DOUBLE-LAYER DIAMOND-LIKE CARBON ANTIREFLECTION COATINGS FOR GaAs SOLAR CELLS

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1. Introduction

There are many methods for improvement of performance of semiconductor solar cells (SC). One of them is the reduction of reflectance from SC surface. For this purpose different type thin-film coatings are used. Such an approach leads to enlargement of the absorbed part of solar irradiation in the whole optical and near IR regions when the corresponding antireflection coating (ARC) with appropriate refractive index (n) and layer thickness (d) is chosen.

GaAs has received attention for photovoltaic applications because this material is direct band gap semiconductor with a near optimal bang gap values for solar photovoltaic conversion and with high stability; thereof such solar cells have found wide application in solar space systems. On the other hand, it is necessary to improve the radiation resistance of GaAs-based SC when it operates in space. The main reason for space SC efficiency degradation is “solar wind” proton and electron irradiation, the action of which leads to the reduction of the carrier concentration in the base region, in addition to the decrease in the carrier lifetime [1]. Therefore for long time operation the space solar cells must be covered by coverglass or protective films which must be characterized by radiation protection and improvement of SC optical and thermal properties and be radiation stable themselves. The coverglass thickness is typically of about a few hundred micrometers. It is very important to reduce the SC weight, especially for space applications. To achieve this aim, relatively thin protective film must be applied. For such purpose diamond-like carbon (DLC) films are very promising coatings. The advantage of DLC films are their high hardness, chemical and radiation stability as well as the possibility to change their optical properties by varying the deposition conditions [2-4]. The latter enable to form multi-layer coatings which satisfy the requirement for optimal antireflection and protection of SCs simultaneously.

Therefore, in this paper we investigate the possibility of application of diamond-like carbon films as antireflection coatings for GaAs-based SCs.

1. Results and discussion

To carry out the calculation of reflectance spectrum of double-layer DLC ARC for GaAs SC, the optical matrix approach method was used [5,6]. This method allowed us to calculate the reflectance spectrum of different type ARC for silicon solar cells with high accuracy [7-13]. Besides, this method allows us to estimate the reflectance spectrum of any material-based solar cells by interposing the corresponding refractive index of material in which we are interested.

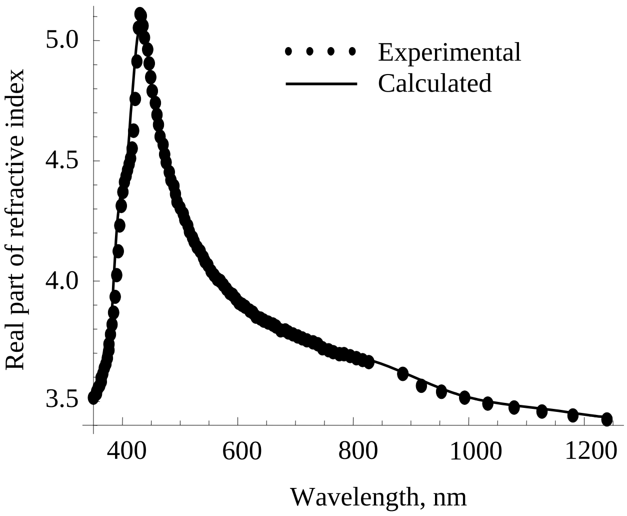

Fig. 1 Real part of the refractive index of GaAs.

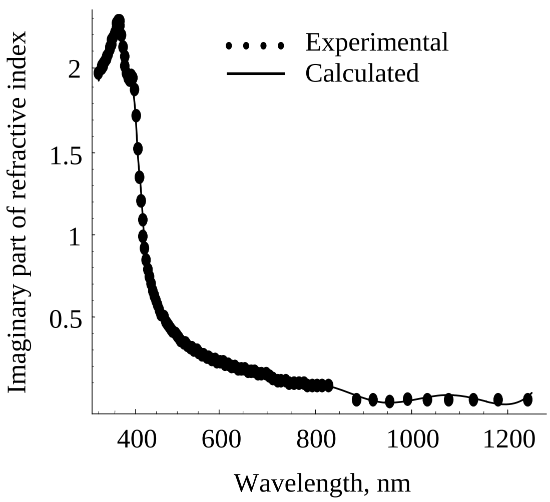

Fig. 2 Imaginyart of the refractive index of GaAs.

Therefore, before the estimation of reflectance spectra of double-layer DLC ARC for GaAs SC the simulation of real and imaginary parts of the refractive index of GaAs was carried out by the “Mathematica 5.1” software. Results of simulations are shown in Fig.1 and Fig.2. As can be clearly seen from these figures, the results of simulation coincide with the experimental data. Therefore we can use obtained results for calculation of the reflectance spectra for different type ARC for GaAs solar cells.

To obtain the optimal values of refractive indices and thicknesses of DLC layers, the simulations have been carried out for several values. Results of our simulations show that increase in the refractive index of the top layer at the fixed refractive index of the bottom layer and thicknesses of all layers leads to a formation of maximum on the reflectance curve near the wavelength 500 nm, at which the maximum of solar irradiation occurs. This implies that application of ARC with such parameters will not be effective. Further simulations showed that the growth of the value of the refractive index of the top layer when other parameters remain fixed leads to an increase in the maximum observed in the reflectance curve and its shift to the long-wavelength region. Hence, it is necessary to treat to careful possible application of top layers which have small thicknesses and high refractive index. Small increase in the thickness of the top layer at fixed values of the thickness of the bottom layer and refractive indices of all layers leads to a decrease in the reflectance of such constructions. Therefore, it is necessary to choose a bottom layer with large thickness. The same characteristics are obtained when parameters of the bottom layer are a subject of change. An increase in the values of the refractive index and thickness of the bottom layer at fixed values of the top layer leads to a decrease in value of the reflectance maximum at the wavelength 500 nm. At the appropriate low value of the refractive index of the top layers and large values of the bottom layer refractive index and large thicknesses of all layers it is possible to reduce the reflectance value near the wavelength 500 nm.

The best simulations results have been obtained at the following parameters of layers: refractive indices n_1=1.5, n_2=2.8, and thicknesses d_1=90 nm, d_2=41 nm (Fig. 3). As can be clearly seen from Fig. 3, it is possible not only to preserve a low reflectance in the mid-IR and visible regions of solar irradiation but also to enlarge it to the short-wavelength (UV) region of spectrum. Therefore, application of double-layer ARCs proposed by us in GaAs solar cells will be effective.

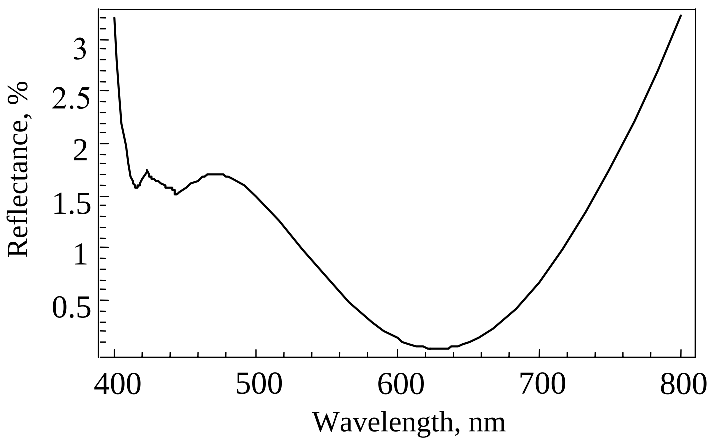

Fig. 3. Reflectance spectrum of double-layer DLC ARCs.

3. Conclusion

Calculations of the reflectance spectrum of double-layer DLC antireflection coatings have been carried out, using the optical matrix approach method and the “Mathematica 5.1” software. Obtained results showed a much lower reflectance with a large energy range including the short-wavelength, visible, and infrared regions of the solar spectrum.

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