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# Optimization of Single layer Antireflection Coating for Infra-Red Spectrum on Silicon Substrate for Solar Cell Applications

**Sunil Kumar**

Dept. of Electrical & Electronics, Kalinga University, Atal Nagar Raipur

*Corresponding Author: Sunilbirla2004@gmail.com*

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***Abstract*** -Antireflection (AR) coatings are widely applied on optical devices for not only reducing the undesired reflection loss from the surfaces of the devices, but also for improving the contrast of the image of optical systems. Without the application of AR coatings on optical devices, the partial reflected light from the surfaces results in the formation of ghost images on the image plane, which reduces the contrast of the optical image. In general, the construction parameters of the optimal AR coating design for substrates with different refractive indices are different, thus the substrates should be coated in separate deposition runs. For saving time and reducing cost, this is of practical importance for a commercial thin-film coating shop if different substrates need to be AR-coated.

The present work has been carried out to investigate the optimum values of reflectance as a function of wavelength in the infra-red region. The reflectance has been reduced from 32% of silicon surface to less than 1% using ARC film.

***Keywords***:- AR Coating, Optimum value, Refractive indices, Substrate etc.

## I. INTRODUCTION

### Infrared Material Properties 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 a thermalization difficult. The high index of refraction also necessitates that good anti-reflection coatings be used. Germanium is quite expensive.

**Table1** 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 17.0mm |
| Silicon | 3.4255 | N/A | 2.7 | 150 | 1150 | 1.2 –9.0mm |
| ZnS (Cleartran) | 2.2523 | 2.2008 | 4.6 | 54 | 230 | 0.37-14.0mm |
| ZnSe | 2.4331 | 2.4065 | 7.1 | 60 | 105 | 0.55-20.0mm |
| Magnesium Fluoride | 1.3526 | N/A | 8 | 20 | 415 | 0.11 – 7.5mm |
| Sapphire | 1.6753 | N/A | 5.6 | 13.7 | 1370 | 0.17 – 5.5mm |
| Gallium Arsenide | 3.3069 | 3.2778 | 5.7 | 148 | 721 | 0.9 – 16.0mm |
| CaF2 | 1.4097 | 1.3002 | 18.9 | -11 | 170 | 0.13 -10mm |
| BaF2 | 1.458 | 1.4014 | 18.4 | -15 | 82 | 0.15-12.5mm |

## II. FABRICATION PROCESS

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.

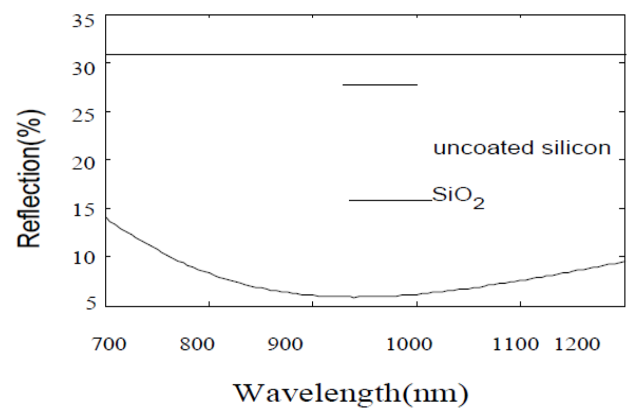
## III. DESIGN METHODOLOGY

The necessary and sufficient conditions to produce zero reflectance are calculated the research has been carried out for the Optimization of single Layer Antireflection Coating for Infra-Red Spectrum on Silicon Substrate for Solar Cell Applications using MATLAB. The program is optimized at $\lambda 0$ = 940 nm central wavelength for infra-red spectral region. The parameters like optical thickness and refractive index for each layer coating are optimized. The materials selected have low wave absorption, homogeneity, high packing density, good adhesion, low stress, hardness and ability to survive in different environments.

## IV. SINGLE LAYER ANTIREFLECTION COATING

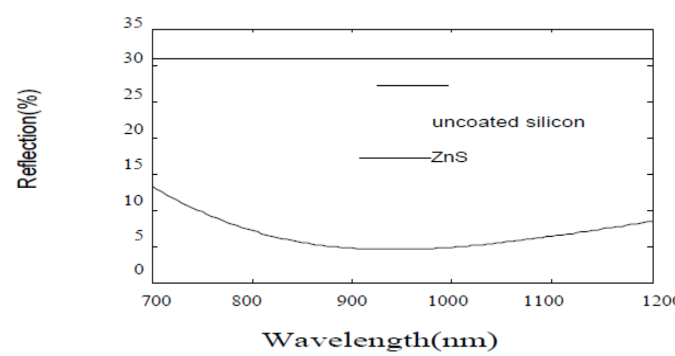
As we know that important application of silicon in the infrared region is the IR lasers and IR optoelectronic devices. A single-layer coating is the simplest, both theoretically and experimentally, and is widely used in practice. Figure 5.1- 5.6 shows the relationship between reflectance and wavelength plots for the six materials which are investigated. The dielectric materials are: SiO2, ZnS, Na3AlF6, TiO2, MgF2, and CeO2. The plot shows that the single layer ARC of SiO2 and TiO2 has reduced the minimum reflectance from 32% to less than 5% in the infrared region of 700 to 1200 nm. The CeO2 layer has an average reflectance of 4.8% and a minimum reflectance of 2.58% at a wavelength of 940nm. On the other hand the single layer of ZnS has the average reflectance of 6.6% and a minimum reflectance of 4.5% at a wavelength of 930 nm. The CeO2 and ZnS single layer antireflection coating films have shown better results in terms of minimum reflectance and average reflectance as compared to single layer antireflection coating of other materials in the entire infrared spectrum of light and therefore these two types of single layer ARC films may be suitable for use in antireflection film on IR lasers and other IR optoelectronic devices.

**Silicon Dioxide (SiO2):-**



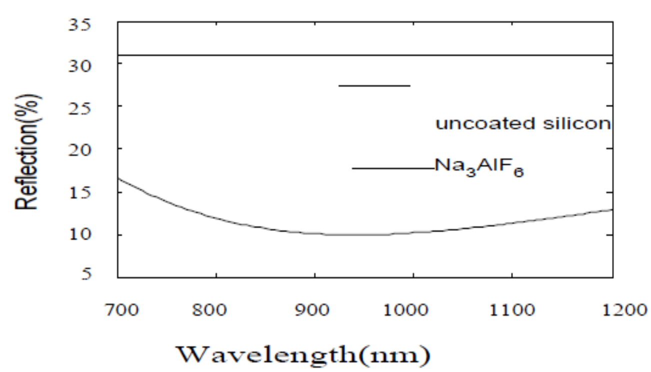

Reflectance spectra of SiO2 single layer antireflection coating on silicon.

**Zinc Sulphide (ZnS):-**



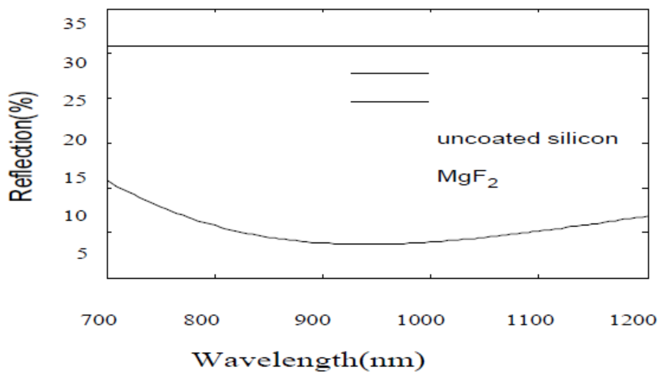

Reflectance spectra of ZnS single layer antireflection coating on silicon.

**Cryolite (Na3AlF6):-**



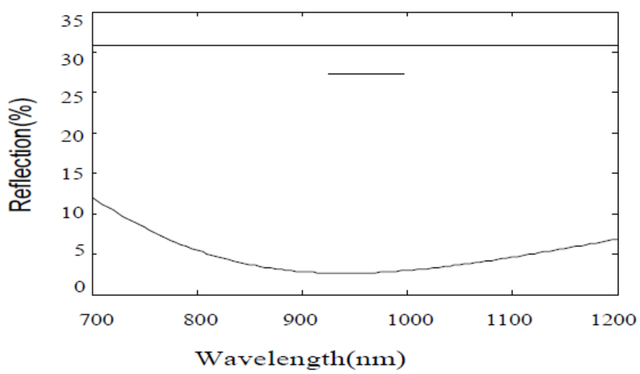

Reflectance spectra of Na3AlF6 single layer antireflection coating on silicon.

**Magnesium Fluoride (MgF2):-**




Reflectance spectra of MgF2 single layer antireflection coating on silicon.

**Cerium Oxide (CeO2):-**




Reflectance spectra of CeO2 single layer antireflection coating on silicon.

## V. RESULTS AND DISCUSSION

The surface of silicon reflects huge part of the incident light radiation in the whole spectral range between 700-1200 nm as its refractive index is relatively high. The high reflectance can be well minimized by a layer of ARC film in the complete infra-red region between 700-1200 nm, as its average reflectance is lower than the other forms of ARC films. Hence using ARC reflectance has been reduced from silicon surface.

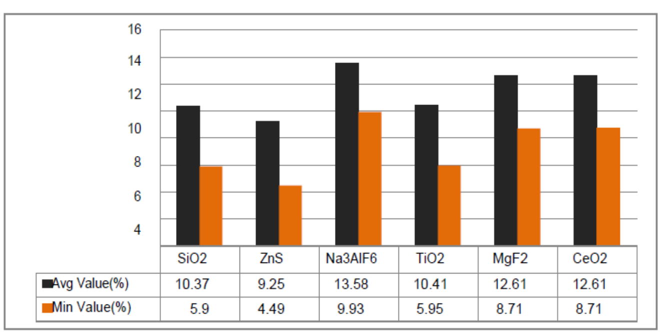



Fig. shows bar graph chart for comparison of reflectance spectra of single layer antireflection coating on silicon. The graph shows the percentage average and minimum values for six different materials (SiO2, ZnS, Na3AlF6, TiO2, MgF2, CeO2). This bar chart shows that ZnS and SiO2 give the better performance for Infra-red spectrum while Na3AlF6 gives the poor performance.

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