

Reactive lamination of thermoplastic materials with thermosets

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We developed a Reactive Lamination Process that is capable of connecting incompatible thermoplastic materials like polymethyl methacrylate (PMMA) and cyclo olefin copolymer (COC). In this work, we describe the Reactive Lamination Process and investigate its potential with regard to thermoplastic material and thermosets.

1 Introduction

To generate an optical sensor foil, optical devices need to be integrated in a substrate foil. To ensure that those optical devices do not lose their shape and with it their function caused by the thermal treatment of the final assembly process, it is of high interest to use combinations of thermoplastic materials and thermosets. However, incompatibility is often observed between thermosets and thermoplastic materials, meaning they cannot be sufficiently connected by standard processes like conventional thermal lamination.

2 Description of the process

In conventional thermal lamination, two substrate foils are pressed against each other and heated above their glass transition temperature. This enables thermal interdiffusion of polymer chains if the surface energies of the polymer substrates are comparable (Fig. 1).

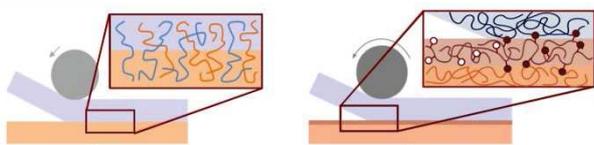


Fig. 1 Conventional thermal lamination (left) vs Reactive lamination (right)

If the surface energies of polymer substrates differ much, this interdiffusion no longer takes place and another mechanism is needed. The Reactive Lamination Process is different from the conventional lamination process, because it relies on covalent coupling instead of entanglement of polymer chains (Fig 1). A thin layer of a photoreactive material [1] is sandwiched between the incompatible polymer substrates and then activated by UV-irradiation. This material reacts via an unselective CHIC-insertion mechanism which was previously described [2].

This process has already been used to create embedded multimode waveguides to obtain strain sensors [3].

3 Experimental

The Reactive Lamination Process flow consists of the following steps:

- Depositing
- Drying
- Laminating
- Curing

3.1. Depositing

We chose spray coating as the deposition method for several reasons. It is compatible to Roll to Roll processes (R2R) and offers structured deposition. In addition, it has a good scale-up potential and allows a minimal solvent exposure of the substrate, reducing the corruption of the substrate to a minimum.

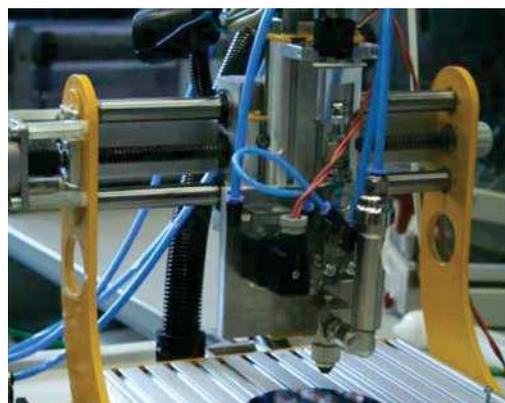


Fig. 2 Custom made spray coater

We designed and used a custom made spray coater that is capable of processing low amounts of a low concentrated solution of the photoreactive material similar to the ones used in [2]. This spray coater is depicted in Fig. 2 and features a servo

motor that allows a very fine tuning of the nozzle opening of the spray gun.

COC substrates (COC 8007; TOPAS; 30 mm x 10 mm x 165µm) were coated with PMMA-co-11%-AOAQ in ethyl acetate (c = 5 mg/ml) by spraying a spot with a diameter of $\varnothing = 3.2$ mm on the substrate using a mask. The layer thickness of the spray coated layer was determined by AFM to be between 100 and 500 nm.

3.2. Drying, Laminating and Curing

The coated COC substrates were dried in an oven (T = 60 °C; t = 15 minutes).

Three types of polyimide substrates (PI; Flexiso; MÜLLER AHLHORN, 30 mm x 10 mm x 40 µm) were created. The first substrate type was pure PI, the second substrate type was PI coated with Polydimethylsiloxane (PDMS; WACKER, Elastosil 601) using a hot embossing machine. The third substrate type was PI coated with Epoxy resin (EP; POXYSYSTEMS; epoxy resin "wasserklar") using doctor blading. The wet layer was left to cure for several days.

The coated COC substrates were laminated with pure PI substrates, the PDMS substrates and the EP substrates respectively using a hot roll laminator (STORCK) with a lamination speed of $v_L = 0.3$ m/min and a roll temperature of 140 °C on both the upper steel and lower neoprene roll.

The laminates were then crosslinked with a stratlinker (STRATAGENE) with a dose of $d = 2$ J/cm² at a wavelength of $\lambda = 254$ nm. A negative laminate group was left untreated and measured as referencing material.

3.3. Evaluation

Then the substrates were folded and shear tests performed with a tensile testing machine (DAGE 4000). The results are shown in Tab. 1.

Irradiation dose [J/cm ²]	Materials	Tensile stress [N/mm ²]	Failure type
0.0	PDMS / COC	0.0	Adhesive
2.0	PDMS / COC	0.0	Adhesive
0.0	PI / COC	0.0	Adhesive
2.0	PI / COC	0.0	Adhesive
0.0	EP / COC	0.0	Adhesive
2.0	EP / COC	4.5 ± 0.2	Cohesive

Tab. 1 Tensile stress capacities of reactive laminates

4 Discussion

Several substrate combinations of COC and hard-to-laminate materials were tested in the Reactive Lamination Process. The combination of COC and epoxy polymer was successfully laminated with a high tensile stress capacity of 4.5 ± 0.2 N/mm².

We were not successful to laminate PI and COC by reactive lamination. This fact confirms the theory, that aromatic carbon-hydrogen bonds are not reactive enough for reactive lamination, and aliphatic carbon-hydrogen-bonds are needed instead.

We were also not successful to laminate PDMS and COC by reactive lamination, although there were enough aliphatic carbon-hydrogen-bonds present. We believe this may be because of the abundance of PDMS-oligomers with a low molecular weight. These oligomers inhibit a high-quality lamination as well as solvent molecules would, but they are much harder to remove.

5 Summary

In this work, the Reactive Lamination Process is described. We achieved a stable lamination using the Reactive Lamination Process with already cured epoxy resin and COC, demonstrating the compatibility of this process with thermoset materials.

6 Acknowledgement

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7 References

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