On the improvement of adhesion between glass and polymeric materials

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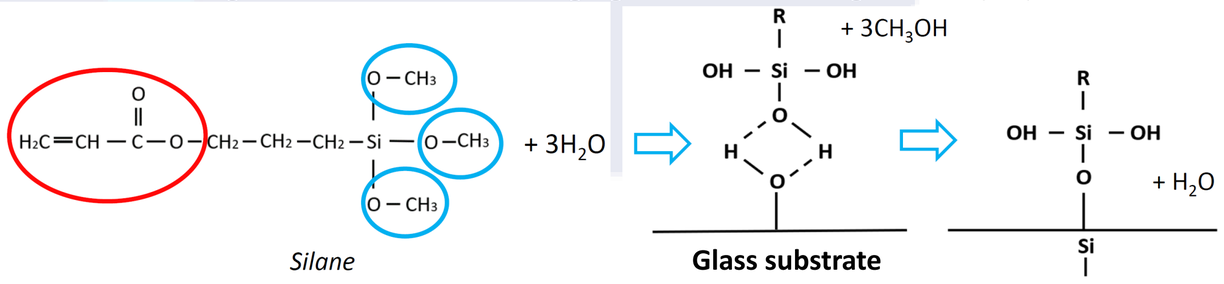
Objective

The goal of this research is to improve the adhesion between UV-curable polymers and glass and demonstrate, using two examples, how a strong and reliable adhesion can lead to the development of stronger, more durable, and lighter load-bearing glass structures. The adhesion-promoting properties of silane coupling agents with polymers are used to create strong bonds between 3D printed materials and glass to develop lighter and more reliable composite materials, as well as to provide durable connections between glass and a coating developed by the authors to prevent stress corrosion.

Silanization

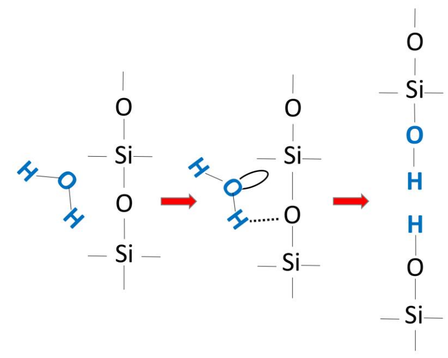
Glass surface modification by immersion in water solution of the silane (0.2 % vol): Creation of strong and durable Si-O-Si bridging bonds between glass and polymers.



Glass stress corrosion mechanism

Decrease of the bending strength during aging under load, favored by the presence of water:

- related to the sub-critical growth of micrometric surface defects and cracks
- rupture of silicon-oxygen bonds
- activation energy provided by external stress

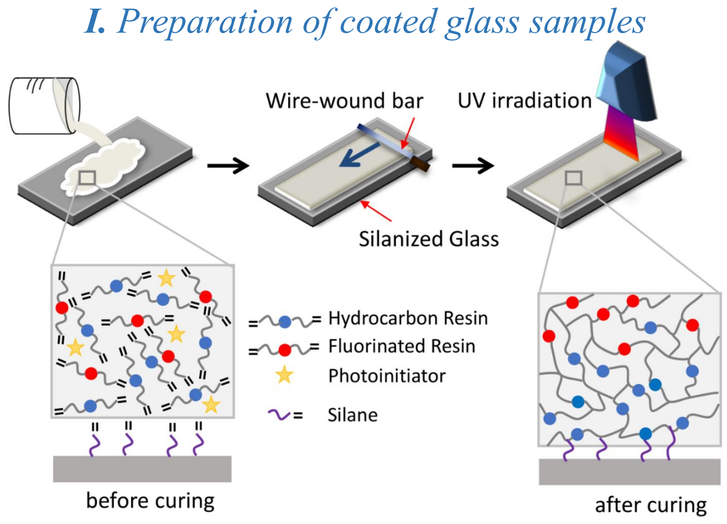


Development of a functional coating for inhibiting stress corrosion

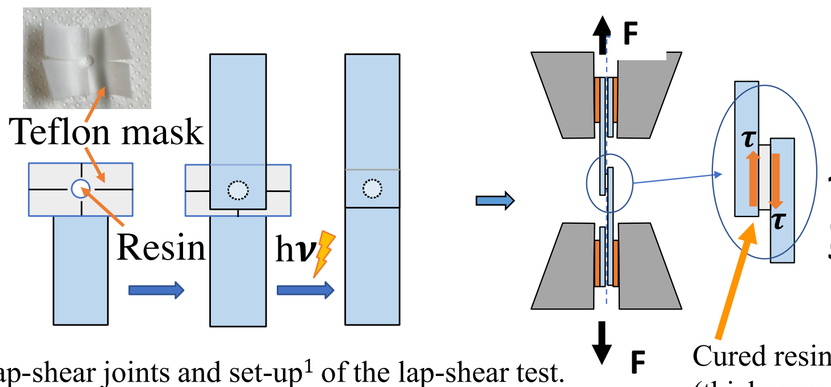
Requirements:
Hydrophobicity,
Low permeability to water
Good adhesion to glass

Main challenge and approach:
Hydrophobicity and **adhesion** are competing properties: need for a compositional profile from the air side to the substrate. External surface (exposed to the environment) enriched with fluorinated moieties, acrylated silane to improve adhesion at the surface in contact with glass.

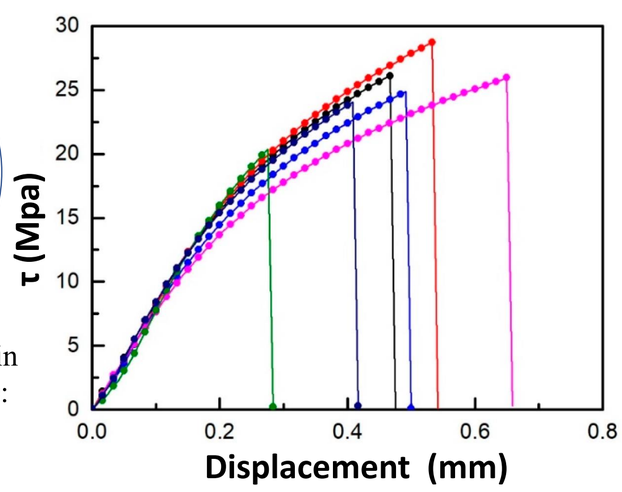
I. Preparation of coated glass samples



II. Evaluation of the adhesion between coating and glass

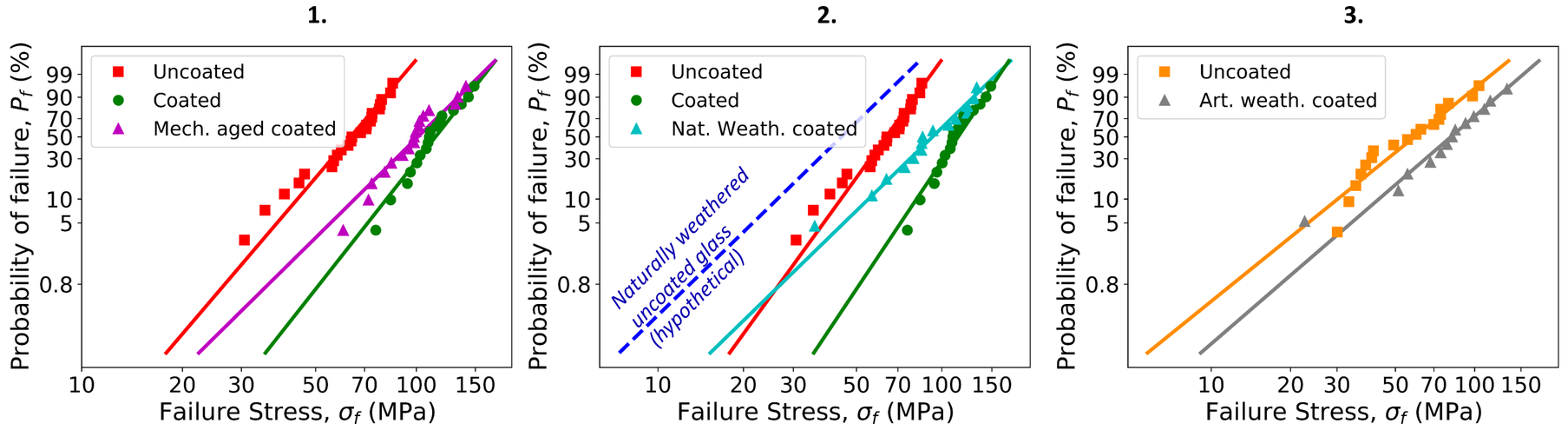


Lap-shear joints and set-up[1] of the lap-shear test.
1/ Swentek and Wood, Composites: Part B 58 (2014) 235–241



III. Evaluation of the effectiveness and durability of the coating and the adhesive bond

1. **Mechanical ageing**, accomplished by subjecting coated samples to cyclic loads;
2. **Natural weathering**, performed by exposing coated samples to atmospheric agents;
3. **Artificial weathering**, carried out by exposing coated specimens to fluorescent UV lamps, heat and water.

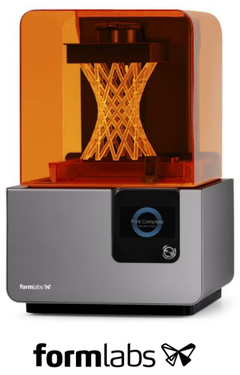


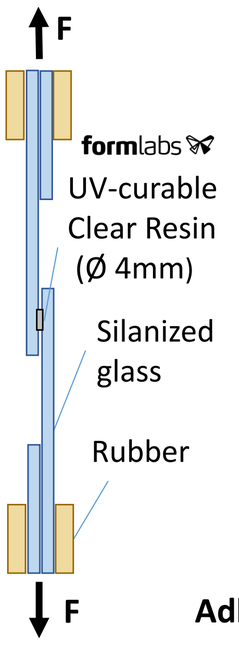
Enhancement of the adhesive strength of 3D-printed materials to glass

Sandwich panels consisting of two outer thin glasses and an inner additively manufactured polymeric core can replace conventional façade glazing[2] because of their superior strength-to-weight ratio, which reduces manufacturing costs and emissions. However, the structural integrity and full exploitation of the bending strength of composites depend on the reliability, strength and durability of the bond between polymer and glass. The employment of silane coupling agents allows to create covalent bonds between glass and UV-curable polymers, resulting in:

- Very high adhesive strength $\tau \approx 40$ MPa
- Transparent and nanometer-thick adhesive layer
- Printing of the polymeric core directly on the silanized glass
- Fully automatable production of the glass-polymer composite

2/ Kothe, Bodenko, Nicklisch, Louter. Civil Engineering Design. 2021; 3: 35– 42.

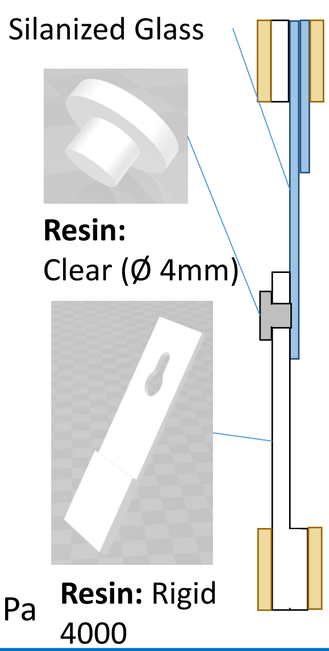




Lap-shear test results

Sample	Adhesive strength τ (Mpa)	Failure
1	48,99	Stock break
2	52,15	**Adhesive**
3	39,22	**Adhesive**
4	39,60	**Adhesive**
5	56,00	Stock break
6	42,22	Stock break
7	47,84	Stock break
8	53,27	Stock break
9	47,97	**Adhesive**
10	53,13	Stock break
11	36,65	**Adhesive**

Adhesive Strength $\tau = 43{,}12 \pm 6.61$ MPa



Research products

- S. Dalle Vacche, G. Mariggiò, A. Vitale, R. Bongiovanni, M. Corrado: Compositionally Graded Hydrophobic UV-Cured Coatings for the Prevention of Glass Stress Corrosion. Coatings 9:7, 2019.
- G. Mariggiò, S. Dalle Vacche, R. Bongiovanni, C. Louter, M. Corrado: Enhancing the design bending strength of new and aged glass with a functional coating. Glass Structures & Engineering, 5:135, 2020.
- G. Mariggiò, S. Dalle Vacche, R. Bongiovanni, C. Louter, M. Corrado: A durable coating for an improved glass bending strength under long-term loads. Glass Structures & Engineering, 2021. (in press)

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