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SOLAR FILMS COMPARISON FOR PROTECTION AGAINST UV AND IR RADIATION

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Abstract- Due to damage that solar radiation causes on humans, in this work, solar control films (SCF) were compared in order to assess radiation protection. The evaluation criteria were that the SCF must have visible light transmittance greater than 85%, ultraviolet (UV) and infrared (IR) blocking greater than 95% and 40% respectively. 282 SCF data sheets belonging to 12 different brands (films most used in polarizing vehicles and buildings) were compiled. An analysis was made to one statistical sample of SCF in the optical laboratory, using the solar radiometer, spectrometer and spectrophotometer. The results showed that 15 SCF belonging to 4 brands satisfy the evaluation criteria.

1. INTRODUCTION

Since 1985, when Montreal protocol was signed to eliminate gases that destroy the ozone layer of everyday products, due to the ozone layer is the natural filter that protects the earth from UV and infrared (IR) radiation 1. As the ozone layer ages, more UV radiation enters. Prolonged exposure to UV radiation is associated as a cause of skin cancer, cataracts in the eyes, among other pathologies, this is why it is important to use UV protection on the skin using creams containing sunscreen, in the eyes using UV-protected lenses, in the windows of vehicles and buildings installing solar control films 1-2.

Brian S. BoxerWachler and daughter Micaela BoxerWachler evaluated 29 automobiles of 15 automobile manufacturers. They measured the UV-A radiation behind the windshield and behind the side window driver's side. The percentage of blocking of UV-A radiation in the windshield was 96% on average, varying the readings from one model to another in a range of 95% to 98%. The percentage of blocking of UV-A in the side window was 71% on average, varying the readings in a range of 44% to 96%. The difference between the windshield readings and the side window was 25% on average 3. It should be noted that vehicle manufacturers have placed UV protection on the windshields of the vehicles they produced during the past 30 years, but no UV protection was placed on the side window of most of the vehicles in the sample. Only 4 of the 29 vehicles analyzed have UV-A blockage in the side window. It is important to note that driving a vehicle for long periods of time without UV protection in the side window can lead to premature aging on the left side of the face and cataracts in the left eye 3.

In areas of extreme heat it is common to polarize windows of the vehicles, to reduce the entry of heat, it should be noted that traditional inking does not include UV protection, therefore, it is advisable to ink the windows with films that contain UV protection. The materials that offer UV protection are nanoceramic filters, such as, which is present in creams with sunscreen, thanks to these compounds the solar control films (SCF) have a significant block to radiation UV [4]. The SCF are a range of products that claim to block 95% or more of UV radiation and reject a considerable amount of solar energy 3-4. The SCF is an inking combined with a nanoceramic filter, for this reason it blocks UV and IR radiation and reduces the transmittance of visible light to the interior of the vehicle, therefore, it is necessary to take into account the traffic laws.

Current legislation allows films in the side windows of vehicles with transmittance greater than 85% and 15% in the rear window 5. The current legislation of each USA state is available at the International Window Film Association (IWFA) 5. In this association are registered the main producing and selling brands of solar control films 5. The production companies provide the data sheets of each film. The data sheets show how the reduction of heat flow occurs through the windows, this reduction is reflected in the energy consumption due to the use of air conditioning 6,7,8.

In order to measure the performance of the SCF it is necessary to separate the solar radiation, this is divided into UV radiation, visible light and IR radiation (Table 1). From here we take UVC and UVB radiation, prolonged exposure to these two radiations causes skin cancer 2. In the past, UVC and UVB radiation were almost completely eliminated by the ozone layer. The medium IR, far IR, and extreme IR radiation are invisible radiation that manifests as heat. The healthy radiations of the solar spectrum are UVA, visible light and near IR, because its moderate exposure causes positive effects on health 5.

Table 1. Wavelength (λ) of ultraviolet radiation, visible light, infrared radiation measured in nm (nanometer) 9,10,11

Type of radiation.	Wave length (λ)
UVC (noxious)	220 nm a 280 nm
UVB (noxious)	280 nm a 320nm

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UVA	320 nm a 400 nm
Visible Violet	400 nm a 455 nm
Visible Blue	455 nm a 492 nm
Visible Green	492 nm a 577 nm
Visible Yellow	577 nm a 597 nm
Visible Orange	597 nm a 622 nm
Visible Red	622 nm a 780 nm
IR near	780 nm a 3000 nm
IR intermediate	3000 nm a 6000 nm
IR far	6000 nm a 15000 nm
IR extreme	15000 nm a 1 mm

In an attempt to contribute in the field of sun protection, a comparison of the data sheets of the most common films on the market was made to determine the most efficient film protection under criteria visible light transmittance greater than 85%, a blockage of UV radiation greater than 95% and a significant blockage of the IR radiation.

2. EXPERIMENT AND MATERIALS

5 samples of the SOLAR GARD brand with different level of visible light transmittance (VLT): nr charcoal 54 = 54%(VLT), Nr charcoal 35 = 35%(VLT), Nr charcoal 23 = 23%(VLT), Nr charcoal 17 = 17%(VLT), Nr charcoal 7 = 7%(VLT) were analyzed in order to prove the data sheet furnished by provider on its website.

The rejected solar energy was measured using a solar radiometer. MARK VI SOL-A-METER model, brand MATRIX INC. Made in MESA, ARIZONA USA, serial number 3702.

The part of the UV-visible spectrum was measured using a UV-VISIBLE spectrophotometer VARIAN. Model CARY 50 Tablet,

The IR radiation was measured using a Spectrometer BRUKER. Model TENSOR 27.

3. RESULTS AND DISCUSSION

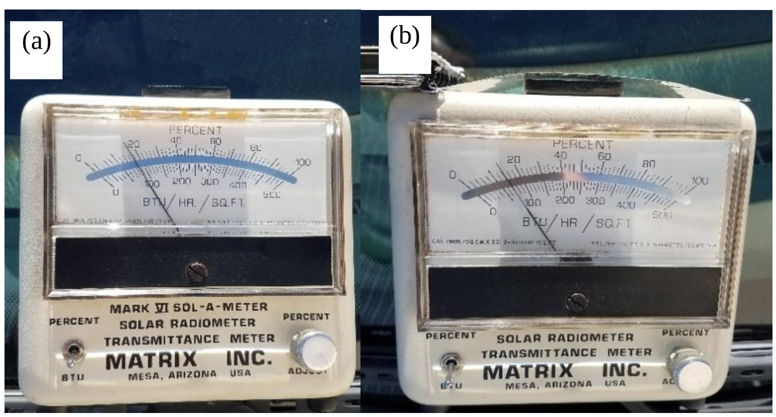

Figure 1. Radiometer a) without solar film, b) with solar film.

The transmittance of solar energy was measured on a sunny January day, temperature 19 ° C at 12:30 pm, the solar radiometer was placed outdoors with the sensor perpendicular to the sun and the reading was taken with the nude sensor, giving a result of 79 Btu/h/Sq. Ft. (Figure 1 (A)).With the solar radiometer in position, readings were taken covering the sensor with the film samples, Figure 1 (B).

The readings were taken 15 seconds after covering the sensor with the SCF samples. Knowing the transmittance of the solar energy, the rejected solar energy of the material was calculated by calculating the difference between the readings of the samples and the naked sensor reading, the results are shown in Btu / h / Sq. Ft. at figure 2.

Figure 2 compares the solar rejection between values of the supplier's data sheet and the readings obtained in solar radiometer when the sun is at the highest point and a clear sky. It can see that 3 samples block the energy indicated by the supplier and the other two cleaners block between 4 and 5% less than that indicated by the supplier. Figure 2.

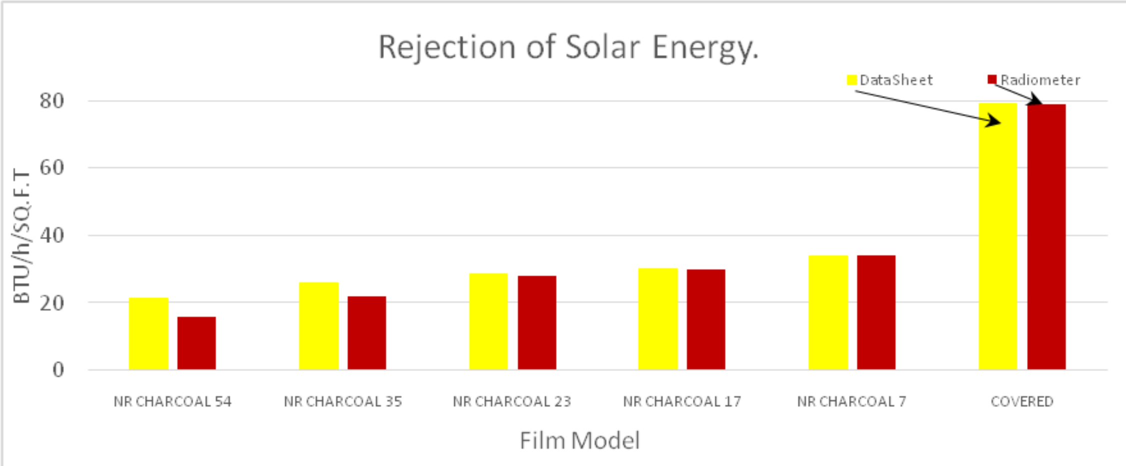

Figure 2. Rejection of solar energy. Comparing the data sheet against the readings obtained by the solar radiometer.

It can see in figure 2 that the darkest film (charcoal 7) just block 34 % of total sun energy, so it can mention that darkness grade it is not synonymous of solar energy rejection because just block visible light. Also, it can observe that films NR charcoal 23, 17 and 7 block similar quantity of solar energy. Looking for an equilibrium between visible light transmittance and rejection of total energy, it recommendable a film between NR Charcoal 35 and 23.

Figure 3 shows the UV-VIS transmission window for 5 studied samples. It can observe that there is an almost total blockage of UV radiation in region of 200 to 400 nm, which according to Table 1 is the most harmful radiation for human body. The blocking of UV radiation was due to the nanoceramic filter on the film. The average was calculated and differences were observed between the readings obtained and the values of the manufacturer's data sheets.

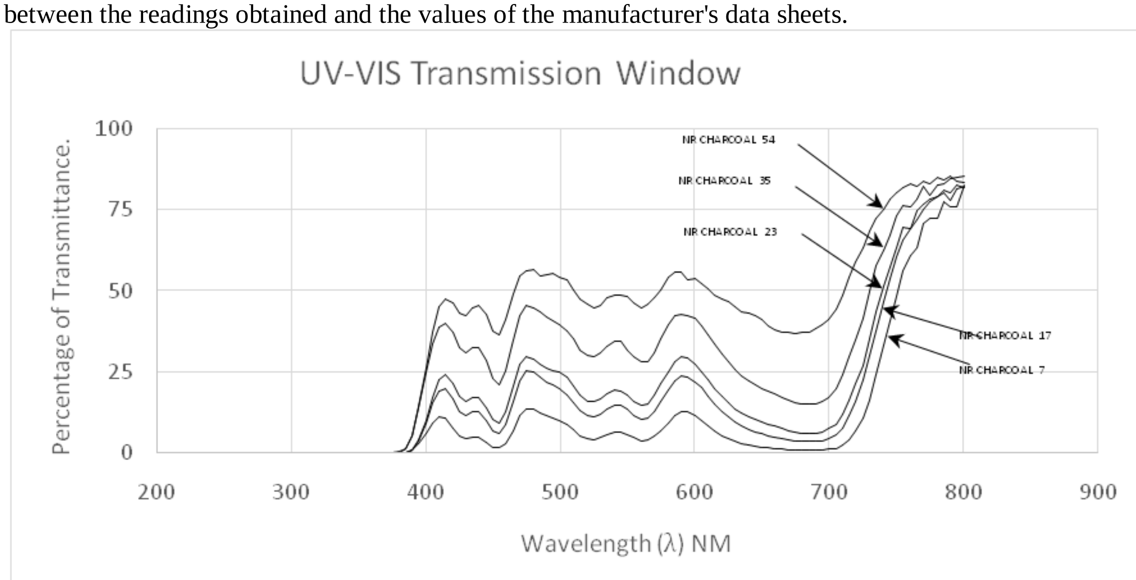

Figure 3. UV-VIS transmission window for 5 studied samples.

In the region of 400 to 800 nm visible light transmittance behavior is observed. It can see that the darker the film is, the lower the percentage of visible light transmittance. According to the criteria, the films with the highest percentage of visible light, such as NR charcoal 54 and 35, are recommended.

Figure 4 shows a IR blockage identical in the 5 samples. It is observed that at a λ of 2502 - 2753 nm it passes 60% IR (IR near). It is also observed that in the range of 2493-5521 nm there is a transmission window of 25% IR corresponding to the intermediate IR. After that all IR transmittance is totally blocked.

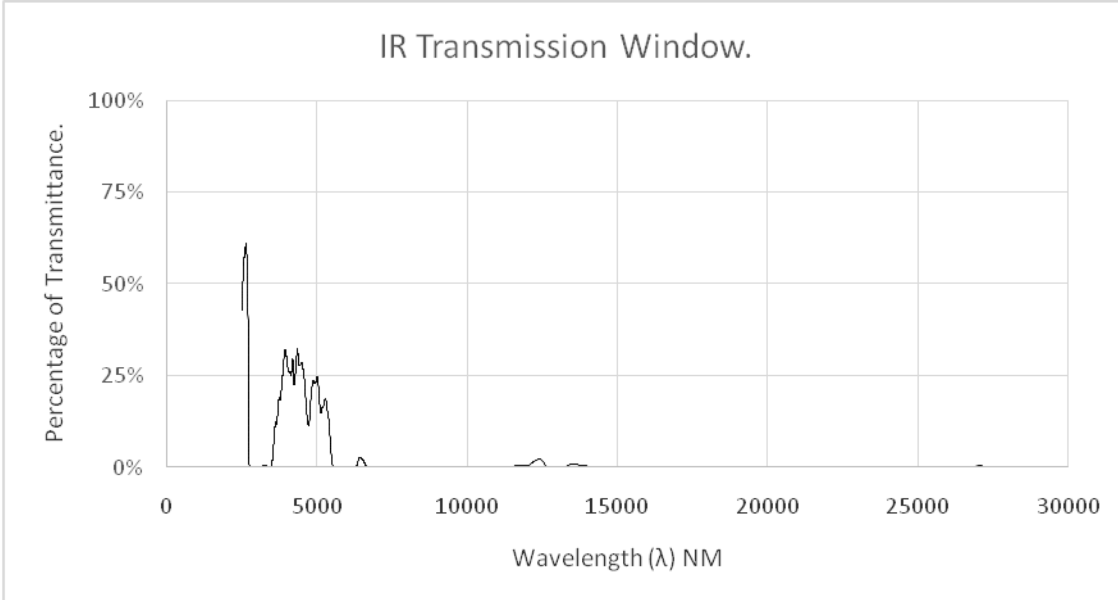

Figure 4. IR transmission window for 5 studied samples.

On the other hand, data sheets of 282 solar control films corresponding to 12 different brands (most popular in USA) were analyzed.

From the transmission windows information provided by manufacturer, 2 nanoceramic materials were selected due to great visible light transmittance, almost totally blocked UV radiation and largely blocked IR radiation. These materials are and Al2O3 as shown in Figure 5.

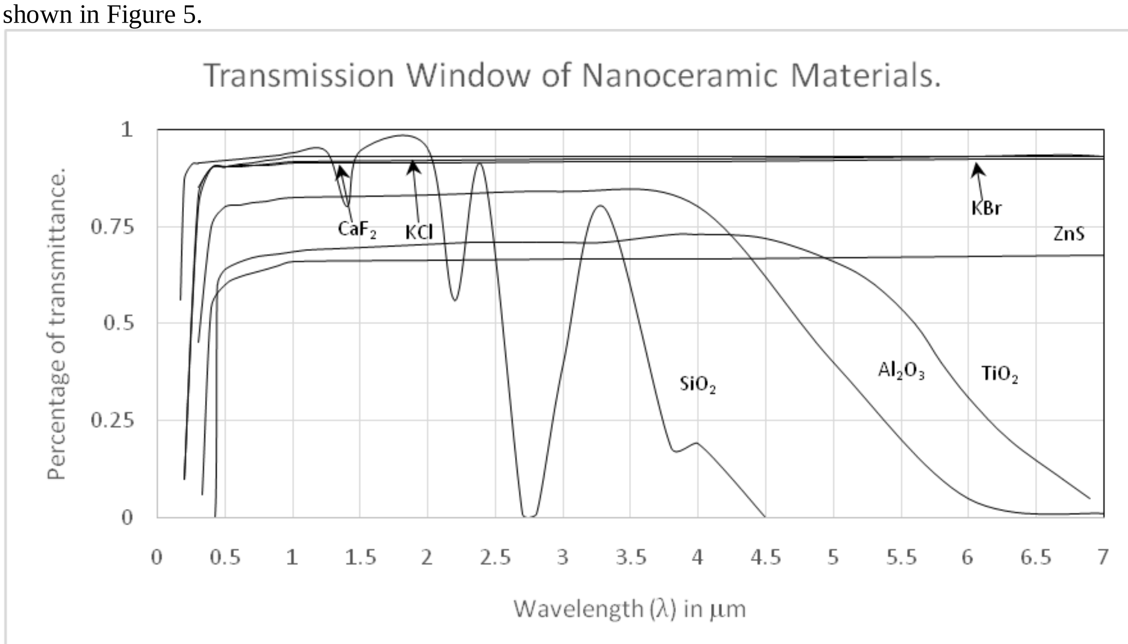

Figure 5. Transmission windows for nanoceramic materials that showed a blockage in most of the UV radiation and had a high transmittance of visible light 12–18.

From 282 sun protection films, 15 (corresponding to 4 brands) had visible light transmittance greater than 85%, blocked UV radiation more than 95% and blocked IR radiation were recorded in order of higher to less visible light transmittance efficiency (Figures 6 and 7).

The importance of the transmittance of visible light is because the visible light allowed us to see behind the windows where the nanoceramic filter was applied. The blocking of UV radiation was considered important to protect the health of people's eyes and skin, because prolonged exposure to UV radiation causes skin cancer and cataracts in the eyes. The blocking of IR radiation was considered important because the IR radiation is manifested in the form of heat inside the window.

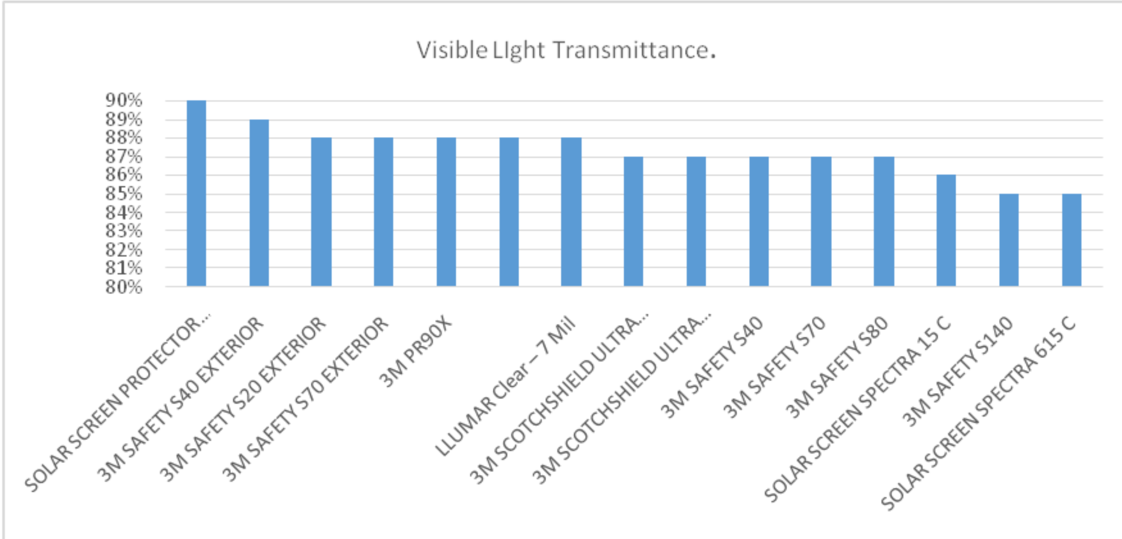

Figure 6. List of the most efficient SCF in transmittance of visible light in order of greater to less.

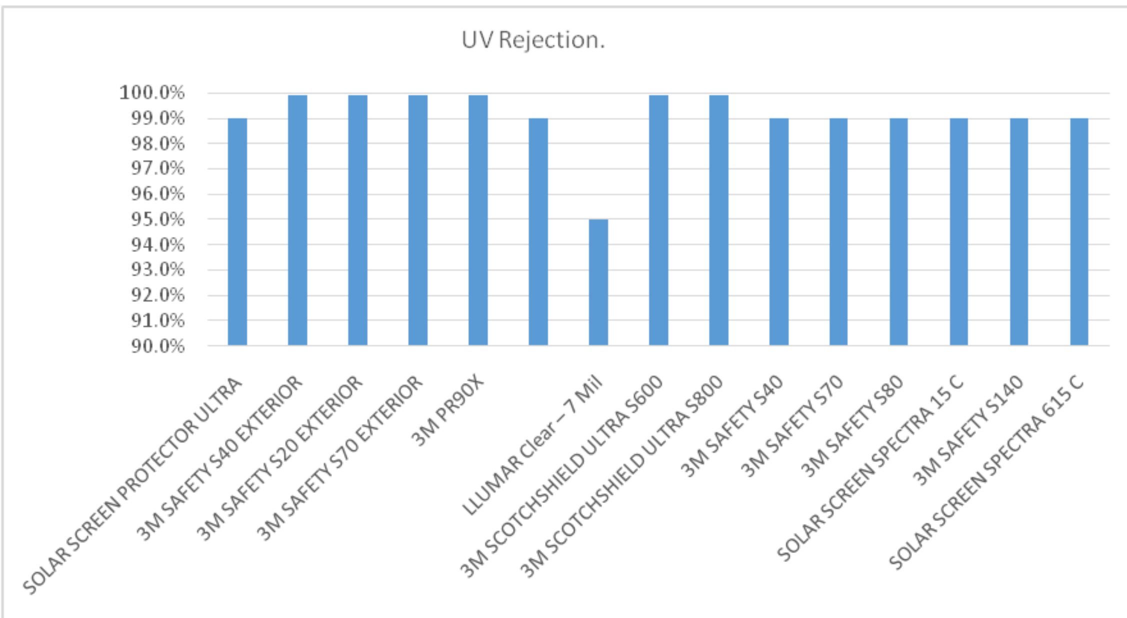

Figure 7. List of SCF showing the blocking efficiencies of UV radiation.

4. CONCLUSION

The aim was achieved. Our experiment results are similar to the data provide by manufacturer.

The nanoceramic materials that best block UV and IR radiation and have good visible light transmittance are Ti02, Al2O3 and ZnS.

From 282 studied films only 15 showed a visible light transmittance greater than 85%, a blockage of UV radiation greater than 95% and a significant blockage of the IR radiation.

Darkness grade on windows films it is not synonymous of solar energy rejection because just block visible light. Looking for an equilibrium between visible light transmittance and rejection of total energy, it recommendable a film between NR Charcoal 35 and 23.

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