The Engineering of Biobased Epoxy Resin

Comparing thermal and tensile properties of biobased and fossil curing agents in epoxy composites

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Introduction

The research compares key thermal, tensile, surface and structural properties of 3-methylphthalic anhydride (MPA)-based epoxy composites to phthalic anhydride (PA)-based composites under ISO standard conditions. These structures are found in Figure 1, with a cured epoxy molecule in Figure 2. The results contribute to the Better Biobased Building Blocks (B4) project [1], advancing sustainable material solutions for construction, automotive, aircraft and shipbuilding applications [2].

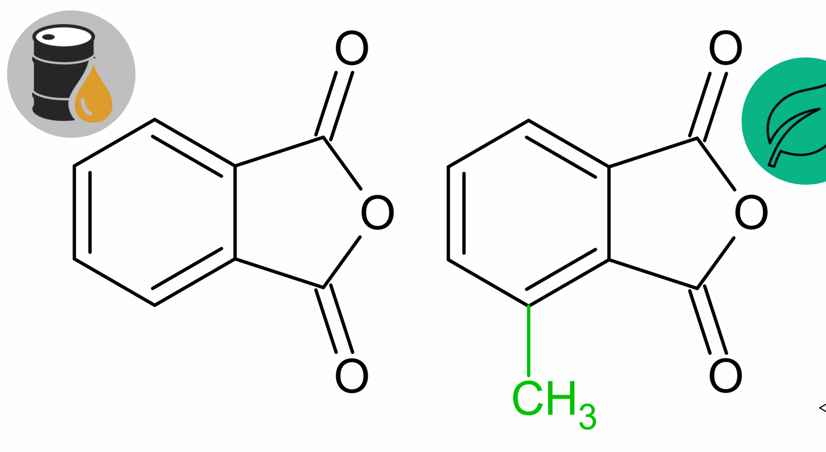

Figure 1: Structure of PA(l) and MPA(r)

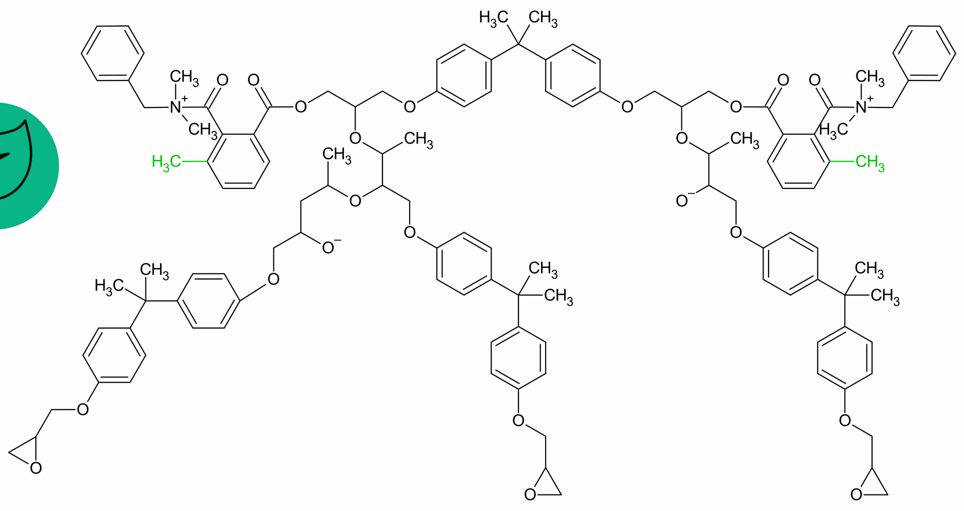

Figure 2: Cured epoxy structure

Materials & Methods

To make epoxy composite plates, (M)PA was dissolved in heated BADGE x:x stoichiometrically. Glass fibers (2,5 & 5 wt%) were mixed in using a mechanical stirrer, and a catalyst was added in. The mixture was degassed using a sonification bath (Figure 3). Next, the epoxy was poured into a preheated square mold and cured in an oven. After curing, the plates were cut into tensile bars using a waterjet cutter (Figure 4).

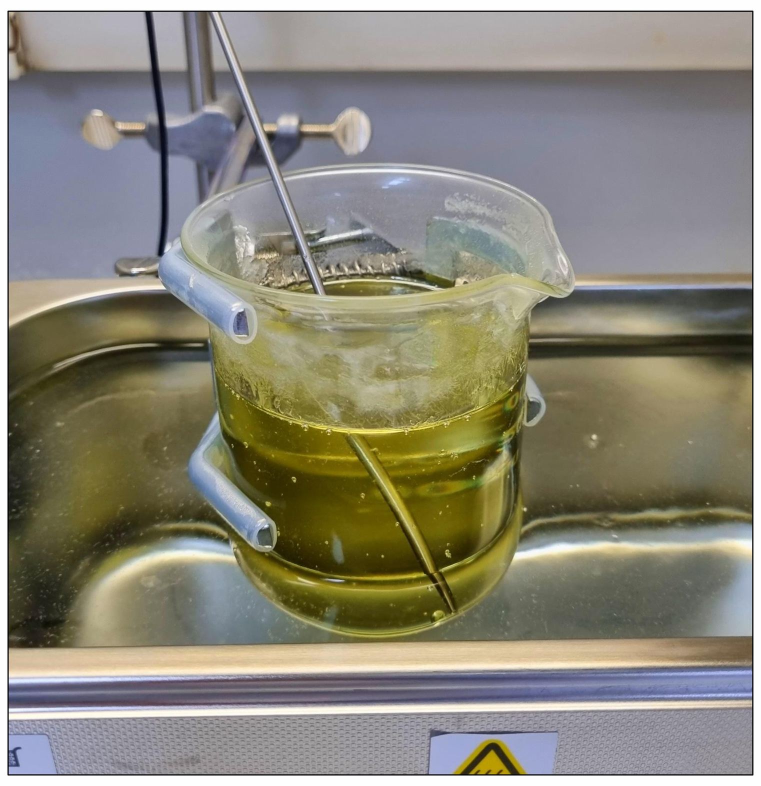

Figure 3: Degassing process of the epoxy

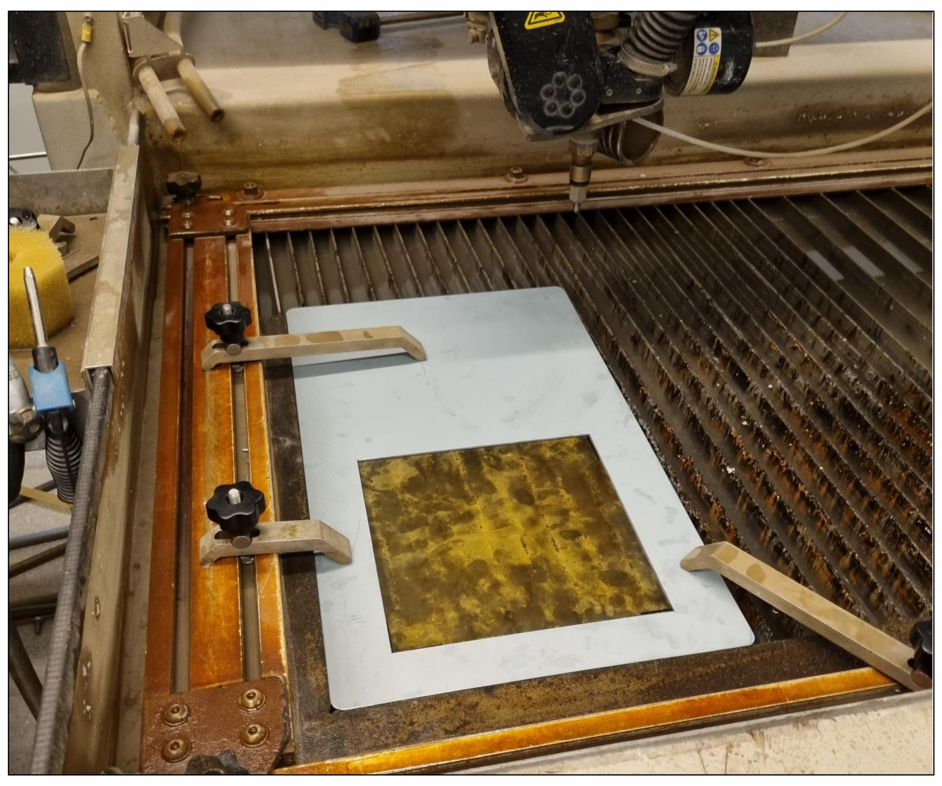

Figure 4: Cutting tensile bars

The analysis of the samples included tensile testing, DSC, TGA (Figure 5), Optical Contact Angle (Figure 6), Mohs' Hardness test and SEM. These techniques were used to determine the tensile, thermal, surface and structural properties, such as tensile strength, glass transition temp (Tg), thermal degradation (Td), hydrophilicity and scratch resistance.

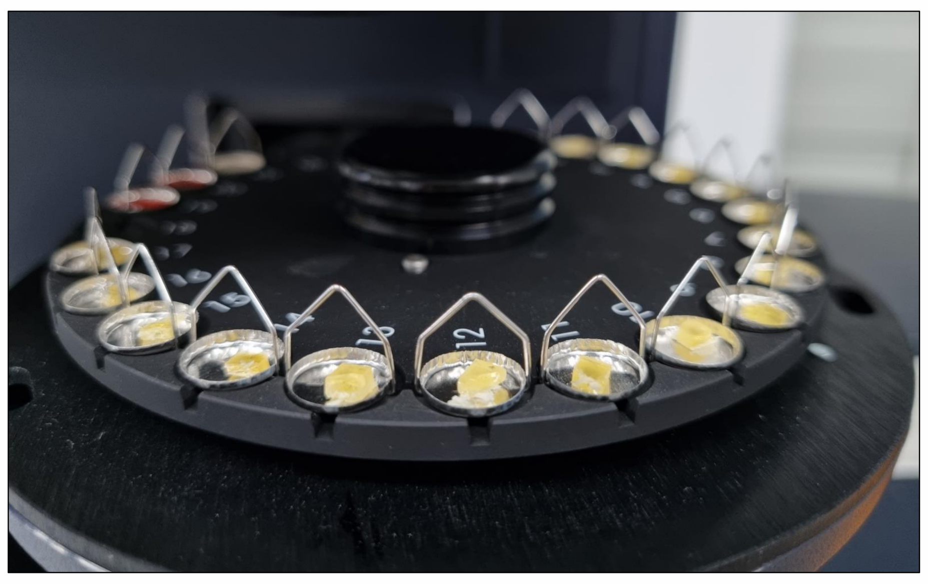

Figure 5: Epoxy samples in TGA pans

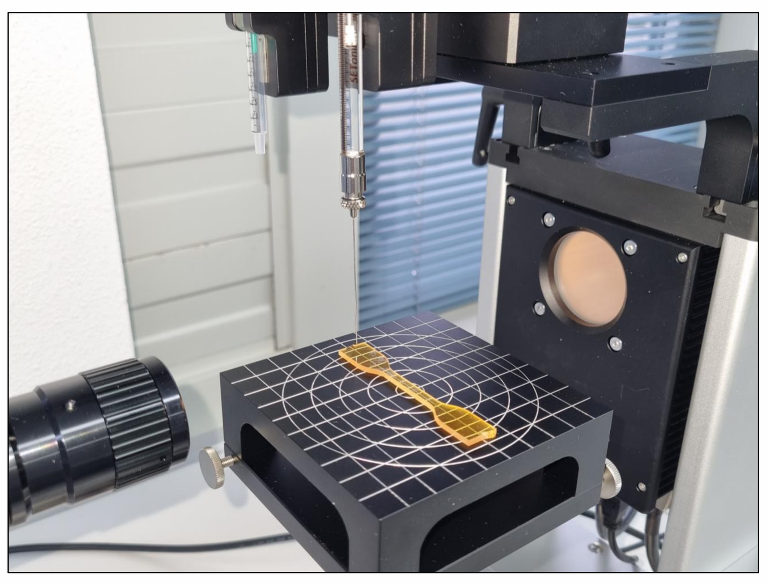

Figure 6: Optical Contact Angle analysis

Results

When comparing PA- and MPA-based epoxy thermosets, DSC analysis shows a 11% higher Tg with MPA-based epoxy, at XXX°C. The thermal degradation is the same for both samples, starting at XXX ± X°C and losing 90% of its weight. Tensile test results are found in Figure 7, showing ultimate stress.

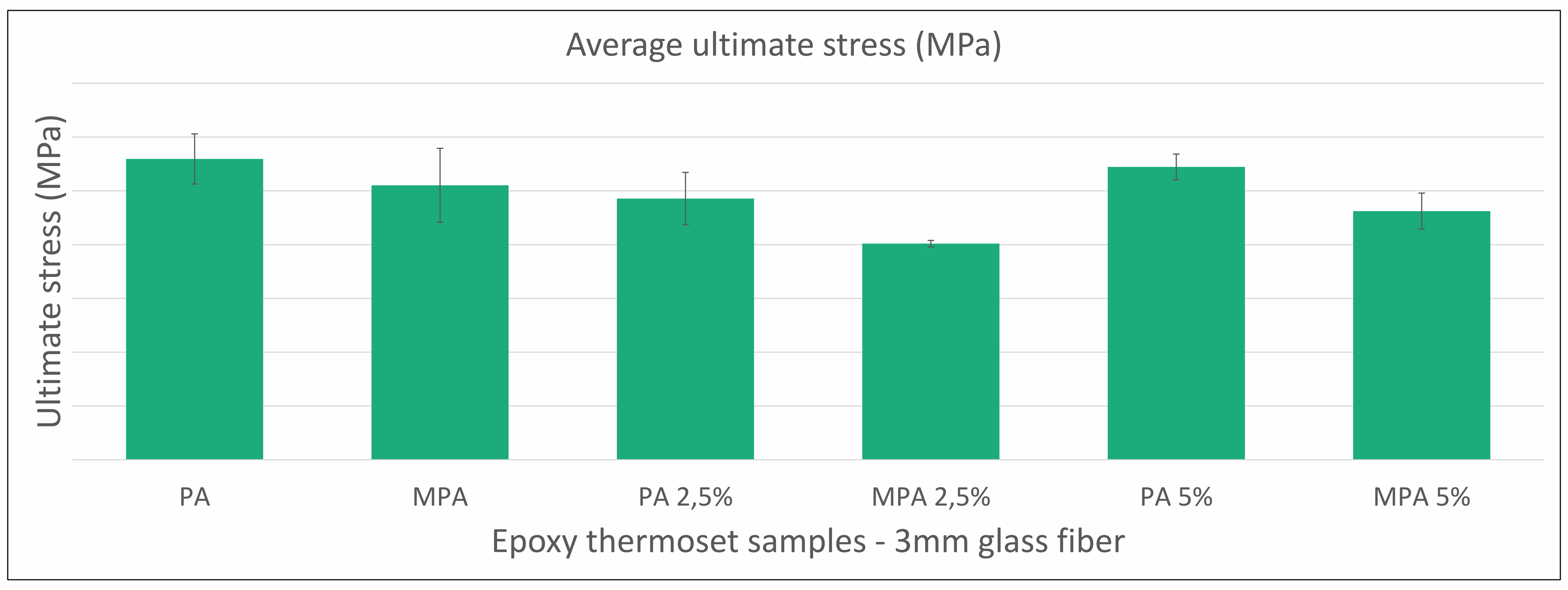

Figure 7: Tensile test results of all different epoxy samples, including error bars

Hardness and contact angle is proven to be the same for both samples by a statistical F-test. Averaging at a hardness of 2,5 on Mohs' scale, and a contact angle of 73,5° (Figure 8), both samples have the same hardness and hydrophilicity. SEM showed both samples have the same structural properties (Figure 9).

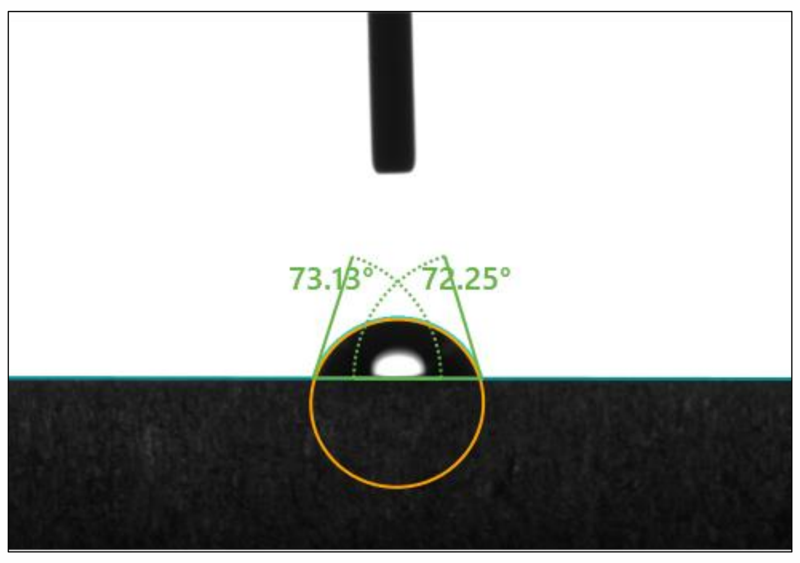

Figure 8: Contact angle picture of PA

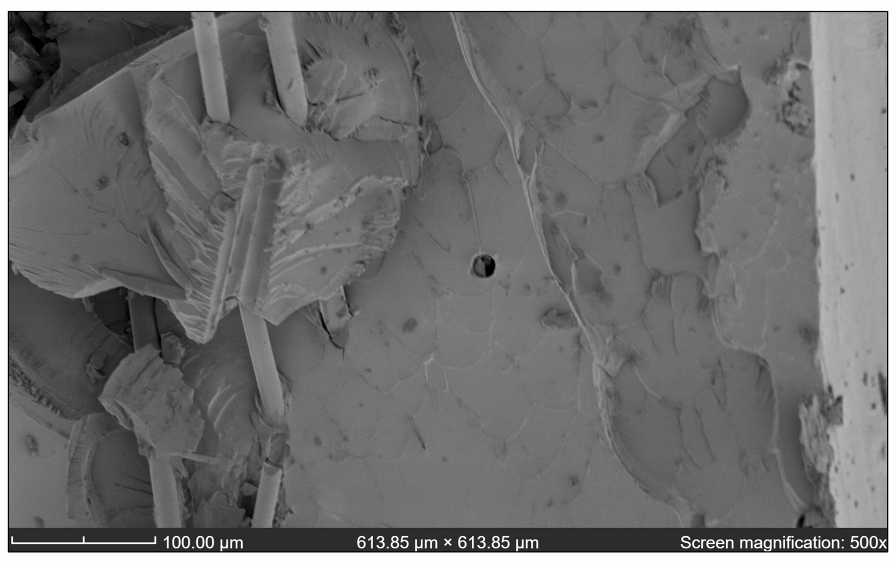

Figure 9: SEM picture of 5% glass fiber in PA

Conclusion

This research confirms the potential of biobased MPA as a sustainable alternative to fossil-based PA in epoxy composites. MPA-based composites showed superior thermal stability, with a 11% higher Tg at XXX°C, compared to PA-based composites at XXX°C. Tensile testing revealed a slightly lower average ultimate stress for MPA-based epoxy thermosets (XX MPa vs. XX MPa for PA), but the difference was statistically insignificant.

Both materials exhibited comparable thermal degradation, hardness (2,5 on Mohs' scale), and hydrophilicity (contact angle: ~73.5°). The findings highlight MPA's suitability for industrial applications in construction, automotive, and aerospace, offering a more sustainable solution while maintaining essential material properties. Future work should focus on optimizing mechanical performance and fiber integration.

References

[1] „Biorizon verduurzaamt chemische industrie met bio-aromaten," TNO, [Online]. [Opened 09 September 2024].

[2] M. F. Ashby, H. Shercliff en D. Cebon, Materials : engineering, science, processing and design, Butterworth-Heinemann, 2019.

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