MATERIALS FOR INFRARED OPTICS

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OPTI 521 Tutorial

1. Introduction

There are numerous glass types available for the visible spectrum, but there are only a small number of materials that can be used in the MWIR (mid-wave infrared) and LWIR (long-wave infrared) spectral bands. The purpose of this tutorial is to familiarize the reader with the best and most common Infrared glasses. The extent of the MWIR and LWIR bands can be seen in Figure 1.

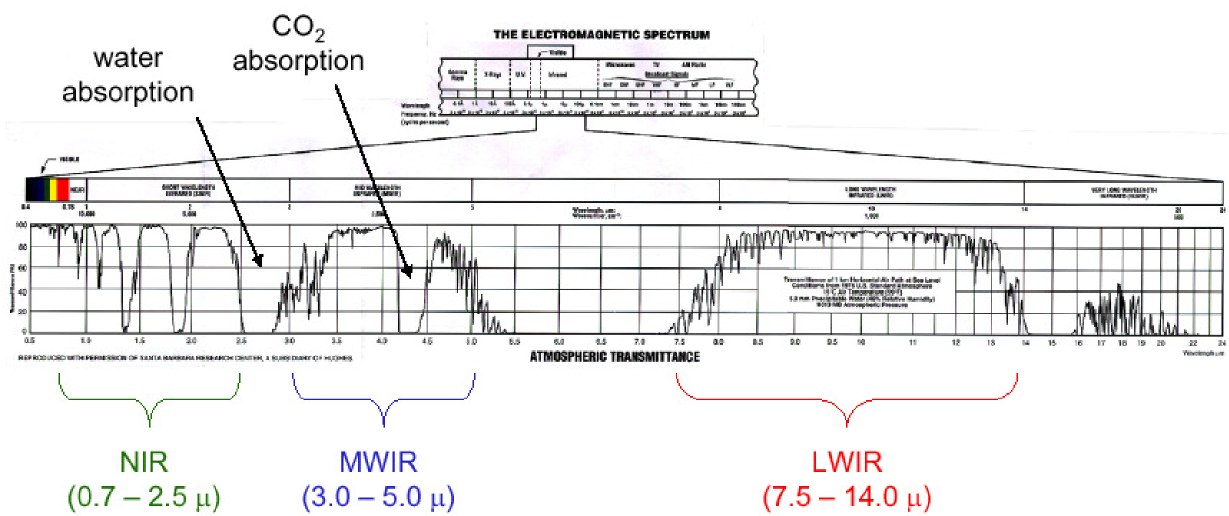

FIGURE 1: ATMOSPHERIC TRANSMITTANCE

2. Infrared Glasses

Figure 2 shows the transmittance of some of the most common Infrared glasses and Table 1 lists some of the material constants for Infrared glasses. Several of the glasses will be discussed in this section. Table 2 gives a list of Infrared glass suppliers.

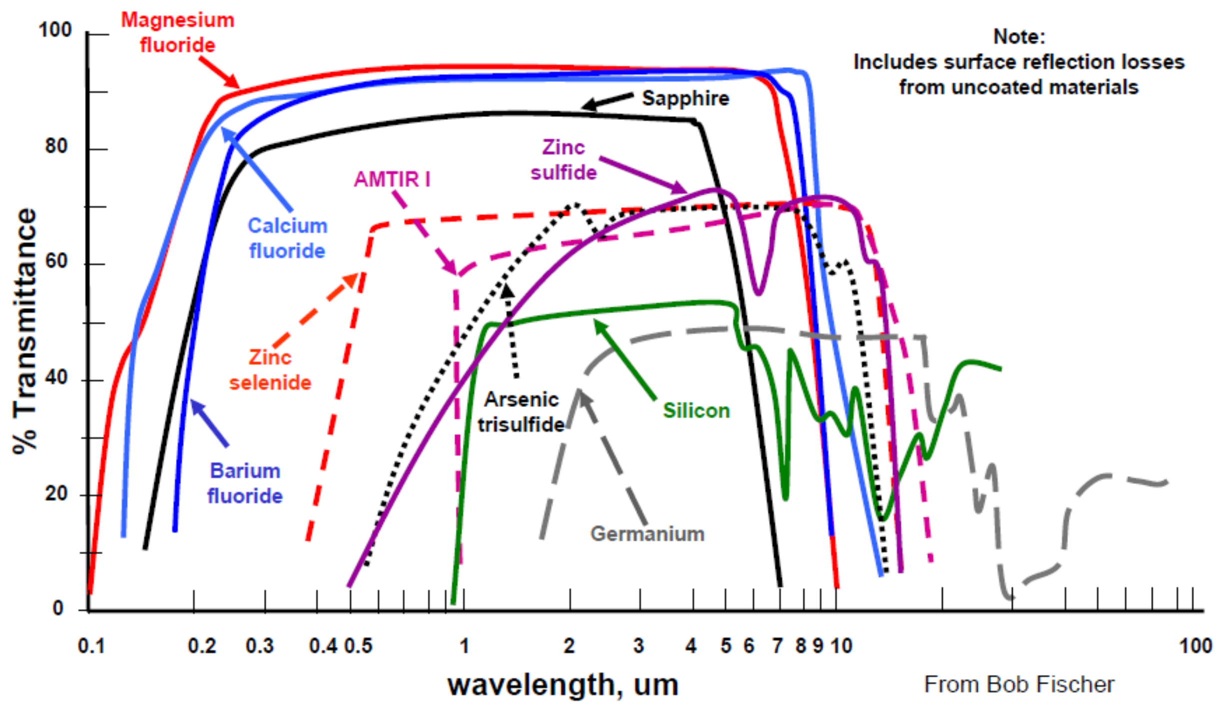

FIGURE 2: INFRARED GLASS TRANSMITTANCE

TABLE 1: INFRARED GLASS SUPPLIERS

Infrared Glass Suppliers	
• **Elcan Optical Systems**	• Janos Technology
• **Corning NetOptix**	• DRS Optronics
• **Exotic Electro-Optics**	• Coherent
• **Optimum Optical Systems**	• Diversified Optical Products
• **II-VI Incorporated**	• Telic OSTI

TABLE 2: INFRARED MATERIAL PROPERTIES

Material	Refractive Index		CTE (ppm/K)	dn/dT (ppm/K)	Knoop Hardness (g/mm2)	Spectral Range
	@4mm	@10mm				
Germanium	4.0243	4.0032	6	396	800	2.0 – 17.0 mm
Silicon	3.4255	N/A	2.7	150	1150	1.2 – 9.0 mm
ZnS (Cleartran)	2.2523	2.2008	4.6	54	230	0.37 – 14.0 mm
ZnSe	2.4331	2.4065	7.1	60	105	0.55 – 20.0 mm
Magnesium Fluoride	1.3526	N/A	8	20	415	0.11 – 7.5 mm
Sapphire	1.6753	N/A	5.6	13.7	1370	0.17 – 5.5 mm
Gallium Arsenide	3.3069	3.2778	5.7	148	721	0.9 – 16.0 mm
CaF_2	1.4097	1.3002	18.9	-11	170	0.13 – 10.0 mm
BaF_2	1.458	1.4014	18.4	-15	82	0.15 – 12.5 mm

2.1 Germanium

Germanium is a crystalline material. It is one of the most common infrared materials, and it can be used in the MWIR and the LWIR band. Germanium has a very high refractive index (n = 4.0243), which makes elements with long radii feasible. It has a large dn/dT (396 ppm/K) which can cause large focus shifts with temperature changes. This could make athermalization difficult. The high index of refraction also necessitates that good anti-reflection coatings be used. Germanium is quite expensive.

2.2 Silicon

Silicon is a crystalline material like germanium. It is used primarily in the 3 µm to 5 µm MWIR spectral bands, because of absorption in the 8 µm to 14 µm LWIR band. The index of refraction for silicon is also large ($n = 3.4255$), as well as the refractive index change with temperature ($dn/dT = 150$ ppm/K). The dispersion is relatively low. It can be diamond turned, but it is difficult.

2.3 Zinc Sulfide

Zinc sulfide is another common material that is used in both the MWIR and the LWIR. Zinc sulfide is commonly manufactured by chemical vapor deposition (CVD). Cleartran is the most commercially available clear zinc sulfide and it can be used for windows and lenses from the visible through to the LWIR.

3.4 Zinc Selenide

Zinc selenide transmitsin the IR and the visible. It is very similar to zinc sulfide, but it has a slightly higher refractive index and is structurally weaker. The advantage that zinc selenide has over zinc sulfide is that it has a much lower absorption coefficient than zinc sulfide. Zinc selenide is expensive.

3.5 Magnesium Fluoride

Magnesium fluoride is also a crystalline material. It transmits from the UV through the MWIR spectral bands. Magnesium fluoride is manufactured by crystal growth or by “hot pressing.” Magnesium Fluoride is relatively low cost, and it has poor thermal properties.

3.6 Sapphire

Sapphire (aluminum oxide) is an extremely hard material that transmits deep UV through to MWIR. Because of its hardness it is very difficult and very expensive to manufacture, and takes time. The index change with temperature, dn/dT , is relatively low for an Infrared material (10 ppm/K) and it has very low thermal emissivity at high temperature. Overall it has good thermal properties and it is often used for missile domes. It is also birefringent meaning that the refractive index changes with the plane of incidence. Sapphire cannot be diamond turned.

4. Fabrication

Fabrication methods for Infrared materials such as germanium, silicon, zinc sulfide, and zinc selenide are in general similar to normal glass optics. Many of the crystalline materials are hygroscopic (absorbs water), which can be challenging to work with.

Some Infrared materials - like germanium, silicon (though it is difficult), zinc sulfide, zinc selenide and the fluorides - can be single-point diamond turned. Sapphire cannot be diamond turned. Diamond turning becomes important when you need to incorporate aspheric surfaces in a design.

Good antireflection coatings are required, because IR materials generally have a very high index of refraction, which cause Fresnel reflections to increase significantly, and thus lower transmission. Proper coatings are also needed to protect these materials from moisture damage from moisture.

5. References

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