Materials for Infrared Optics

By Melanie Saayman

Overview

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- Comparison IR vs. Visible glasses
- Properties of some common IR glasses
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  - Silicon
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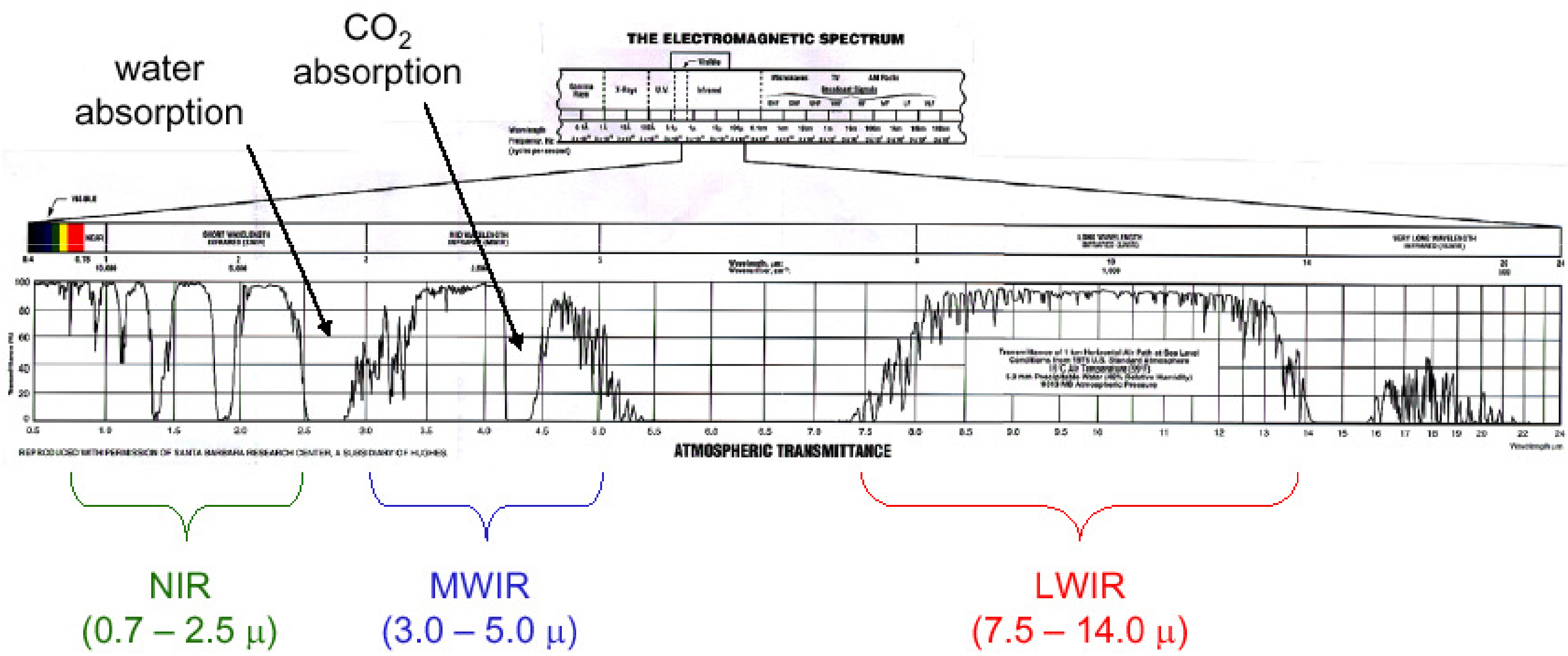
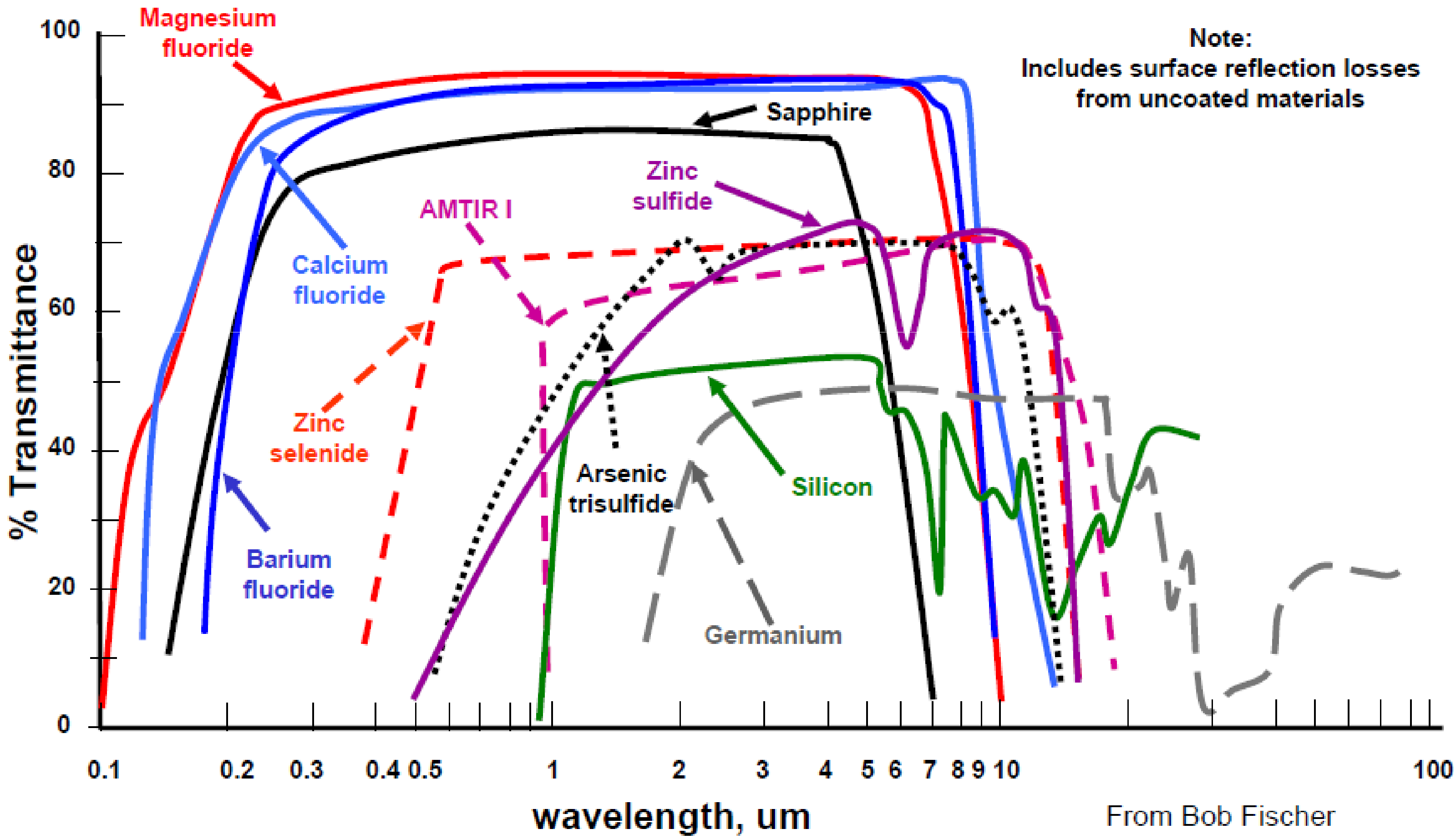
Atmospheric Transmittance



Transmittance of IR glasses



From Bob Fischer

Comparison: IR vs. Visible Glasses

- There are much fewer IR glasses than visible glasses.
- Refractive indices for IR glasses much higher.
  - Visible: $n = 1.45 - 2.0$
  - IR: $n = 1.38 - 4.0$
- Dispersion is often much lower for IR glasses.
  - Visible: $\nu = 20 - 80$
  - IR: $\nu = 20 – 1000$

Comparison: IR vs. Visible Glasses

- Many IR glasses are opaque in the visible.
- Most visible glasses are opaque in the IR.
- IR glasses are often heavier than visible glasses.
- IR glasses have significantly higher dn/dT values (x10 or more) - athermalizing difficult.
- IR glasses are more expensive than visible glasses (x2 or more).

Germanium

- Most common IR material
- LWIR and MWIR
- High refractive index: $n = 4.0243$
- Large dn/dT (396 ppm/K) can cause large focus shift as a function of temperature.
- Expensive

Silicon

- Large dn/dT – 150 ppm/K
- Primarily 3 – 5 MWIR
- Large n = 3.4255
- Relatively low dispersion
- Can be diamond turned (with difficulty)

Zinc Sulfide

- Common material
- LWIR and MWIR
- Cleartran in the most common commercially available zinc sulfide

Zinc Selenide

- Similar to zinc sulfide but structurally weaker
- Expensive
- Very low absorption coefficient
- Transmits in the IR and visible

Magnesium Fluoride

- Low cost
- Transmits from UV to MWIR spectral band
- Poor thermal properties

Sapphire

- Extremely hard.
  - Difficult, time consuming and expensive to manufacture.
- Transmits deep UV through MWIR.
- Very low thermal emissivity at high temperature.
- Cannot be diamond turned.
- $n = 1.6753$, $dn/dT = 10$ ppm/K

Summary of IR Material Properties

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

Concerns using Lens Design Programs

- Most lens design programs use some literature source of data for IR materials, then fit the data to Sellmeier equations.
- Sometimes this data is inconsistent, coming from different measurement sources, and may not have sufficient significant digits.
- Thermal data, such as CTE and dn/dT, may vary widely for some materials, depending on who measured it.
- Often, the software does not include this data, as there is no official source.

Suppliers

- Elcan Optical Systems, Richardson, TX
- Corning NetOptix, Keene, NH
- Exotic Electro-Optics, Marietta, CA
- Optimum Optical Systems, Camarillo, CA
- II-VI Incorporated, Saxonburg, PA
- Janos Technology, Keene, NH
- DRS Optronics, Palm Bay, FL
- Coherent, Auburn, CA
- Diversified Optical Products, Salem, NH
- Telic OSTI, North Billerica, MA

References

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- Max Riedl, Optical Design Fundamentals for Infrared Systems (SPIE Press, 2001)
- Richard C. Juergens, Infrared Optical Systems, Practical Optics Seminar (2006)
- Wolfe and Zissis, The Infrared Handbook, Office of Naval Research (1978)
- Paul Klocek and Marcel Dekker, Handbook of Infrared Optical Materials (1991)