ANTI-REFLEX COATING ON BALL LENSES

1 Introduction

If a beam of light goes trough an optically clear material (glass or mono crystal), a part of the light is reflected. The reflection of the light, at the interface between the air and material surface, is dependent of the entering angle and polarization of the occurring beam of light and the index of refraction nd of the material. In the easiest case:

Reflection $R = (n_d -1)^2/ (n_d+1)^2$

n_d: index of refraction of the material for defined wavelength

Example: mineral glass NBK-7 with an index of refraction n_d 1.517 reflects 4.3% of the light.

The reflection can be minimized with the help of a so-called anti-reflex layers (AR layers) for a certain wavelength or wavelength area. The AR layers are optically transparent layers of 10 to more than 100 nm thickness of low-refractive (LI) and/or high-refractive (LH) materials.

Low-refractive or high-refractive means, that the index of refraction of the layer is lower or higher than the one of the glass.

Board details

LI-layer		HI-layer	
Name	**index of refraction**	**Name**	**index of refraction**
Magnesiumfluorid	1.38	Hafniumoxid	1.95
Siliciumdioxid	1.46	Zirkonoxid	2.05
Aluminiumoxid	1.63	Titandioxid	2.3

The reflection of a high-refractive substrate can be minimized with the help of just one low refractive layer. In this case, it is a single band coating

Example: Magnesium fluoride on sapphire with n_d = 1.77

Illustration 1

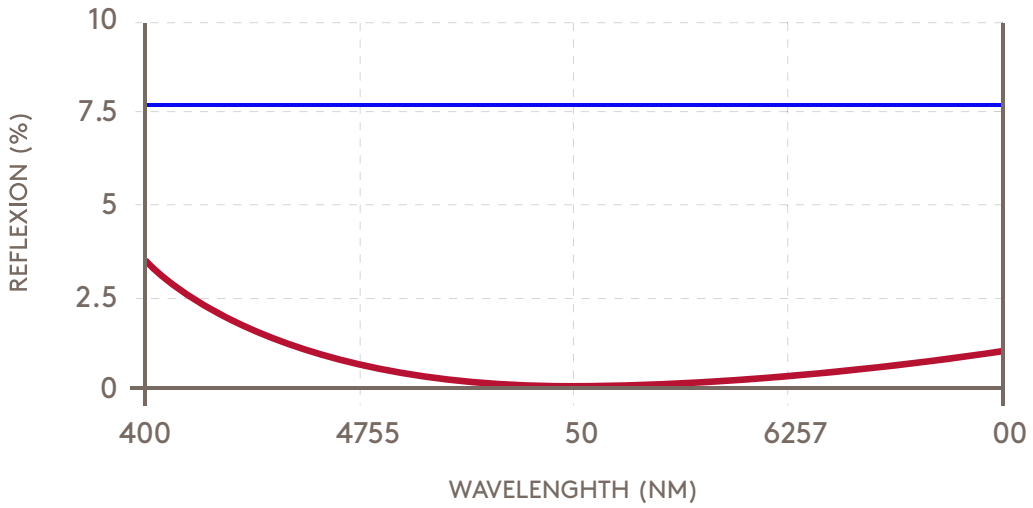

Illustration 1: blue curve: 100 nm MgF2 on sapphire. Red line: reflection of sapphire

Illustration 2

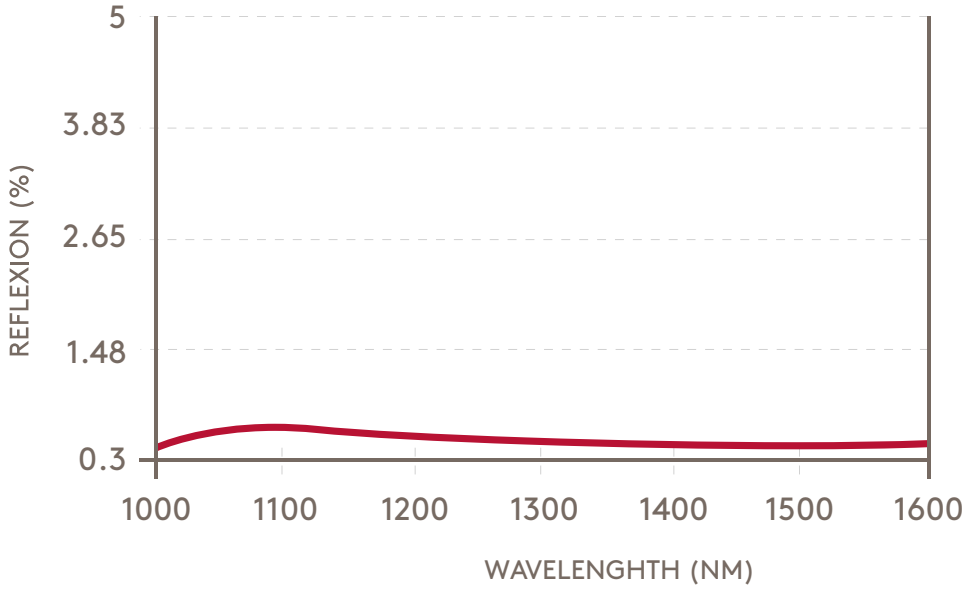

Illustration 2: AR 1200 to 1600 nm on BK-7 reflection <1%

If the reflection is minimized for a certain wavelength area, several layers are necessary.
Then the case is a multi band coating.

Example : AR 1200 to 1600 nm on BK-7 consisting of 5 layers.

2 AR coating of ball lenses

Ball lenses are used in large quantity in the telecom industry to bring the light of the laser source into the fiber and optical connection of two fibers. The balls are manufactured from optical glass, like BK-7, sapphire, lanthanum glasses, etc. Here again optical science apply, i.e. with every crossing beam of light, from air to glass, or reverse, a part of the light is reflected. To minimize the loss of the light's performance, the ball lenses will be coated with an AR coating. We call single band if the coating is necessary only for one wavelength, and multi band for a wavelength area. The wavelength areas most current at the moment in the Telecom industry are 830 - 850 nm, 850 - 1300 nm, 1270-1310 nm, 1500 - 1600 nm and 1200 - 1600 nm.

3 Test criteria for the AR layers

ADHESION TEST	MIL C 675 C section 4.5.10 : tape test
SALT WATER BOILING TEST	MIL C 675 C section 4.5.10 : tape test
LAYER HARDNESS	MIL C 675C section 4.5.10 : rubber wear test
CLIMATE TEST	40 ° C, 95% relative humidity : 56 days without layer change
TEMPERATURE RESISTANCE	PVD coatings : max. 500° C in dry air
OTHER TESTS ON REQUEST	CVD coatings : max. 800° C in dry air

Other tests on request:

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