I-Photonics

Anti-reflective coatings for infrared applications on IG6 substrates

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Abstract

Chalcogenide glasses, due to their unique optical properties, open new prospects for infrared optics in various fields of industry and science. This paper presents a technology that has been developed to overcome the long-term problems associated with the adhesion of coatings to glass and contributes to the development of more durable coatings. The new technology has been proven through successful environmental testing and promises to significantly improve capabilities in the field of infrared optics.

Keywords: electron beam evaporation, anti-reflective coatings, adhesion, IG6.

1. Introduction

Infrared optics play an important role in a wide range of industrial sectors, including defense, space, automotive, communications and healthcare. IR devices measure temperature by detecting emitted and reflected infrared radiation from a surface. The warmer an object is, the more infrared radiation it emits. IR cameras detect this radiation and convert it into an electronic signal to create a thermal image. One of the main features is a material that can transmit detectable radiation wavelengths. In this regard, chalcogenide glasses, which are characterized by ease of formation, high refractive index, low phonon energy, high nonlinearity and low weight, are used more widely. Chalcogenides also have the advantage of high transmittance across the entire IR range, and due to their low index variation with temperature DN/DT they are ideal for optically athermic infrared lenses. The main challenge for manufacturers over the years remains the task of creating high-strength coatings on chalcogenide glasses with high adhesion due to the thermal coefficient of expansion and a limited number of materials operating in the IR range. To overcome these challenges, I-Photonics has developed a chalcogenide glass coating technology that demonstrates impressive results. This technology allows the creation of coatings with excellent characteristics and a high durability. Moreover, these coatings have successfully passed environmental tests (meeting MIL-C-675C, MIL-C-14806A and MIL-C-48497A standards), confirming their reliability and effectiveness.

2. Experiment

Deposition of coatings was performed on the ORTUS-700 vacuum coater of the company I-Photonics (Fig 1.). ORTUS is a family of coaters based on electron beam evaporation technology with ion assistance (IBAD technology).

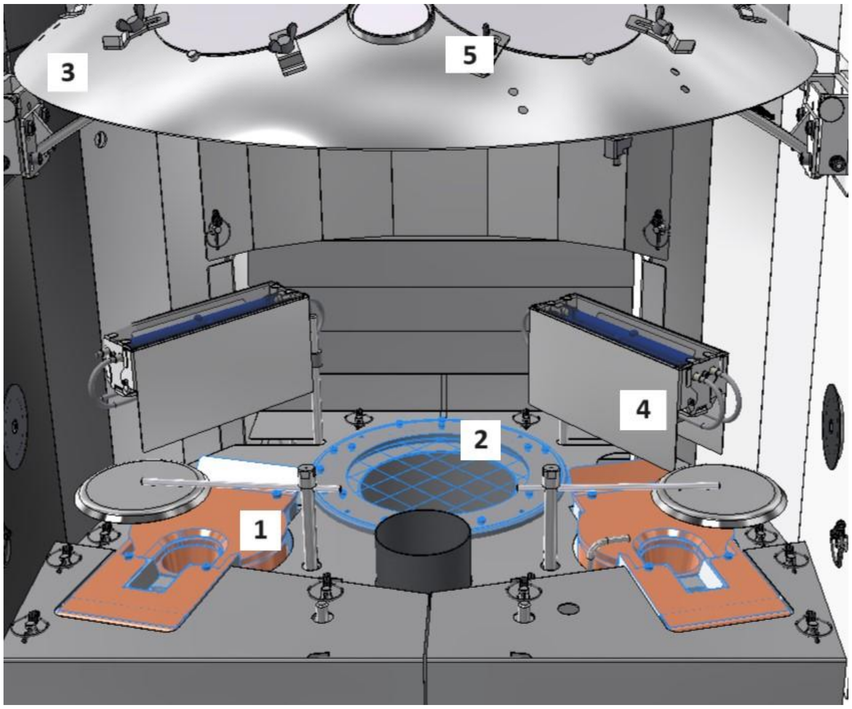


Figure 1 – ORTUS-700:
1 – electron beam evaporator Ferrotec EVM-8, 2 – plasma beam source Copra DN-250, 3 – dome type substrate holder, 4 – IR heaters, 5 – optical monitoring test glass

Various mid- and far-IR materials such as Y_2O_3, ZnS, Ge, YF_3, MgF_2, Si, Al_2O_3 were deposited on polished silicon and IG6 substrates (by Vitron) [1,2]. A Copra DN251 plasma beam source was used to clean and activate the surface of the substrates. The materials were evaporated using Ferrotec EVM-8 electron beam evaporators. The substrates were heated using IR heaters. The process control was performed based on quartz and optical single-wave monitoring using the OCP SW's fly-by optical test glass from I-Photonics.

The important parameters of the technological process of evaporating coatings to IG6 substrates is the precise maintaining of set temperature, ion-plasma treatment before deposition, correctly selected adhesive layers and layers that form an optical characteristic. The technological process for producing anti-reflective coatings on IG6 substrates using the ORTUS-700 vacuum coater is described below:

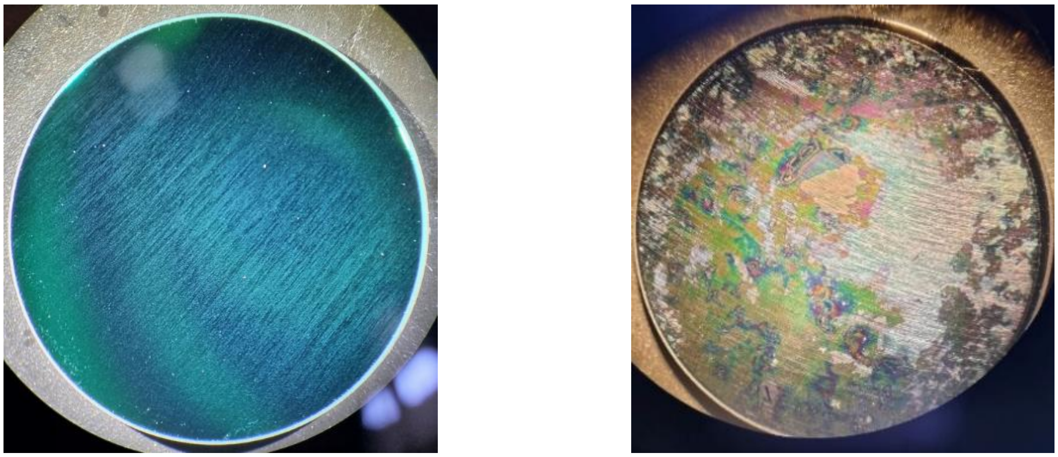
1. Test substrates are loaded onto a dome-shaped substrate holder. Also, a test glass made of polished silicon is placed on a holder, needed for optical control.

2. After loading the substrates into the chamber, the stage of pumping down to $8 \cdot 10^{-4}$ Pa begins. At the same time, the substrates are heated to 100 °C. To ensure optimal coating conditions and achieve the desired properties of the final product, temperature must be maintained throughout the entire process.

3. After reaching the required vacuum and specified temperature, the next step is ion-plasma cleaning in an argon environment (15 sccm) using Copra DN250. The optimal cleaning

time was experimentally determined to be 10 minutes. With a decrease in the time of ion-plasma treatment, the adhesive properties of the coating deteriorated.

4. Next comes the stage of evaporating the adhesion layer. This step is an important part of the process because the adhesion layer provides a strong bond between the substrate and the evaporated coating, which is important for its durability and quality. (Figure 2).



a b

Figure 2 – Photos of coated IG6 substrates, illustrating high (a) and low (b) adhesion of a coating

5. After completing the process of evaporating the adhesion layer, next stage begins, at which coatings are evaporated using various materials in order to obtain the required optical characteristics [3].

To measure the optical characteristics, Essent Optics Photon RT and Bruker Alpha II FT-IR spectrophotometers were used for wavelengths of 1-5 and 7-14 µm, respectively.

Environmental testing was performed according to MIL-C-675C, MIL-C-14806A and MIL-C-48497A standards.

3. Results

Below are the results of measurements of coatings for various IR ranges [4].

The first type of coating is a standard antireflective coating in the wavelength range of 8-12 µm for an angle of incidence (AOI) of 0 degrees (Figure 3). Average reflectance is below 0.7% was obtained for double-sided coating on an IG6 substrate. The average transmittance is 97.5%. The AR coating consists of 5 layers of materials YF_3, Ge, ZnS (Table 1). To solve the problem of adhesion of the coating to the IG6 substrate, Y_2O_3 was used. Since oxides have absorption in the far IR range, it is necessary to consider the thickness of the adhesion layer (Y2O3 – 25 nm).

Table 1 – Optical thickness of the AR coating in the wavelength range 8-12 µm for the AOI of 0 degrees:

Material	Optical thickness, nm
Y_2O_3	40.0
Ge	381.6
YF_3	173.6
ZnS	2493.5
YF_3	2837.7

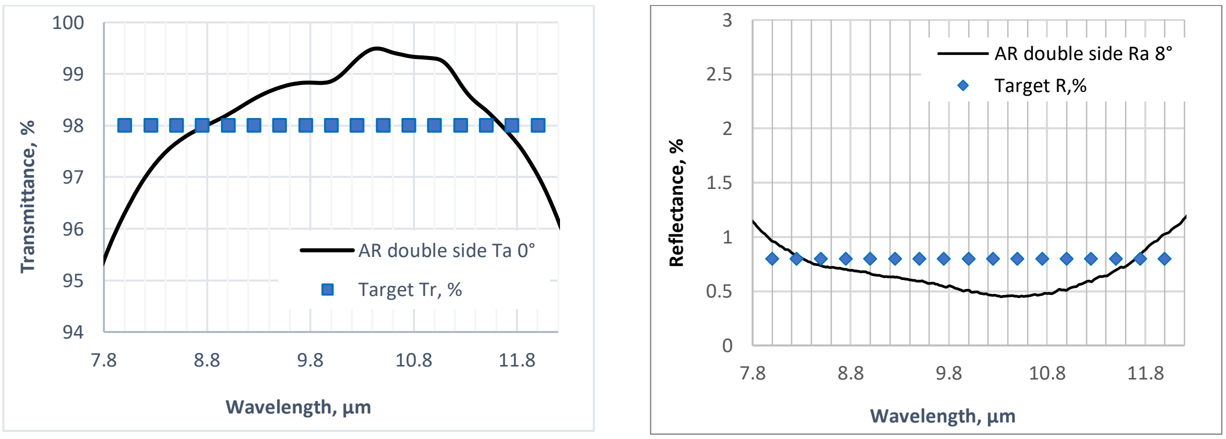


Figure 3 – Transmission and reflection graphs of the IG6 substrate with double-sided AR coating in the wavelength range 8-12 µm

One of the important properties of AR coatings is maintaining a low level of reflection at various AOI's.

The second type of coating is a high-durable AR coating in the wavelength range of 2-2.5 µm + 4-5 µm for the AOI within 0-40 degrees (Fig. 4). Average reflectance below 0.7% was obtained on the IG6 substrate. The average transmittance is 99%. AR coating consists of 9 layers of ZnS, YF_3, MgF_2 materials (Table 2). To solve the problem of adhesion of the coating to the IG6 substrate, thin layer of Y_2O_3 was used.

Table 2 – Optical thicknesses of high-durable AR coating in the wavelength range 2-2.5 µm + 4-5 µm for the AOI within 0-40 degrees.

Material	Optical thickness, nm
Y_2O_3	42.5
ZnS	1009.4
YF_3	110.8
ZnS	504.7
YF_3	229.0
ZnS	1568.0
YF_3	258.5
ZnS	288.3
MgF_2	756.8

To find out more about our range of coating systems

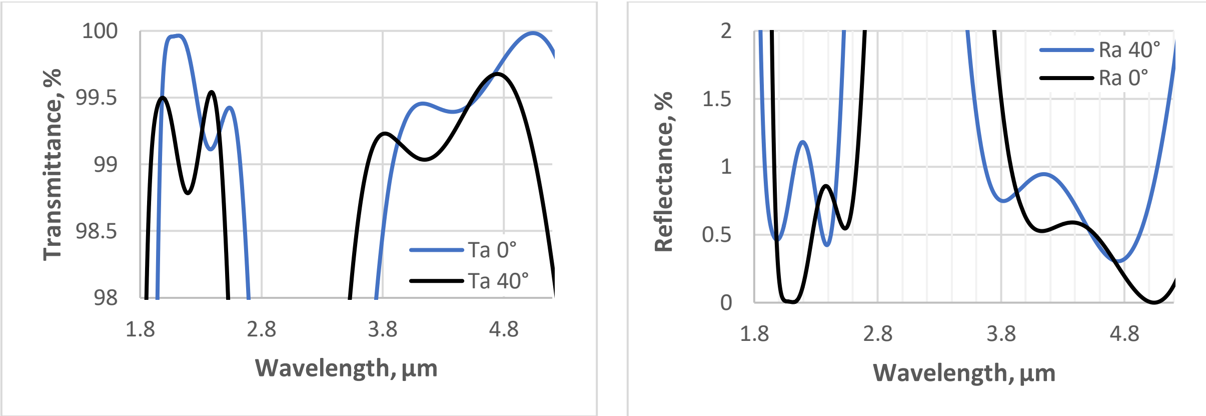


Figure 4 – Dual broad band AR coating on IG6 for 2-2.5 um + 4-5 um

4. Conclusion

Although it is difficult to create high-durable, high-adhesive coatings on chalcogenide glasses, we have successfully developed advanced technology capable of creating coatings that will not only withstand environmental testing, but also has a high durability. This progress has implications for a variety of areas where infrared optics plays a key role and underscores our ability to provide reliable and efficient solutions to customers.

5. References

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