient structural changes are accompanied by a change in the solubility of ChG films, and negative amine-based etchant dissolve illuminated areas of chalcogenide films, i.e. act as positive etchants. But etching selectivity of the annealed films was strongly dependent on the intensity of exposure [1]. Here we present the results of more detail investigations of this phenomenon. The samples for study were prepared by successive thermal evaporation in vacuum at a residual pressure of 2×10^{-3} Pa, with a 40-nm thick adhesive layer of Cr and $GeSe^3$ layer with thickness 200 nm, deposited onto substrates. Deposited films were annealed for 1 h near glass transition temperature (T_g). Then the samples were irradiated with light pulses of the variable intensity and duration (focused argon ion laser beam, $\lambda = 476.5$ nm, the shutter and neutral density filters were used also) while the exposure was maintained a constant. After exposure the samples were treated in amine-based etchant and studied using microinterferometer MII - 1. It has been found that the dependence between the rate of etching of the irradiated areas of the sample (or the etching selectivity) and the light intensity is nonlinear. Selective etching is observed only at intensities exceeding a certain threshold value. Selectivity wasn't observed in the samples which were annealed repeatedly after exposure at the temperature close to Tg, and appeared again after next exposure (after repeated annealing) at the same conditions. After detail examining of exposure-annealing cycles that were carried out in the same conditions for several times, we have concluded that this selective etching is related to the reversible photostructural changes that occur in annealed ChG films. Selectivity didn't observe in the samples which were annealed repeatedly after exposure at the temperature near T_g, and appeared again after repeated exposure (after repeated annealing) at the same conditions. After detail examining of exposure-annealing cycles that were repeated under the same conditions several times, we have concluded that this selective etching is related to the reversible photostructural changes that occur in annealed ChG films.

The results of this experiment allowed us to develop the new photolithography method on annealed ChG films, which is effective for creating of relief micro- and nanostructures of high quality with deep relief [1].

1. Indutnyi I.Z., Kryuchyn A.A., Borodin Yu. et al. Reestraciya, zberigannya i obrobka danyh. – 2013. Vol.15, №4. – P. 3-12.