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BRIEF COMMUNICATIONS

On the Stability of the Optical Properties of an Antireflection Coating for Solar Cells Based on a Mixture of Germanium with Germanium Oxide

V. G. Dyskin[a], * and M. U. Dzhanklych[a]

[a] *Institute of Materials Science SPA Physics–Sun, Uzbek Academy of Sciences, Tashkent, 100084 Uzbekistan*
**e-mail: dyskin@uzsci.net*

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Abstract—The paper presents the results of measurements of coating reflection coefficients. These coatings are based on a mixture of germanium with germanium oxide deposited on a silicon surface. The volume concentration of Ge in GeO_2 is 20 and 30%. The spectral reflection coefficient of the coating with a volume concentration of 20% has not changed for 11 years. The reflection coefficient of the coating with a concentration of 30% in the range of 400–600 nm has decreased by an average of 5%. The antireflective effect of both coatings is preserved. The coating based on a mixture of germanium and germanium oxide with a volume concentration of 20% is stable and can be recommended as an antireflection coating for solar cells.

Keywords: stability, solar cell, antireflection coating, mixture, transmittance, reflectance

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An urgent task of modern photovoltaics is to reduce the cost of solar cells and to increase their efficiency and service life. The profitability of solar cells is determined by their operating time, which depends on the stability of solar cells (SCs). It is clear that the invariability of SC parameters is determined by the stability of its constituent elements: the collector grid, antireflection coating, *p–n* junction, etc.

In the manufacturing of SCs they are glued to sheet glass, which protects their surface from aggressive environmental influences. Therefore, a change in the optical properties of the antireflection coating can occur both inside the coating itself and at the boundary of the contact of the coating with the semiconducting material of the SC or an adhesive. Experience shows that over time, unstable antireflection coatings acquire a "spotty" and/or fractal structure, and peel off from the substrate (Fig. 1). Therefore, the creation of effective and stable antireflection coatings for SCs is an urgent task [1, 2]. Oxides, sulfides and nitrides of silicon, zinc, rare earth metals, etc., are used as the material of antireflection coating for SCs. The optical and operational characteristics of these materials are well studied [1–3].

Germanium, along with silicon, is widely used in microelectronics, optoelectronics, and photovoltaics. For example, in thin films of germanium oxides GeO_2 and GeO_x a memristive effect was found [4]. It was suggested that Ge and GeO_2, as anode materials, can greatly increase the capacity of lithium-ion batteries [5]. In solar energy, germanium is used both as a single-junction SC and as part of a cascade SC. Germanium and a mixture of germanium with its oxide were used as antireflection coatings for silicon SCs [6, 7].

For texturing the silicon surface, germanium was used in [6]. An anti-reflective germanium coating was applied at an angle of 75°–80° to the normal to the surface of the silicon substrate. Regular structures were obtained on the silicon surface, which were visible in the form of dots in the field of view of an MII-4 microinterferometer. As a result of surface texturing, the integral reflectance of silicon decreased by 64.0%, and the short-circuit current density increased by 29.0% [6].

It was previously reported that films based on a mixture of germanium with germanium oxide (Ge/GeO_2) [7]. In 2010, based on the results of computer simulation from a Ge/GeO $mixture_2$ tablets with a volume concentration of germanium of 20 and 30% were prepared. The application of antireflection coatings on glass and silicon wafers was carried out on a UVN-71P-3 vacuum unit. Ionic cleaning lasted for 5 min, the residual pressure in the chamber was 6.67×10^{-4} Pa and the deposition rate was ~2 nm/s. The samples were stored in the laboratory in boxes for silicon wafers. During storage, the appearance (Fig. 2) and

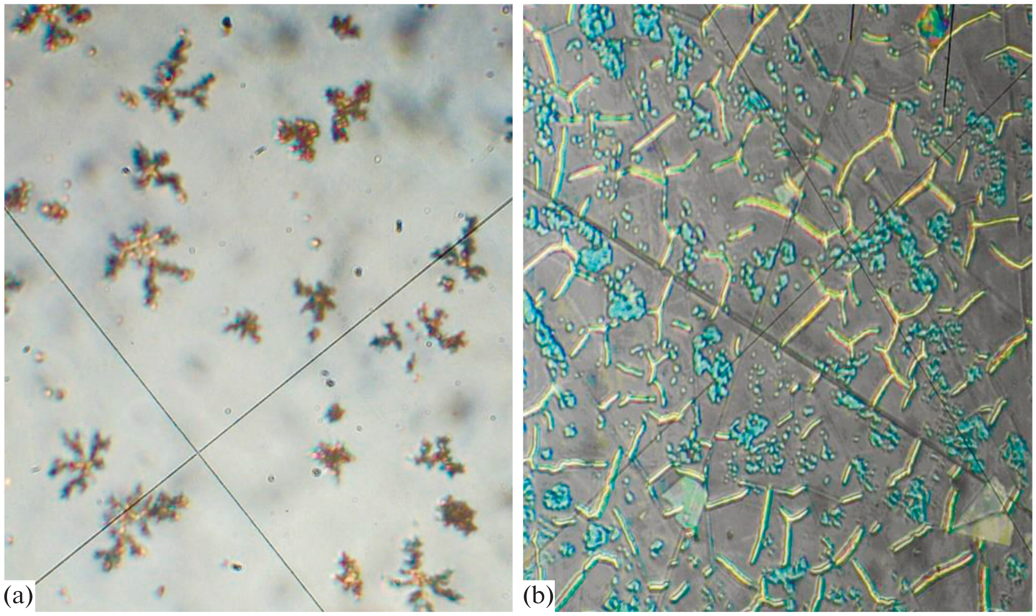

Fig. 1. Photo of the surface of an unstable antireflection coating on glass (a) and on silicon (b). Coating mixture of Ag with SiO_2.

the structure of the coating did not change (visual inspection and inspection of the surface on an MII-4 microinterferometer). The reflectance and transmission spectra both in 2010 and 2021 were measured on a FO-1 photometer and a Lambda EZ-150 spectrophotometer.

The transmission spectra of antireflection coatings (not shown) are practically identical and indicate that the coatings retained transparency in the spectral sensitivity region of silicon. The reflection coefficients of the samples averaged over several measurements are shown in Fig. 3. It can be seen that over 11 years of storage, the reflection coefficient of the coating with a volume concentration of germanium of 20% did not change. The reflection coefficient of the coating with a volume concentration of germanium of 30% in the spectral range from 400 to 600 nm decreased by an average of 5%, i.e., the coating is unstable. As a result of computer simulation, the assumption that the decrease in the reflection coefficient is due to a change in the optical constants of the film was not confirmed.

Fig. 2. Photo of the surface of the Ge/GeO_2 antireflection coating on silicon.

CONCLUSIONS

Based on the results of measurements of the optical characteristics of coatings based on a mixture of germanium with germanium oxide deposited on the silicon surface in 2010, it can be concluded that:

(1) Spectral reflectance of the coating with a GE volume concentration of 20% in GeO_2 remained practically unchanged.

(2) The reflection coefficient of the coating with a volume concentration of 30% in the spectral range of 400–600 nm decreased by an average of 5%.

(3) The antireflection effect was preserved for both coatings.

(4) Ge/GeO_2 coating with a volume concentration of 20% is stable and can be recommended as an antireflection coating for SCs and solar panels.

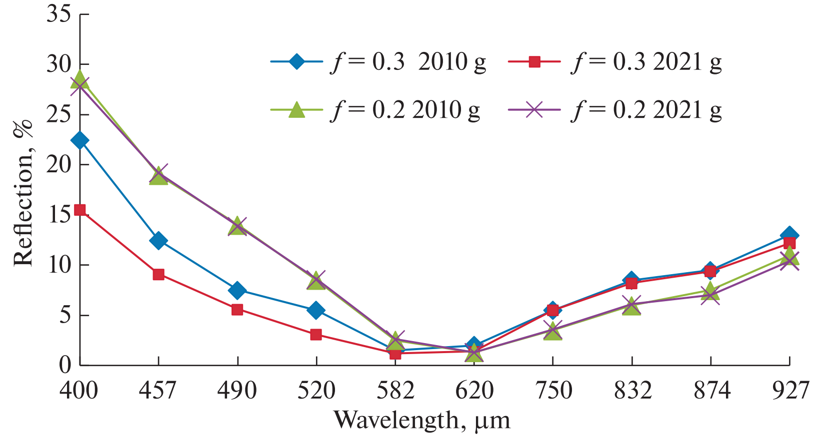

Fig. 3. Spectral reflectance of the Ge/GeO_2–Si system.

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CONFLICT OF INTEREST

The authors declare that they do not have a conflict of interest.

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