UV-Cured Coatings with Switchable Adhesion via Dynamic Covalent Bonds

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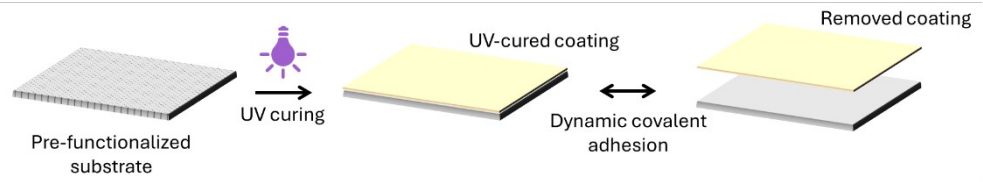
Abstract

Due to growing consumer awareness and stricter European Union regulations, there is an increasing demand for recyclable packaging materials. However, efficient recycling is often hindered oy coatings and multilayer structures composed of thermodynamically immiscible polymeric and non-polymeric materials. Innovative coating technologies that combine strong adhesion with controlled removability are essential to support recycling efforts.

This study explores a dynamic covalent bond (DCB) strategy [1,2] to develop UV-cured coatings with reversible adhesion on various substrates (i.e., glass, PET, and PE). Two types of DCBs were investigated, namely disulfide and imine bonds. In the first approach, the substrates were pretreated with bis(triethoxysilylpropyl)tetrasulfide (TESPT) silane, followed by UV curing of a novel disulfide-functionalized polyurethane diacrylate monomer to form thin and transparent coatings. During irradiation, sulfur–sulfur interactions enabled covalent bonding between the coating and the substrate. As a result, strong adhesion was obtained across all tested materials. The coatings could be efficiently removed by cleaving the disulfide bonds under specific conditions, such as in acidic media or in the presence of a reducing agent. In the second approach, the substrates were prefunctionalized with (3-aminopropyl)triethoxysilane (APTES), and vanillin-based coatings were subsequently UV-cured. Imine dynamic bonds formed between the aldehyde groups of vanillin and the amine groups of the APTES-modified substrates, yielding strong adhesion also in this case. These coatings were readily removed under mild acidic conditions.

Overall, the proposed dynamic covalent bonding strategies offer a promising way for developing recyclable UV-cured coatings that provide strong adhesion and are selectively removable under specific stimuli. This approach supports more efficient packaging waste recycling and aligns with the goals of a circular economy.



Keywords: UV-cured coatings, Dynamic covalent bonds (DCBs), Stimuli-responsive adhesion

References

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