Application Note: A001

Optical Thin Film Coatings

Light Interference

Noticed the rainbow colors on soap bubbles? Light is made up of waves and the rainbow colors are caused by the natural phenomena of light interference. This same principle is used in optical thin film coatings. When light hits a surface (Figure 1), some light is transmitted and some light is reflected. Light is reflected from the incident (top) surface and some light can also be reflected from the second surface i.e. the bottom-inner surface of the substrate.

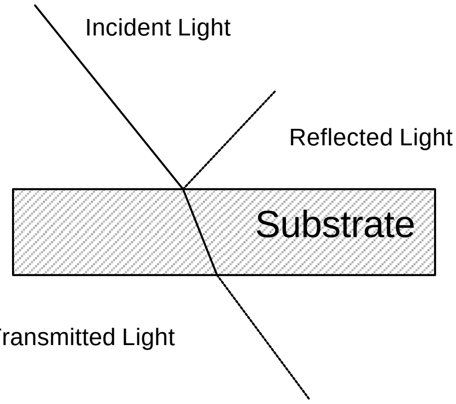

Figure 1

There are a few factors determining the amount of light reflected. They are:

(a) the angle of incidence
(b) refractive index of the substrate
(c) the wave-length of light

Typically for common glass, the reflection per surface is in the range of 3% to 7%. The total light reflected from the top and bottom surface is in the range of 10%. The rest of the light is transmitted and in some cases absorbed by the substrate.

In optical thin film coating, the substrate is coated with thin layers of transparent material of different reflective index. For example, if glass is coated with a thin layer of Magnesium Fluoride (MgF_2), the coated glass will have anti-reflection (AR) properties. How the AR properties work is explained below.

From Figure 2, it could be seen that light now is reflected from the air-to-MgF_2 surface and the MgF_2-to-substrate (glass) surface. The thickness of the coating is controlled so that the light waves reflected from both surface are anti-phase. Just like two stones thrown into a pond close to each other, some of the ripples generated on the surface of the water by each of the stones will cancel each other when they meet. In the AR coated glass, the light waves go through a destructive interference and since energy cannot be destroyed, most of the light energy is transmitted rather than reflected.

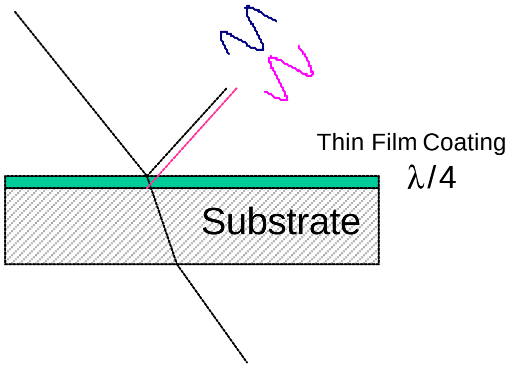

Figure 2

The thin film is in the order of quarter wavelength of the incident light or in the order of 100ths of nanometer thick. (The wavelength of visible light is from about 400 nm to 700 nm). To give better AR properties, more layers (multi-layer coatings) of different coating materials are used. This multi-layer coatings are commonly found in our eye-glasses. Coatings can also be done to the underside of the substrate to reduce reflection further.

What Is The Difference Between Anti-Glare And Anti-Reflection?

The two terms anti-glare and anti-reflection are sometimes used interchangeably to mean the same thing but actually there is a difference. The light 'rays' reflecting from a smooth surface (Figure 3 (a)) are parallel and if our eyes are in the path of the reflected rays, we will see a very reflective surface. With AR coatings, most of the reflected light is reduced thus we do not see any reflection from the surface. In anti-glare glass, e.g. used in LCD computer screens, the surface is not smooth but undulated. Light hitting the surface are reflected in different directions (Figure 3(b)) or diffused. Since less of the reflected light enters our eyes, we do not see much reflection.

The application of anti-glare glass on systems that emit light, such as the computer screen, is fine but not in situations where you want as much light as possible to be transmitted, such as in the lens of a camera. In this case, optical thin film coating will have to be used.

How Does Optical Filters Work?

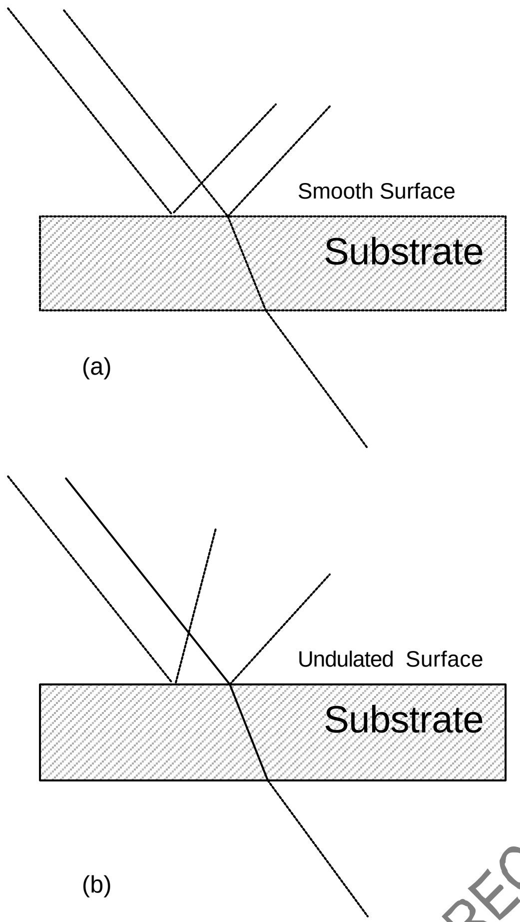

Figure 3

Even for the LCD computer screen, it could be seen that light is not efficiently used if an anti-glare surface is used. Since the glass surface is undulated for an anti-glare surface, all the light emitting out of the screen will not reach the eyes of the user. So to get a better contrast, we typically increase the back-lighting of the LCD screen and this effectively consumes more power. This does not go well with portable devices (one of the major power guzzler of portable devices are the back-lighting of the displays). Using optical thin film technology, the coatings can be designed such that stray light hitting the surface of the screen from outside will not be reflected but at the same time, most of the light emitting from the screen is transmitted to the user. Light is then efficiently used and this requires lower intensity back-lighting, thus extending the battery life.

Optical interference filters or sometimes just called optical filters are used in many places. It is used in photography, display projectors, optical storage devices, digital cameras and optical telecommunication. Filters, as its named implied, selectively allow only certain wavelength of light to go through. For example, in a Red filter, light of wavelength 600 – 700 nm are allowed to pass through and all other wavelength of light is blocked. The coated glass will then appear red. Filters are also used to cut off harmful ultra-violet light in the region below 400 nm or to cut off the heat (infra-red) in the region above 1000 nm.

The principle of operation is the same as described for the AR coating. In this case (Figure 4), the coating is multi-layered, e.g. for a red filter the number of layers could be in the region of 40.

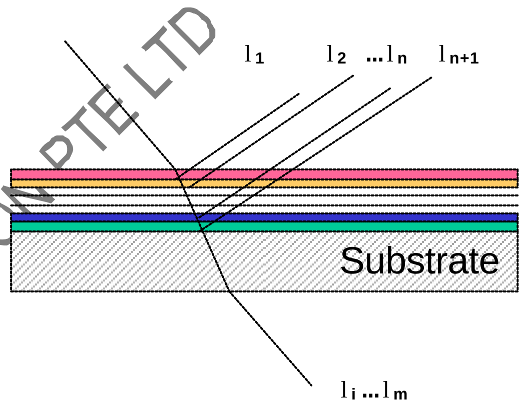

Figure 4

Each layer of the coatings selectively remove certain wavelength of light and allowing the desired wavelength of light to go through.

Coatings can also be designed to split the beam. For example, a filter can be design such that when white light hits it, the red light is transmitted and the green light is reflected. This kind of filters are used in projection displays to generate the primary colors.

Coatings are commonly produced using vacuum deposition methods [1].

References:

[1] "Ion-Assisted Deposition", *Opto-Precision Application Note: A002.*

…………*September 2003* ………………