Smart Window Film

Nano particle coatings and applications

C. De Meyer, R. Moerkerke, S. Lapshin, J. Vaneecke,
P. Goemaere, P. Persoone, H. Lievens
Bekaert Technology Center, NV Bekaert SA,
Bekaertstraat 2, BE-8550 Zwevegem, Belgium.

There is growing interest for so called "smart coatings", using nano particles and atmospheric web coating technology. The very small light scattering of nano particles is the main driver for their use in optically clear films with special functionalities, and a broad range of applications exist. The use of nano particles in solar control window films is given as an example, along with the performance comparison between nano particles in web coating technology, as opposed to vacuum wet coating.

Introduction

Nano particles can add special properties to window films, while their small size makes them invisible for the human eye. A good example is that of nano particles providing light and heat control when incorporated in the window film construction. The major criteria for using nano particles in spectrally selective solar control film are:

1) High transparency in the visible light spectrum
2) Absorption in the IR

Both criteria will be explained in this article in view of obtaining a solar control window film. The performance and the properties of Ultra Performance 75 (UP75)* with embedded nano particles are given as an example. This new technology based on heat absorption by nano particles will be compared to the existing reflecting technology, achieved by vacuum deposition of metal layers and stacks. A comparison will be made with a high end commercial alternative solar control film based on an IR reflecting stack, i.e. Hilite**.

High transparency in the visible range of the electromagnetic spectrum

Micron range size particles tend to cause haze because of scattering but smaller particles not absorbing in the visible become transparent. Mie's theory allows the transmission of a layer of non-absorbing spherical nano particles in a polymeric matrix to be calculated. Fig. 1 shows the transmission in the visible range of the electromagnetic spectrum for spherical nano particle of different size. The smaller the nano particle, the more transparent the resulting coating will be. Similarly, one can calculate that nano particles with higher refractive index, require smaller particle size to obtain the same high transparency.

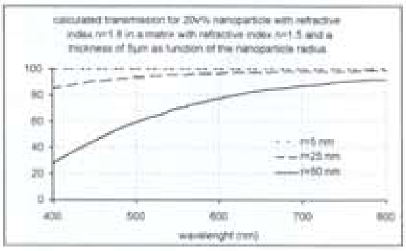

Figure 1 Theoretical transmission as function of wavelength calculated using Mie's theory

Absorption in the infrared range of the electromagnetic spectrum

Conducting nano particles exhibit surface Plasmon resonance absorption caused by the excitation of surface Plasmons (collective oscillations of free electrons at the surface). To avoid impact on the visual transmission, the resonance wavelength should not be in the visible part of the electromagnetic spectrum, as is the case with noble metal nano particles, like Ag and Au. Materials of interest have moderate densities of mobile electrons so that they absorb in the infrared range of the electromagnetic spectrum. The best known nano particles for IR

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absorption are ITO, ATO and LaB6. Fig. 2 shows literature data on the conductivity related to the Plasmon absorption peak for several materials.

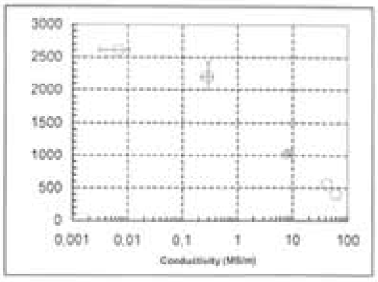

Figure2 Graph illustrating the relationship between the Plasmon absorption peak wavelength and the conductivity for some spherical nano particles. ATO, ITO and LaB6 absorb in the IR range of the electromagnetic spectrum. Ag and Au absorb in the visible range.

For spherical nano particles, the absorption peak also depends on the medium, and also shifts to longer wavelengths if the shape of the particle deviates from spherical to ellipsoidal.

Parameters characterizing the performance of spectrally selective window films

Transmission and reflectance data of glass installed with a window film are measured with a spectrophotometer and further used to calculate the performance parameters using CEN methodology and LBNL Window software. The most important parameters are:

- The Visual Light Transmission (VLT): the weighted average of the transmittance over the entire visual wavelength range (380 nm to 780 nm). The weighting functions are the spectrum of the illuminant (e.g. A, C, D65, ...) and the CIE standard color matching functions.
- The total solar transmittance, reflectance as observed form the outside (front) and absorptance, (Tsol, Rsol, Asol): weighted averages over the entire UV/VIS/NIR range (300 nm to 2500 nm). The weighting function is the solar spectrum at sea level.
- The Solar Heat Gain Coefficient (SHGC): the fraction of incident solar radiation admitted through a window, both directly transmitted (Tsol), and absorbed and subsequently released inward by means of convection and radiation.
- The Shading Coefficient (SC): the ratio of the total solar heat gain through a specific window to the total solar heat gain through a single sheet of 3 mm double-strength glass under the same set of conditions.
- The Total Solar Energy Rejected (TSER): the total (direct) solar reflectance plus the part of the total (direct) solar absorptance released outward by means of convection and radiation (100*SHGC + TSER = 100%).
- The Light-to-Solar Heat Gain ratio (LSHGC): the ratio between VLT and SHGC, i.e. a gauge of the relative efficiency of different glazing systems in transmitting daylight while blocking heat gains. The higher the ratio, the brighter the room is without adding excessive amounts of heat. Typically > 1.2 for a spectrally selective solar control window film, and < 1 for other solar control window films.

Performance of the new Bekaert spectrally selective automotive window film, UP 75.

Using the technology of IR absorbing nano particles, Bekaert Specialty Films LLC has

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designed a new spectrally selective window film, the Ultra Performance film, UP75. The spectral transmittance and reflection of a 3 mm clear glass installed with this window film is shown in figure 3.

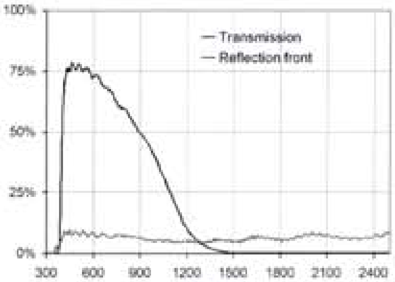


Figure 3 Spectral transmittance and reflectance of a UP75 film installed on 3 mm clear glass

The UV radiation (< 380 nm) is entirely blocked using a window film. In the visible range, the transmission is very high (VLT 75%) but decreases sharply in the IR (800-2500 nm).

As a result, this film has an infrared rejection of 89% due to a combination of ITO and ATO nano particles in the film. Fig. 4 shows an example of the nano particles size in the UP75 film, obtained using atomic force microscopy and particle/particle counting software. The average diameter of the particles, using this methodology, is 32 nm.

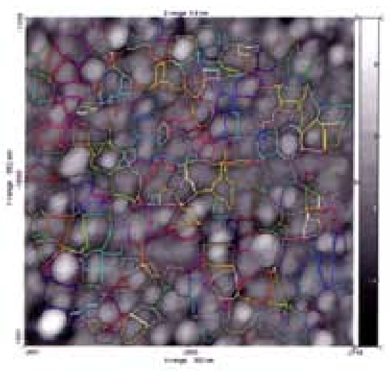


Figure 4 Particle size and counting image based on AFM analysis of the nano particle layer in UP75

How does this film compare to the high performance spectrally selective reflecting films?

The commercially available retro-fit film with the highest spectrally selective performance for architectural applications is Hilite®, a spectrally selective film based on a multilayer stack formed by nano layers of vacuum deposited coatings of Ag and TiOx.

Fig. 5 shows its spectral transmittance and reflection on 3 mm clear glass. Compared to UP75 (fig. 3) it is clear that the high IR rejection of Hilite® is based on the selective reflection whereas the UP75 film absorbs the IR radiation.

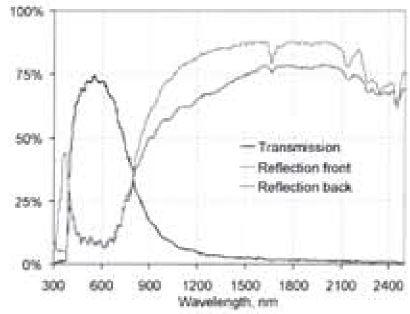
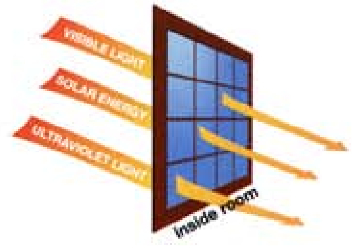


Figure 5 Spectral transmittance and reflectance (both front and back reflection) of Hilite® installed on 3 mm clear glass

Table 1, compares the performance properties of both film technologies. The reflecting technology remains the best option if there are concerns for glass breakage due to thermal stress (the solar absorption for the absorbing film is nearly twice that of the reflecting film). Therefore, Hilite® remains the best spectrally selective film in the market, but the IR absorbing UP75 offers a good performing and lower cost alternative for Hilite® in cases where thermal stress in the glass panes is no issue.

Table 1 Performance comparison between Hilite® 70 (reflecting technology) and UP75 (absorbing technology) using LBNL Window 5 software.

Reflecting technology:	Hilite® 70	
Absorbing technology:	UP 75	
Visual light transmission	72%	75%
IR rejection	95%	89%
Solar Heat Gain Coefficient	0.45	0.60
Total Solar Energy Rejection	55%	40%
Shading Coefficient	0.52	0.70
Solar Absorption	28%	44%
Light to Solar Heat Gain Ratio	1.59	1.23



Summary and Conclusion

For optically clear films such as window films, the growing interest to use nano particle coatings results from the ability of these small particles to add functionalities while remaining optically clear and transparent. As example, the nano particle containing solar control window film UP 75, was demonstrated. This film is able to reject 89% of the IR heat while maintaining high visual transmission.

The working principle is based on the selective IR absorption of the nano particles in this film. Other spectrally selective films are based on IR reflection, created by metal/dielectric stacks that are deposited using vacuum technologies.

The comparison of the best films of both technologies indicates that there is a dissimilarity in performance due to the inherent differences of heat absorption versus heat reflection.

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