PHOTOCLEABABLE NBE EPOXIES FOR EFFICIENT, REWORKABLE MICRO-LED PACKAGING

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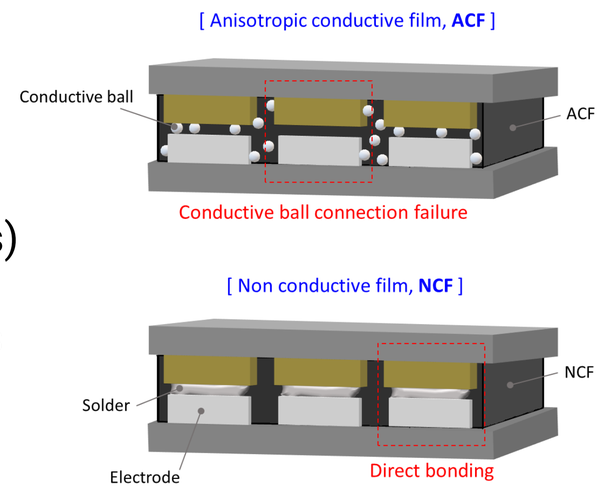
Abstract

Photodegradable epoxy films were developed as non-conductive adhesives for micro-LED packaging. By varying the alkyl chain length of *o*-nitrobenzyl ester (NBE) monomers, we achieved both higher synthetic yields and tunable thermal properties. Upon UV exposure, the glass transition temperature of these epoxies drops at key repair stages, weakening adhesion and promoting clean debonding. This approach enables rapid, residue-free removal of defective LEDs under low-energy UV irradiation.

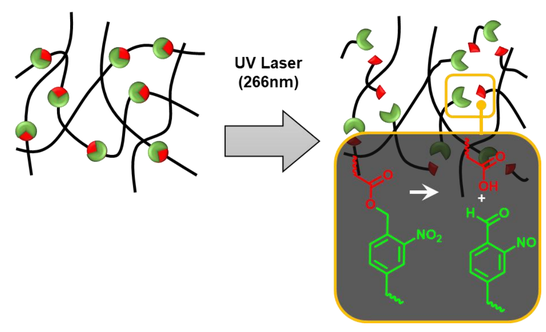
Introduction

Micro-LED packaging challenges: Micro-LED displays require precise placement of minute conductive particles, yet conventional adhesives yield overly strong bonds that hinder removal and repair

Limitations of current methods:
Direct eutectic bonding and anisotropic conductive films (ACFs) can secure chips but complicate rework, often damaging substrates or leaving residues.

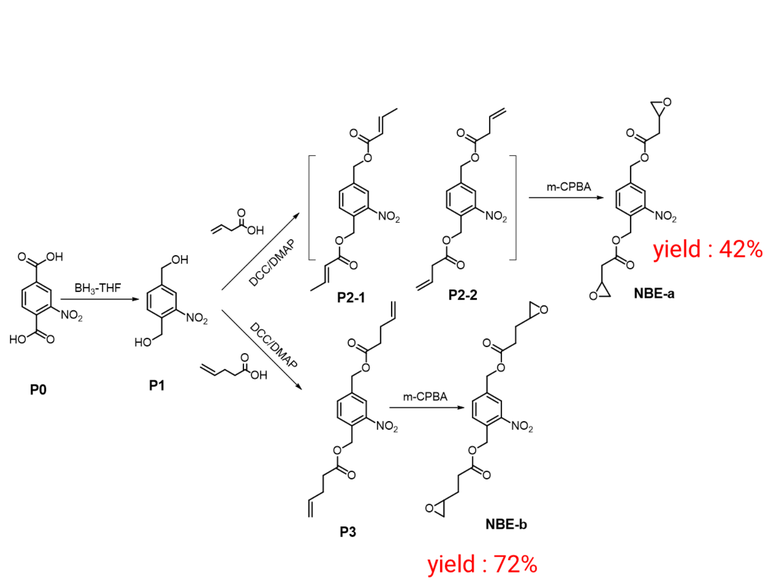


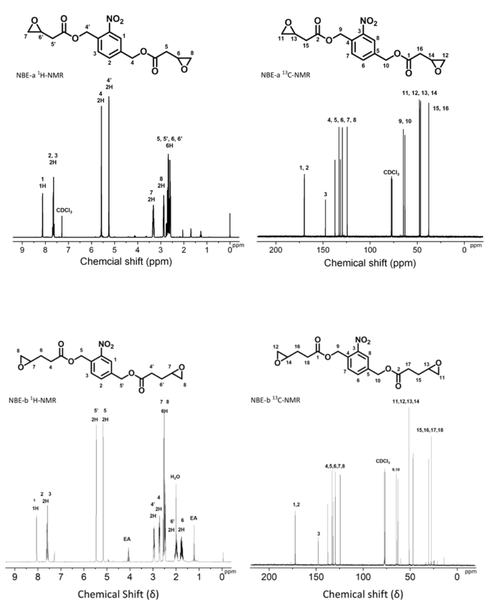
Photodegradable solution:
Incorporating photocleavable *o*-nitrobenzyl ester groups into epoxy networks allows selective crosslink disruption under specific UV wavelengths. This strategy promises strong initial adhesion for reliable bonding, with on-demand debonding to facilitate rapid, non-destructive LED repair.



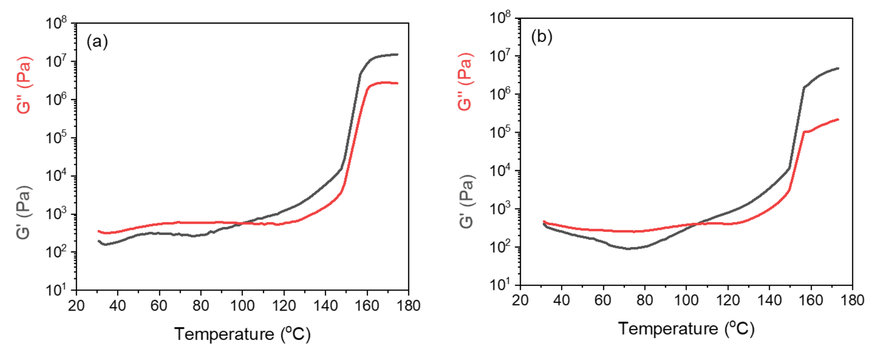
Experimental Results

NBE(o-nitrobenzyl ester epoxy)-a,b synthesis

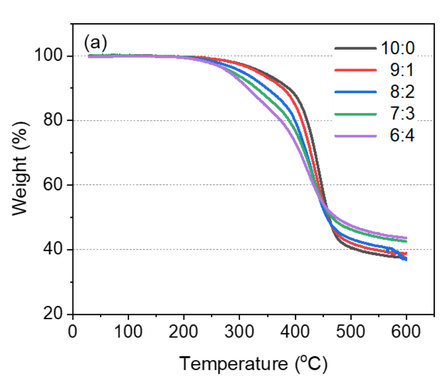




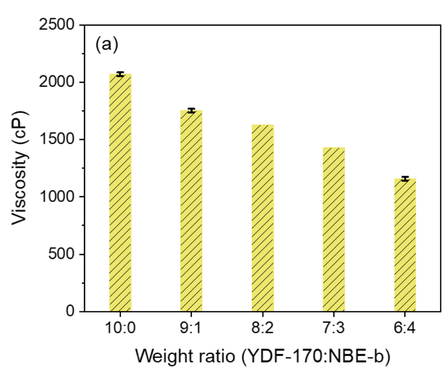
Viscoelastic kinetics of the NCAs systems



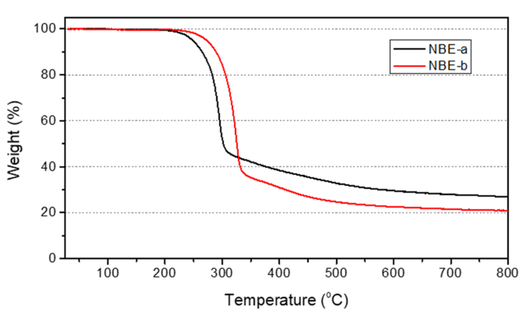
Thermal properties of the NCAs



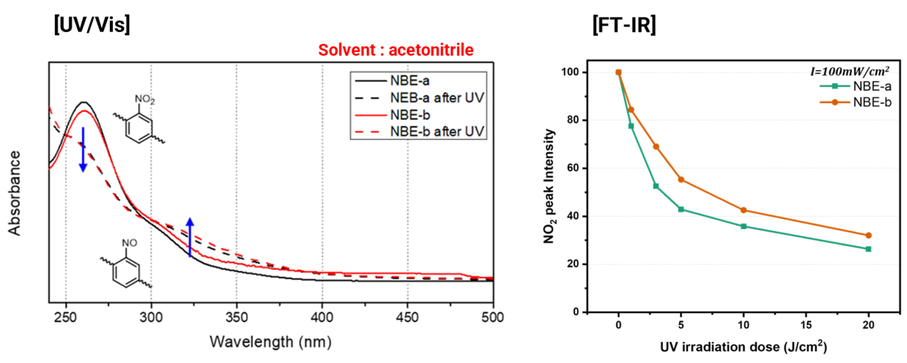
Viscosity variations of the NCAs



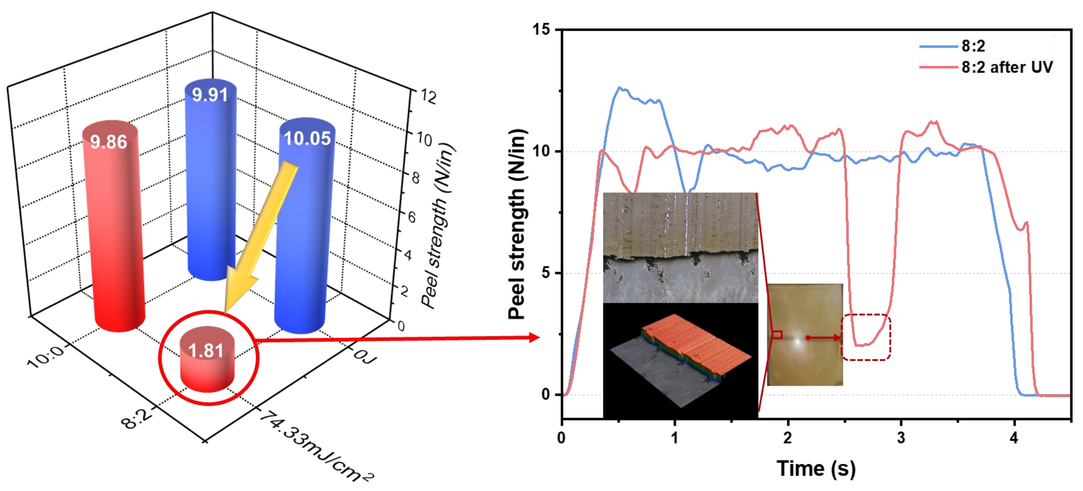
Thermal properties of NBE-a,b



UV induced NBE-a,b decomposition



Peel strength changes by UV irradiation



Composition of the NCAs

YDF-170 : bifunctional epoxy; NMA : curing agent; 2E4MZ : catalyst

Sample Code	YDF-170	NBE-b	NMA	2E4MZ	Filler	Coupling agent
10 : 0	50	0	26.2	1.52	23.2	0.232
9 : 1	45	5	25.9	1.52	23.2	0.232
8 : 2	40	10	25.7	1.51	23.2	0.232
7 : 3	35	15	25.4	1.51	23.2	0.232
6 : 4	30	20	25.1	1.50	23.2	0.232

Conclusion

We synthesized two NBE monomers—NBE-a (42% yield) and NBE-b (72% yield, via 4-pentenoic acid)—and formulated non-conductive adhesive (NCA) systems for micro-LED assembly. NBE-b increased thermal stability (decomposition onset 28 °C higher than NBE-a) and cured at elevated temperatures without compromising performance. Under a 266 nm UV laser (74 mJ/cm²), NCA specimens exhibited a dramatic peel-strength drop (from ~10 N/in to ~1.8 N/in), enabling efficient removal of misaligned or defective LEDs. These photodegradable NCAs offer a practical path to high-throughput, reworkable micro-LED packaging.

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