High-durable coatings for infrared applications

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Outline

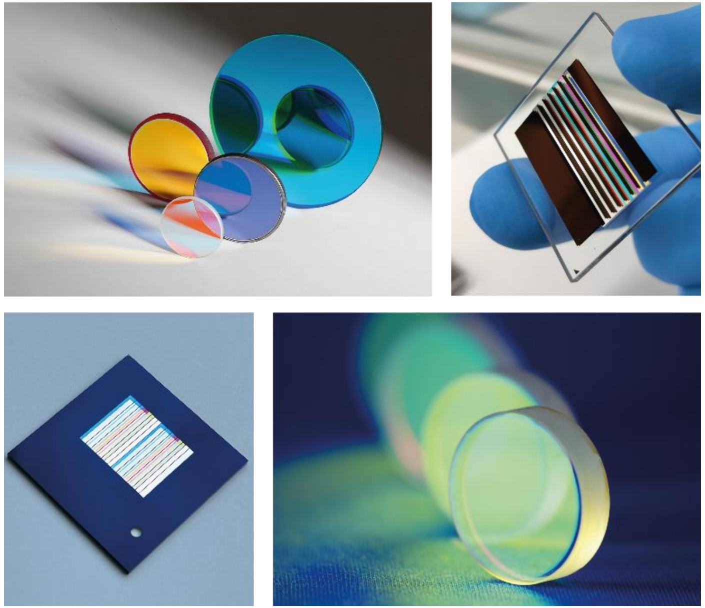
- I-Photonics introduction
- Our experiments and test results for chalcogenide glasses
- Examples of AR Coatings on Ge, ZnS
- Examples of Coatings for IR by PARMS
- IAD coating systems
- Next R&D steps

I-Photonics today

Vacuum coating equipment

IAD, EBE, IBS, MS, PARMS, PECVD

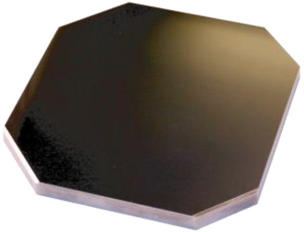
Optical components
Job coating service



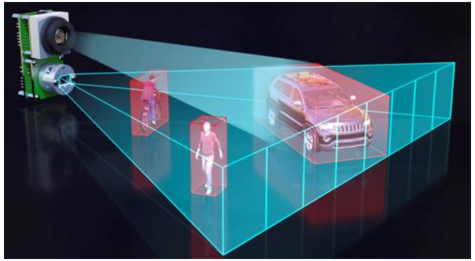
190 – 14 000 nm

IR coatings market & applications

High-durability + High-transmission = DLC



AR 3-5 / 8-12 um for Ge and Si



Accordance to MIL standards

Passed test	Test condition
Humidity (as per MIL-C-675C P4.5.8)	24 Hrs. exposure at RH 95% to 100% at 50°C
Abrasion/Hardness (as per MIL-C-675C P4.5.10)	1. 50 strokes cheese cloth at 500 gm force 2. 20 strokes eraser as 1000 gm force
Temperature (as per MIL-N-13508 P4.4.4)	5 Hrs at – 40°C 5 Hrs at + 70°C
Adhesion (as per MIL-C-675C P4.5.12)	Cellulose tape applied to the coated surface and removed slowly
Salt spray (as per MIL-C-675C P4.5.9)	24 Hrs. salt spray
Solubility (as per MIL-C-675C P4.5.7)	24 Hrs immersion in salt water (10gm per liter)

Applications:

- Night vision
- Thermal infrared imaging
- Pyrometers
- LIDAR
- Earth observation
- Ambient light / rain sensor
- Heat Sensing
- Telecommunication
- Detectors
- Optronic Systems
- Airborne, Border & Marine Surveillance
- Safety & Security

Chalcogenide glasses

Chalcogenide glasses features:

- ease of formation
- high refractive index
- low photon energy
- high nonlinearity
- low weight
- high transmittance for IR

- complex to coat
- a lot of variations/types

Lack of germanium on the market – Chalcogenides are one of possible substitutes

Experiment with chalcogenides

1 step

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 Ge, ZnSe, IG6 substrates (by Vitron).

- A Copra DN251 plasma beam source was used to clean and activate the surface of the substrates.
- 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.

As a result, the most critical parameters were defined and prioritized:

- the precise maintaining of set temperature,
- ion-plasma treatment regimes before deposition,
- correctly selected adhesive layers and layers that form an optical characteristic.

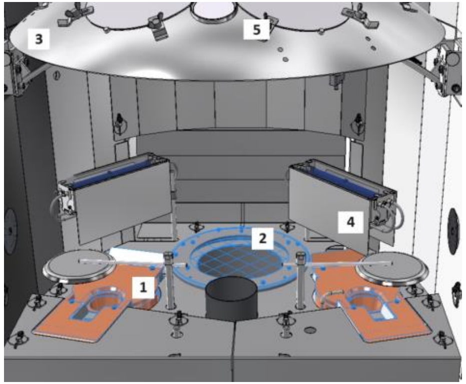


Fig. 1 – ORTUS-700 internal
1 – electron beam evaporator Ferrotec EVM-8,
2 – plasma beam source Copra DN-250,
3 – dome type substrate holder,
4 – IR heaters,
5 – optical monitoring test glass

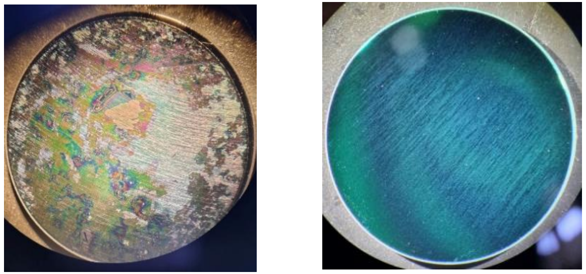
Fig. 2 – ORTUS-700 external view

Experiment

2 step

Coater set-up and Technological regimes were defined

1. A dome-shaped substrate holder,
2. Pumping down to $8 \cdot 10^{-4}$ Pa,
3. Substrates are heated to 100 °C,
4. Ion-plasma cleaning in an argon environment (15 sccm) using Copra DN250. The optimal cleaning time was experimentally determined to be 10 minutes,
5. Evaporating the adhesion layer,
6. Evaporation of the AR coating.



a b

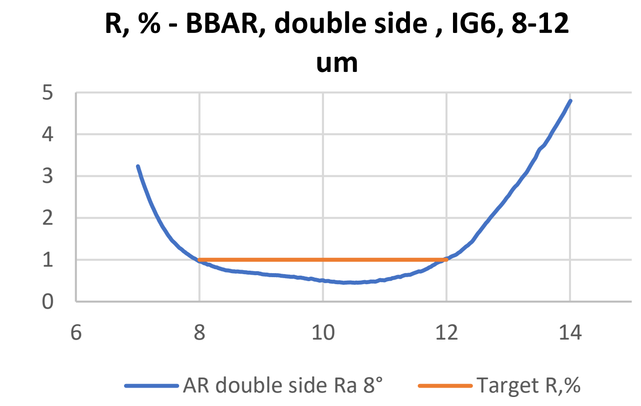
Figure 2 – IG6 substrates, with low (a) and high (b) adhesion of a coating

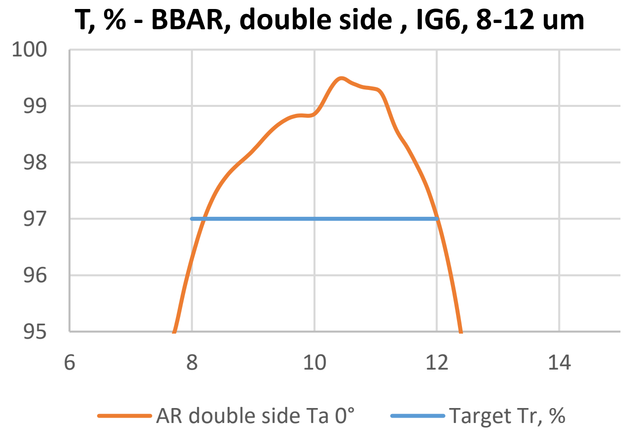
Broad band anti-reflection coating 8 – 12 µm on IG6

Material	Optical thickness, nm
Y2O3	40.0
Ge	381.6
YF3	173.6
ZnS	2493.5
YF3	2837.7

Table 1 – Optical thickness of the AR coating in the wavelength range 8-12 µm, AOI 0 deg.

Substrate		Coating	
Material	IG6	2 sides	
Dimensions	Ø 1-2 inch	λ=8-12 mkm	T_{av}=97.5 % R_{av}=0,7 %
Thickness	$1_{\pm 0,02}$ mm	Angle	α=0°

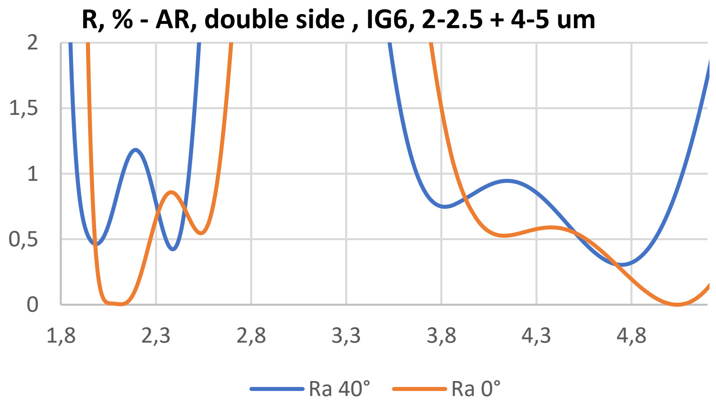


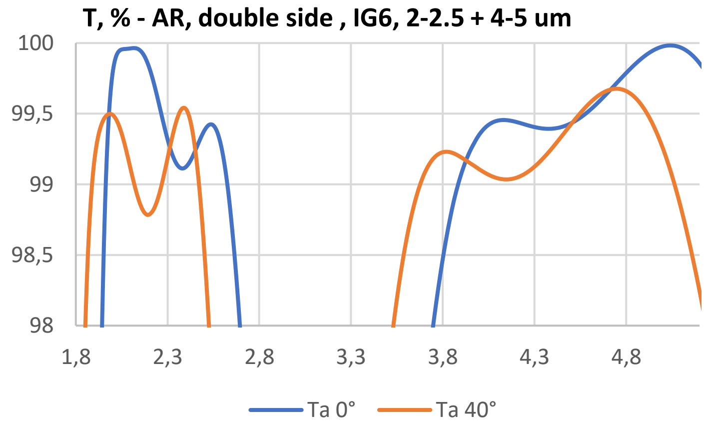


AR coating @ 2-2.5 µm + 4-5 µm on IG6

Material	Optical thickness, nm
Y2O3	42.5
ZnS	1009.4
YF3	110.8
ZnS	504.7
YF3	229.0
ZnS	1568.0
YF3	258.5
ZnS	288.3
MgF2	756.8

Substrate		Coating	
Material	IG6	2 sides	
Dimensions	Ø 1-2 inch	λ= 2-2,5 + 4-5 um	T_{av}=99 % R_{av}=0,7 %
Thickness	$1_{\pm 0,02}$ mm	Angle	α=0-40°

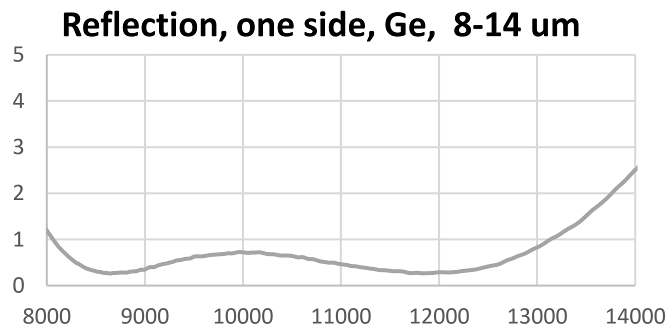




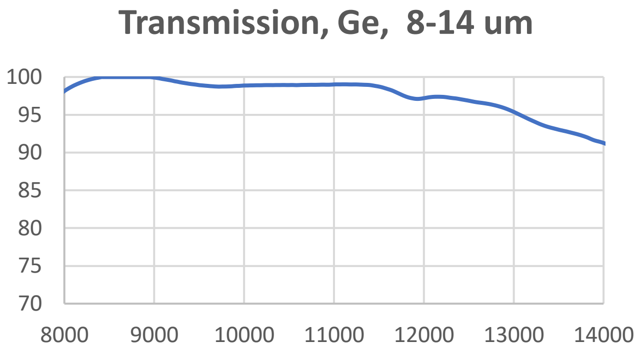
Broad band anti-reflection coating
8 – 14 µm on Ge

Material	Optical thickness, nm
Y2O3	50
ZnS	271
Ge	130
ZnS	652
YbF3	1 023
ZnS	160

Optical thickness of the AR coating in the wavelength range 8-12 µm, AOI 0 deg.



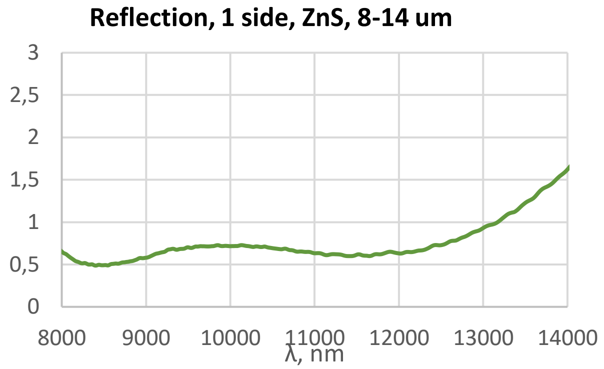
Substrate		Coating	
Dimensions	Ø 1-2 inch	λ=8-12 mkm	T_{av}>99 % R_{av}=0,5 %
		λ=8-14 mkm	T_{av}=98 % R_{av}=0,6 %
Thickness	$1_{\pm 0,02}$ mm	Angle	α=8°

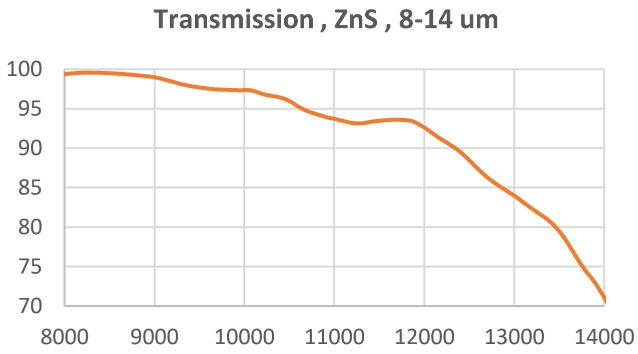


Broad band anti-reflection coating
8 – 14 µm on ZnS

Material	Optical thickness, nm
Y2O3	50
ZnS	271
Ge	130
ZnS	652
YbF3	1 023
ZnS	160

Optical thickness of the AR coating in the wavelength range 8-12 µm, AOI 0 deg.





Substrate		Coating	
Dimensions	Ø 1-2 inch	λ=8-12 mkm	T_{av}>97 % R_{av}=0,6 %
		λ=8-14 mkm	T_{av}=94 % R_{av}=0,7 %
Thickness	$1_{\pm 0,02}$ mm	Angle	$\alpha=8^{\circ}$

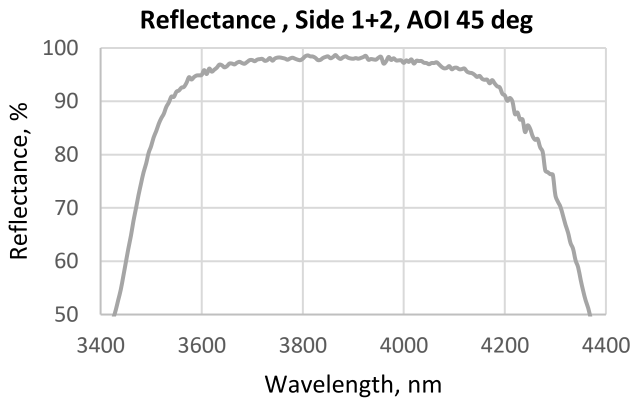
HR coating @ 3.6-4.2 µm + HT @0.45-0,7 µm

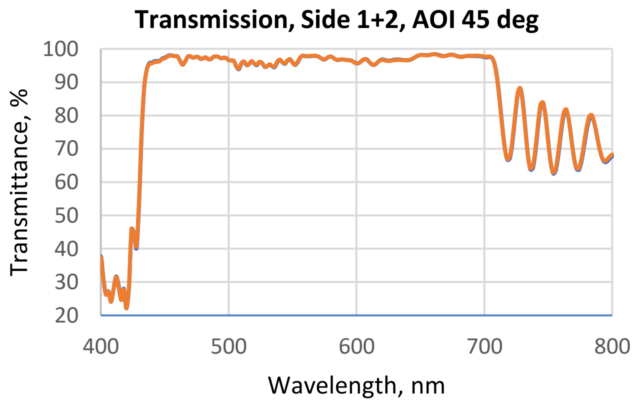
PARMS technology

Material	# of layers
TiO_2 / AL_2O_3	45

Adhesion	MIL-48497A - Para 4.5.3.1
Humidity	MIL-48497A - Para 4.5.3.2
Moderate abrasion	MIL-48497A - Para 4.5.3.3
Solubility and cleanability	MIL-48497A - Para 4.5.4.2

Substrate		Coating			
Material	IG6	Side 1	%	Side 2	%
Dimensions	Ø 1-2 inch	Ta > 90% (λ=450-700 nm), α=45°	92.83	Ra < 1.5% (λ=450-700 nm), α=45°	0.99
Thickness	$1_{\pm 0,02}$ mm	Ra > 96% (λ=3600-4200 nm), α=45°	97.07		





Measurements

- To measure the optical characteristics, Essent Optics Photon RT and Bruker Alpha II FT-IR spectrophotometers were used for wavelengths of 0,4-5 and 7-14 μm, respectively.

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

No	Passed test	Test Condition
1.	Humidity	24 Hrs. exposure at RH 95% to 100% at 50°C
2.	Moderate Abrasion	50 strokes cloth at 1 pound force
3.	Temperature	2 Hrs. at –60 °C 2 Hrs. at +70 °C
4.	Adhesion	Cellophane tape applied to the coated surface and remove quickly

ORTUS systems

ORTUS 700

ORTUS 900

ORTUS 1100

ORTUS 1500

System	Dome, diameter	qty of 1”
ORTUS 700	620 mm	228
ORTUS 900	800 mm	356
ORTUS 1100	995 mm	576
ORTUS 1500	1390 mm	1075

Planetary , diameter and qty.	qty of 1”
270 mm, 4 pcs	132
327 mm, 4 pcs	284
387 mm, 4 pcs	416
590 mm, 4 pcs	850

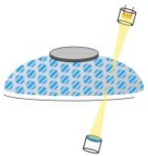
Optical system OCP

OCP type:

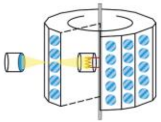
- BroadBand
- SingleWave

Control mode:

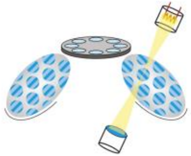
Direct monitor



Intermittent transmission for dome substrate holder



Intermittent transmission for drum substrate holder

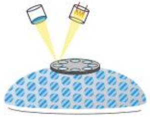


Intermittent transmission for planetary substrate holder

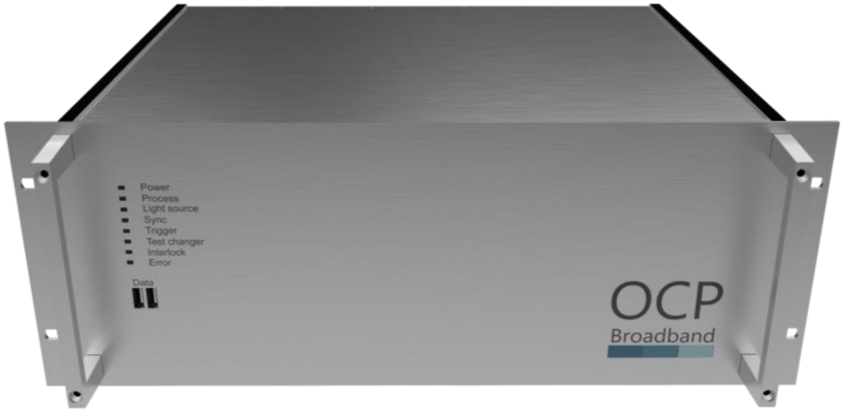
Indirect monitor

Continuous transmission for dome substrate holder

Continuous reflection for dome substrate holder

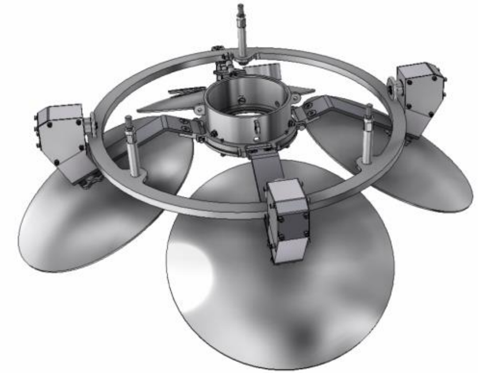


Continuous backside reflection for dome substrate holder



Type of substrate holder

- Planetary unit



- Dome

	Planetary	Dome
ø	Ortus 700 – 270mm/4pcs. Ortus 900 – 327mm/4pcs. Ortus 1100 – 387mm/4pcs. Ortus 1500 – 590mm/4pcs. There is a possibility of customizing the size	Ortus 700 – 620 mm. Ortus 900 – 800 mm. Ortus 1100 – 995 mm. Ortus 1500 – 1390 mm. There is a possibility of customizing the size
Substrate	Lens: 1", 2", 70.76 (3"), 60mm, 80mm 100mm, 124mm, 200mm Prisms and special substrate: according customer request	
Uniformity	<+/- 1,5%	<+/- 2%

Type of substrate holder

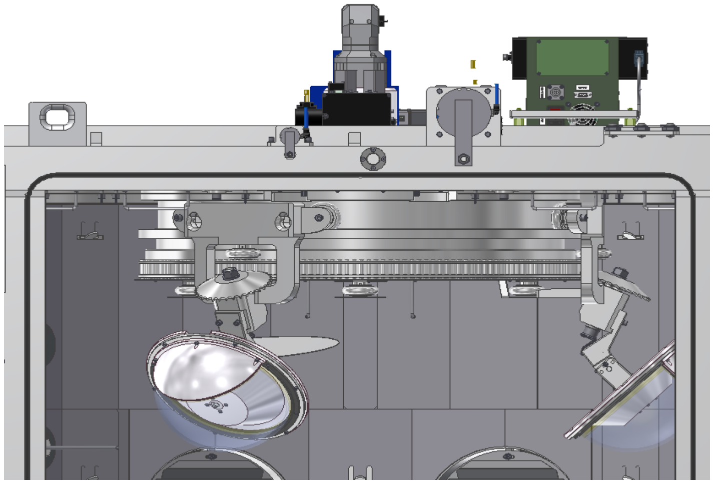
- Special for customer

Coater	Ortus 1100
Substrate	semisphere Ø151,6mm, radius of curvature 77mm. 4 pcs.
Coating	BBAR 8-12um, double side
Uniformity on substrate, %	<+/- 2%

Type of substrate holder

- Special for customer

Coater	Ortus 1500
Substrate	semisphere Ø250mm, radius of curvature 125mm. 3 pcs.
Coating	BBAR 8-12um, double side
Uniformity on substrate, %	<+/- 10%



Next R&D steps

- Adopt the coating technology for chalcogenide glasses of different manufacturers
- Unleash potential of PARMS technology for up to 5 um range
- Improve the performance further

Send us your task!

THANK YOU FOR YOUR TIME AND ATTENTION

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