Taiho Kogyo Tribology Research Foundation

Main report

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Theme: Investigation of the effect of wear on PV module glass surface for mechanical cleaning system

1. Progress and result of the research

The proposed research aims to investigate the wear behavior of PV glass surface due to mechanical cleaning and the effect of wear on glass transmissivity.

1.1 Research Method and Materials

1.1.1 Sample preparation

Samples of as-received soda lime and borosilicate glasses were prepared in 30 mm × 20 mm × 3 mm dimensions to examine their optical (transmittance, absorptance and reflectance) and mechanical (surface roughness) properties. Manual cleaning operations have been carried out using nylon sponge (NS), microfiber cloth (MFC) and nylon brush (NB) on three pairs of sola lime and borosilicate glass samples. Each sample has been manually cleaned for 7 hours which is equivalent to 1 min per cleaning per (2cm × 3cm) size of sample on monthly basis.

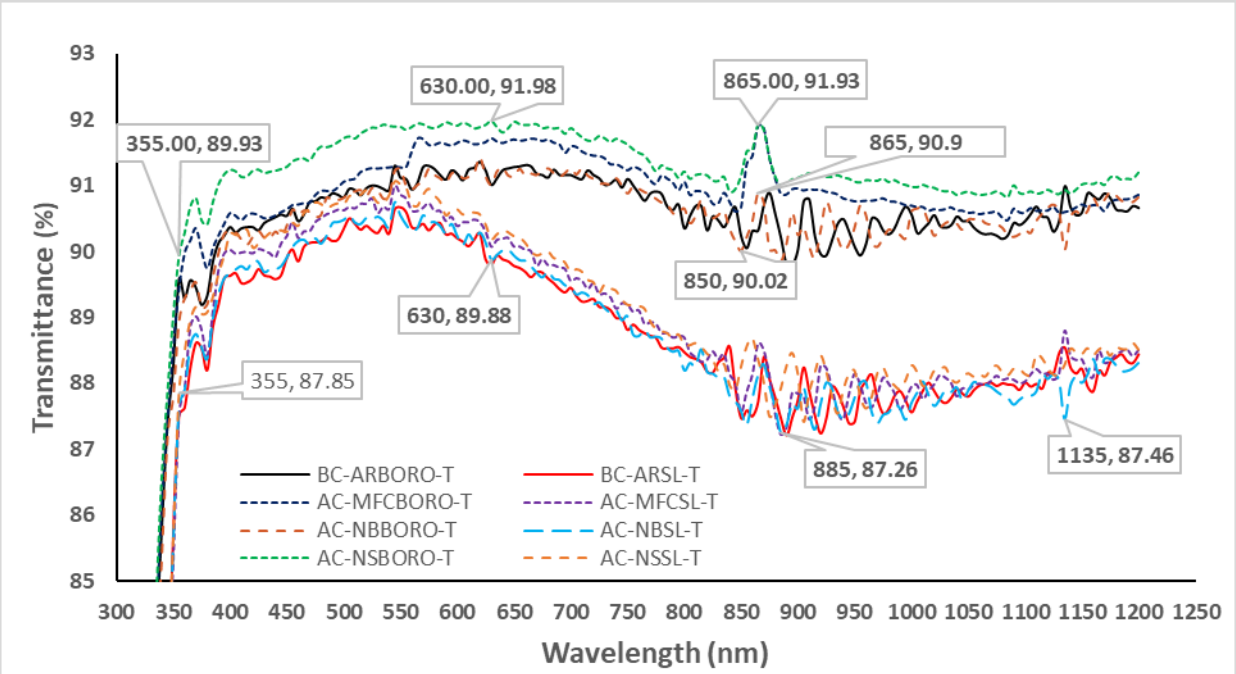
1.1.2 Experimental Investigation

Transmittance and absorptance of the glass samples were examined by a UV-VIS NIR Scanning Spectrophotometer (Model: UV-3101 PC by Shimadzu; Wavelength range: 190 nm to 3200 nm) and reflectance was examined by UV/VIS/NIR Spectrometer (Perkin Elmer; Wavelength range: 190 nm to 3300 nm). All the samples were examined between 300 nm to 1200 nm since any values that are below and beyond this range are outside the spectral response of most PV modules. Moreover, wavelengths below 300 nm are insignificant due to the filtering property of glasses [1]. On the other hand, surface roughness of the samples was measured by using surface profiler (Model: KLA Tencor). To comply with ASTM E384-17 and MS ISO/IEC 17025 standards surrounding temperature were controlled between 21 – 32°C and humidity between 42 – 69% during the tests. All the samples were tested under 40× resolution following the standards of considering three indentations point made on each specimen.

1.2. Results and Discussion

1.2.1 Effect of cleaning on optical properties

Figure 1 shows that the transmission curve for borosilicate glass has started to drop slightly at wavelength of 850 nm but then started to increase back at wavelength 865 nm and become stable until wavelength 1200 nm. The upshot for soda lime glass is quite different, whereby the transmittance started to drop drastically from wavelength 630 nm until 885 nm, hence it remains almost the same in NIR region till 1200 nm. The highest transmittance (Figure 1) for the as-received borosilicate and soda lime glass before cleaning are 91.36% and 90.67% at wavelengths of 620 nm and 550 nm, respectively. Upon cleaning with MFC, all the glass samples except borosilicate glass show the highest transmittance at visible region. Borosilicate glass shows the highest transmittance at near infrared (NIR) region at wavelength of 865 nm. NS produces the highest increase in transmittance for both types of glasses as compared to the other two cleaning materials. Upon cleaning with NS, the highest transmittance for borosilicate and soda lime glass obtained are 91.98% and 91.094% at wavelengths 630 nm and 525 nm, respectively.



[***Note***: *AR: as-received, AC: after cleaning, BC: before cleaning, BORO: borosilicate, SL: soda lime, NS: nylon sponge, MFC: microfibre cloth, NB: nylon brush*]

Figure 1: Transmittance before and after cleaning and brushing for borosilicate glass and soda lime glass at wavelength 300nm – 1200 nm

1.2.2 Effect of cleaning on mechanical properties

Figure 2 shows that surface roughness values (Ra and Rq) for as-received borosilicate glass (Ra 0.73 nm and Rq 0.89 nm) are slightly higher than those values of as-received soda lime glass (Ra 0.57 nm and Rq 0.71 nm). Interestingly the opposite trend is noticed after cleaning.

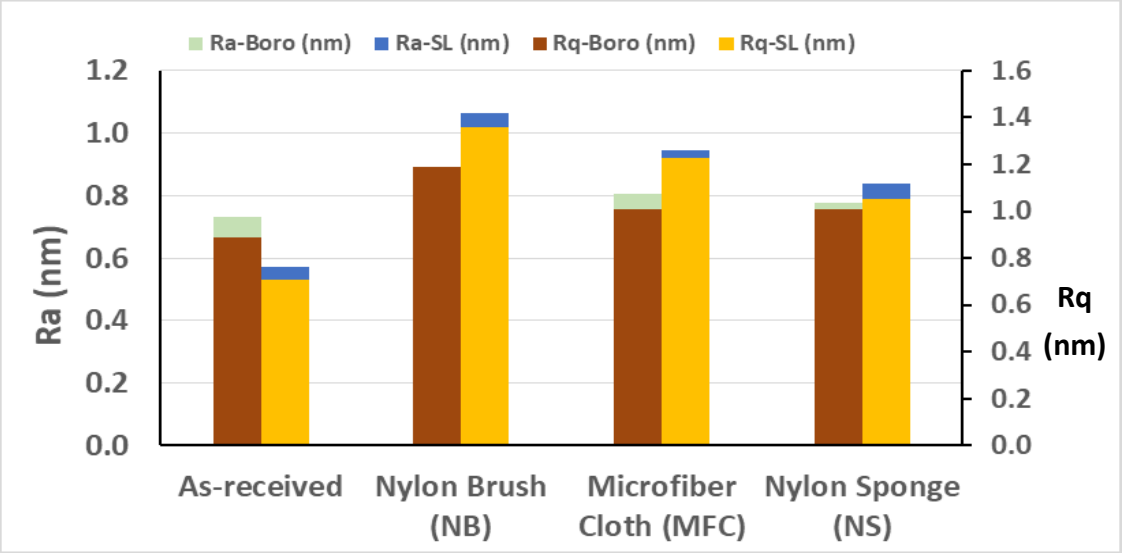


Figure 2: Surface roughness (Ra & Rq) of borosilicate and soda lime glasses before and after cleaning

As compared to others cleaning materials, NB is found to have the highest impact on surface roughness for both borosilicate and soda lime glasses. For borosilicate glass, Ra and Rq values increased up to 0.12 nm and 0.30 nm respectively, whereas for soda lime glass these parameters increased up to 0.50 nm and 0.66 nm respectively. NS produces the lowest average surface roughness values (Ra and Rq): 0.78 nm and 1.01 nm for borosilicate and 0.84 nm and 1.05 nm for soda lime glass. Hence, borosilicate glass has better surface properties and scratch resistance as compared to soda lime glass.

Figure 3 shows that upon cleaning transmittance and surface roughness of the both types of glasses are slightly increased. However, borosilicate glass exhibited greater transmissivity compared to soda lime glass before and after cleaning. Borosilicate glass has also shown the greater surface roughness compared to soda lime glass before cleaning with all types of cleaning materials. As of cleaning material, NB delivers the highest surface roughness and the lowest transmissivity.

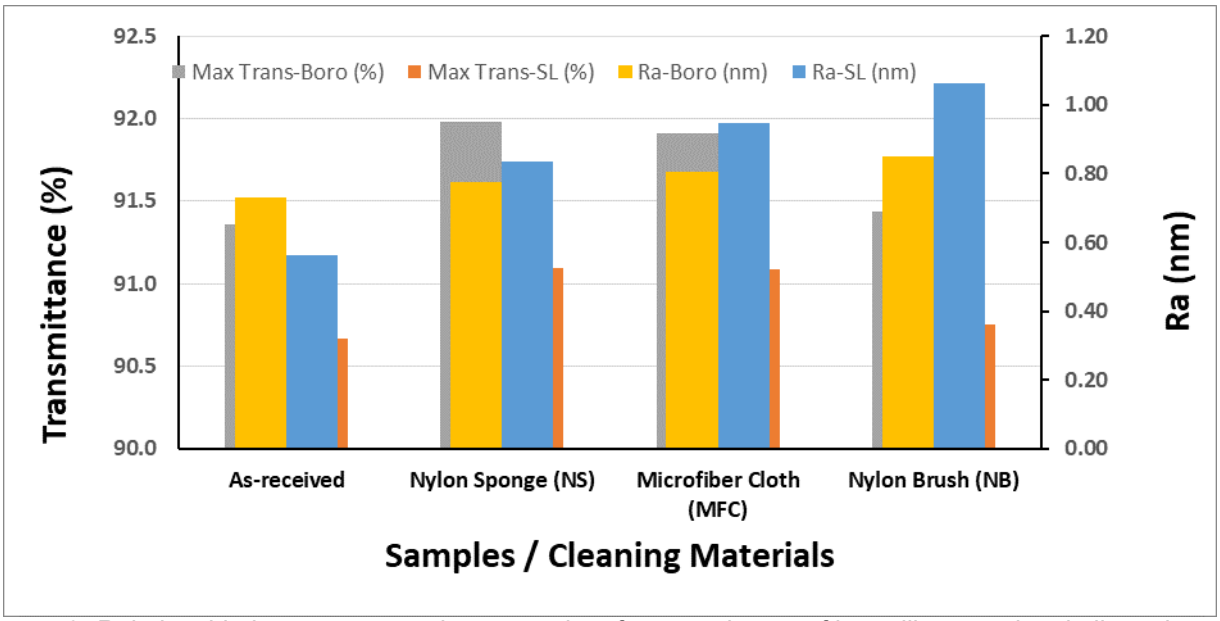


Figure 3: Relationship between transmittance and surface roughness of borosilicate and soda lime glasses before and after cleaning

Reference

1. Qasem, H., T.R. Betts, H. Müllejans, H. AlBusairi, and R. Gottschalg, Dust-induced shading on photovoltaic modules. Progress in Photovoltaics: Research and Applications, 2012. **22**(2): p. 218-226.
2. Beauchamp, W.T. and T. Tuttle-Hart, UV/IR reflecting solar cell cover. 1995, Google Patents.
3. Chandler, H., Introduction to hardness testing. Hardness testing. USA: ASM International, 1999: p. 1-13.

2. Subjects remain to be solved in future/Subjects required further investigation

- Effect of prolonged cleaning on optical and mechanical properties of PV glass under real-time conditions.

3. Plan and past presentation or publication of your research results

1. Nardia Zubir, M. Hasanuzzaman and N.A. Rahim (2020) Experimental Investigation the Effect of Cleaning On the Optical and Mechanical Properties of PV Module Glasses, Materials Science Forum 990: 291-295

2. Nardia Zubir, M. Hasanuzzaman and N.A. Rahim (2019) Experimental Investigation the Effect of Cleaning on the Optical and Mechanical Properties of PV Module Glasses. The 4th International Conference on Materials Technology and Applications (ICMTA2019), October 11 - 14, 2019, Kyoto, Japan (*Awarded for Excellent Oral Presentation*)