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Testing and Evaluation

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Synopsis: Experimental data for Smart Glass Spray I solution has been collected for about one and one half years and has been studied and evaluated by a team at Rice University. This report provides details as to testing and information gathered on Smart Glass Spray I. While several testing approaches have been used, the report specifically presents results regarding standardized testing. Please note that an access of one thousand samples have been tested.

This report was written by E. V. Barrera, Professor at Rice University.
Dr. Barrera serves as the CTO to Smart Glass Spray® but this report is written as a deliverable to the contract (OTT-SRA-15-0458) between Smart Glass Spray® and Rice University where Dr. Barrera is the principle Investigator.
US Customary Unites are used in this report.

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Report: Testing and Evaluation of Smart Glass Spray I Solutions

Introduction:

Rice University (Rice) is currently supported by Smart Glass Spray® (Smart Glass Spray) on a project entitled: Strengthening and Advancing the Multifunctional Properties of Glass Materials (contract no. OTT-SRA-15-0458). In compliance with the deliverables of that project, this report is being submitted to Smart Glass Spray® as a report on Smart Glass Spray I. In this assessment, Rice produced Smart Glass Spray I solutions for testing on glass and glass/film systems. Smart Glass Spray provided float glass and other glass materials according to the specifications given by Rice (in order to conduct standardized testing where possible). Glass in the form of 4” x 4” samples in thicknesses of
1/16”, 1/8” were tested. Samples of 3”x 12” with thicknesses of 1/4” were also tested. Smart Glass Spray solutions were produced at Rice in one and five gallon quantities and production of Smart Glass Spray I was initiated in 55 gallon quantities. For this report, specifics on the ASTM C-1499 and D3330 tests are presented.

Solution Processing and Methods of Testing:

Rice team studied processibility of Smart Glass Spray I solutions and a number of members of the Rice science team and by the Smart Glass Spray science team made Smart Glass Spray I and samples were prepared with Smart Glass Spray I for flexural strength, peel, and impact testing. Many of the solutions that were mixed and studied by Rice showed improvements to properties of the glass via the testing methods used. The recipe was studied and a higher degree of repeatability was observed. Please note that it was the goal of the SRA to improve the Smart Glass Spray solutions manufacturing where possible.

Sample Testing:

Glass Strengthening: According to ASTM C-1499 testing, the following data has been compiled for Smart Glass Spray I where a sample set larger than 1000 samples of 4”x4”x1/8” were used. The baseline is set at zero and the bar graph reflects outcomes that are improvements over plain glass. Figure 1 shows the performance of Smart Glass Spray I for two solutions produced and tested and is representative of a number of other solutions produced during this study.

Note that the data shows an average increase in strength of over 80% where highs and lows reflect the variability of glass.

Flexural Testing: While separate flexural testing is not conducted at this time, change in displacement of the glass during the ASTM C-1499 also shows flexural properties of the glass. Based on a sampling of over 1000 samples, an increase in displacement of the glass improved by up to 83%.

Adhesion Strength: The adhesion strength of Smart Glass Spray I has been tested using an ADMET Peel Tester
(model no. eXpert 7601 system) according ASTM D3330. Figure 2 shows a comparison of adhesion strength for film applied to glass using soap and water and that for when Smart Glass Spray I is used to apply the film to the glass. Peel strength shown is based on testing where the ASTM D3330 is used and is consistent for testing done internal to Rice.

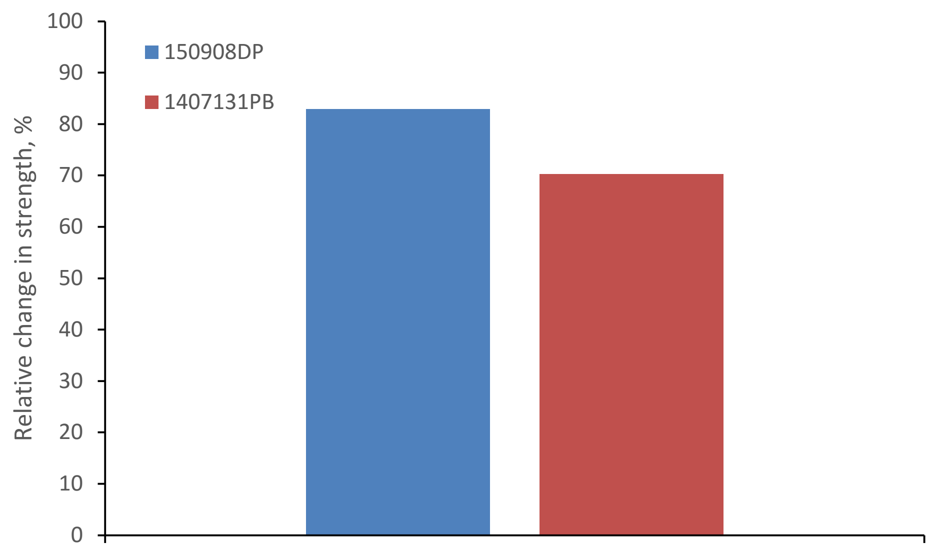


Figure 1. Given that an average value of failure of plain glass was found and set to zero. The bar graph shows how Smart Glass Spray I has shown improvement in strength over plain glass. Testing for two solutions are shown but reflect that seen for numerous other solutions produced and tested.

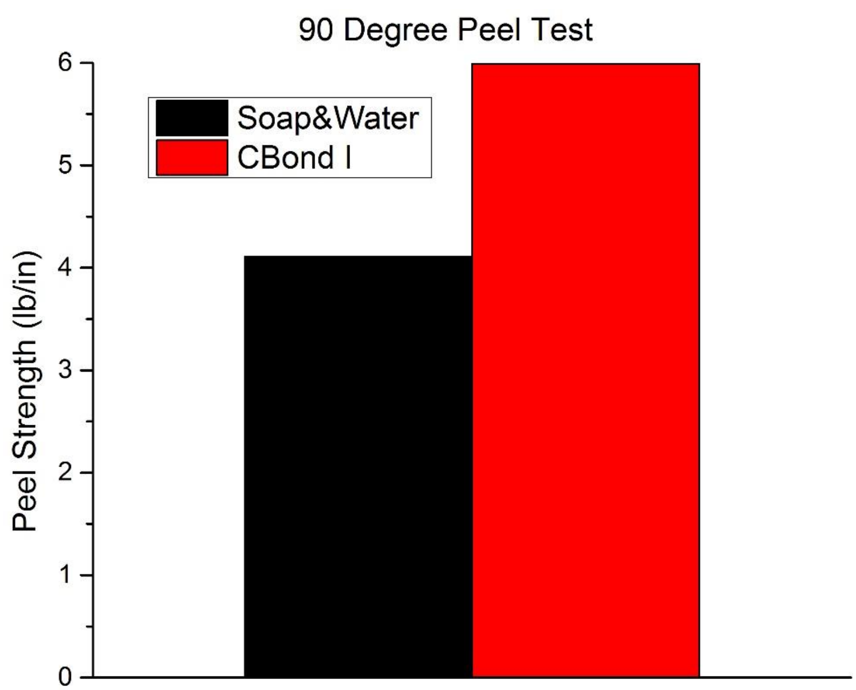
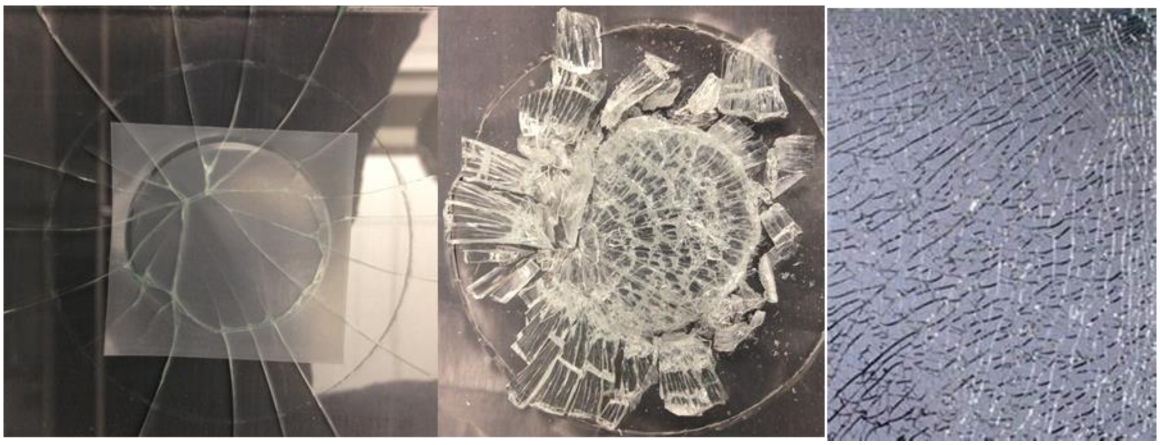


Figure 2. Representative peel strength for film applied to glass with Smart Glass Spray 1 is shown and is compared to film on glass applied with soap and water.

Glass Breakage: The images shown in Figure 3 show three failure modes for glass. As glass gets strengthened by Smart Glass Spray I the glass failure mode moves from failure 1 to Failure 2. Failure 2 has some similarity to Failure 3 which is that seen for tempered glass.

Numerous samples of Glass/film with Smart Glass Spray I have been made and have been tested by Forced Entry, Impact, or Ballistic testing (for demonstration testing).



Failure 1 Failure 2 Failure 3

Figure 3. Three failure modes for glass failure are shown. Failure 1 is for plain glass and Failure 2 is for glass treated with Smart Glass Spray I. Failure 3 is the failure mode for tempered glass.

Summary

Smart Glass Spray I demonstrates over 80% improvement of average flexural strength of glass and 50% improvement of average adhesion strength when used to apply glass to film. Other properties of glass when treated with Smart Glass Spray I are very useful for the glass and film industry.

Rice University Research Team:

Enrique V. Barrera, PhD is a Professor of the Department of Materials Science and NanoEngineering and Chemistry. He conducts Materials Science and Nanoengineering and Engineering research on a broad range of materials including ceramics and glasses. Each of the materials systems he studies and develops is tested and in many cases is tested using ASTM standard approaches. Barrera is a Fellow of the American Society of Materials and a recipient of the 2002 Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring that was awarded in a White House ceremony. He has published over 150 publications with ~60 patents submitted, pending, or issued.

Santoshkumar Biradar, PhD is a Postdoctoral Research Associate for Dr. Barrera. He has a PhD in Materials Science from Norfolk State University. He has a background in Chemical Engineering and Polymer Science and Nanoengineering. He also has a background in designing and developing processes and inorganic nanomaterials.

Liehui Ge, PhD is a Postdoctoral Research Associate for Drs. Enrique Barrera and Pulickel Ajayan. He has a PhD in Polymer Science from the University of Akron. He has a background in polymer materials, nanotechnology, chemistry, and surface, mechanical, and structural characterization.

Maryam Neshastehriz, PhD is a Research Staff member for Dr. Barrera. She has a PhD in Engineering Science and Mechanics from Penn State University. She has a background in Materials testing, characterization and materials processing.

Deborah Pereira is a Research Staff member for Dr. Barrera. She has a BS in Civil Engineering from the Federal University of Parana. She has a background in working with cement and concrete and in testing materials.

Christian Yu is an undergraduate student in Chemistry at Rice University.