Enabling reprocessability and flame retardancy of fiber reinforced epoxy composites via reactive approach

W. Klingler-Wu[1], V. Michaud[2], G. A. Barandun[3], S. Gaan[1]*

[1]Laboratory for Advanced Fibers, [2]Laboratory for Processing of Advanced Composites (LPAC), [3] Institute for Materials technology and plastics processing

The increasing amount of fossil-based plastic waste ending up in our environment is one of the most pressing issues of the oncoming decades. Thus, development of re-usable polymers with a prolonged useful lifetime heralds the switch for a transition towards a more circular economy.[1] A novel class of dynamic phosphonate ester bonds containing thermoset has been designed and synthesized, via a simple one-pot and two-step procedure.[2] The resulting material has been used to fabricate natural fiber reinforced polymer composites (FRPCs), which demonstrated exceptional reparability, recyclability and flame retardancy. The chemical structures and compositions of the chemical precursor and thermosets are confirmed by solution and solid phase NMR spectroscopy, elemental analysis, and Fourier transform infrared spectroscopy. The covalent incorporation of monomer/polymeri phosphite moieties in the thermoset matrix introduced sufficient dynamic P-O ester bonds, and promoted the exchange of network strands under moderate heating condition, resulting in scratch reparability and recyclability. Due to the presence of phosphorus in the structure, the thermoset also exhibited excellent flame retardancy in varied fire tests. Applications of the thermoset as fire protective coating on wood samples and polymer matrix in FRPC were explored. Fire tests confirmed their excellent fire performance via intumescent mechanism.
In order to improve the recyclability of thermosetting materials, various recyclable materials have been synthesized via incorporation of wide variety of covalent exchangeable bond.[3, 4] Some of these materials containing sufficient carboxylic ester, disulfide, siloxane, imine, diketoenamine, Diels−Alder adduct, dioxaborolane bonds etc., can "flow" again like thermoplastics through network topological rearrangement by thermally triggered catalytical bond exchanges. Such network structures are fixed at product operating temperatures when the exchange reaction kinetics are frozen. Among the various dynamic covalent bonds, phosphorous ester based transesterification reaction may provide a multifaceted solution, this functionality not only offers excellent fire protection, but also has industrial relevance due to ready availability of monomers and straightforward synthesis procedure. Phosphate triester based thermosets brought new inspirations into multifunctional vitrimer material.[5] If we could replace the phosphate with phosphonate, the P-C bond will theoretically bring even better material stability and flame retardancy, as it is a chemically and thermally stable analog of a P–O bond.

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