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Development of multifunctional hybrid epoxy composite coatings with hydrophobic or flame retardant properties

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Introduction

Epoxy resins own a combination of thermal stability and chemical resistance, which makes them a primary choice in several industrial applications, including the fabrication of protective and functional coatings. Appropriately designed fillers can provide features like surface hydrophobicity, useful in self-cleaning, anti-icing, and antifouling coatings [1], and improved flame retardance, required to contrast the high flammability of such materials [2]. Here, two approaches to enhance these properties by sustainable procedures based on sol-gel chemistry are presented: the functionalization of particles derived from waste hemp fibers to turn them into hydrophobic fillers [3] and a hydrolytic route to obtain flame retardant epoxy nanocomposites by the growth of silicon-phosphorus inorganic nanostructures from reactive Si and P precursors [4].

Experimental

Hemp microparticles (HMPs), functionalized with Na_2SiO_3 solution, 3-aminopropyl triethoxysilane (APTS), polypropylene-graft-maleic anhydride (PPgMA) and a long-chain silane, were added to DGEBA epoxy resin and casted on aeronautical fiber-reinforced panels. The coatings were analyzed by ATR-FTIR, TGA, DSC, AFM and water contact angle measurements [3]. Si/P-epoxy nanocomposites were prepared by in situ sol-gel: tetraethoxysilane (TEOS) was added to APTS-modified DGEBA and hydrolyzed, then H_3PO_4 was added (Figure 1) [4]. A cycloaliphatic amine hardener was used in both systems. The samples were characterized by solid state NMR, TEM, TGA, DSC, DMA, cone calorimetry and microscale combustion calorimetry.

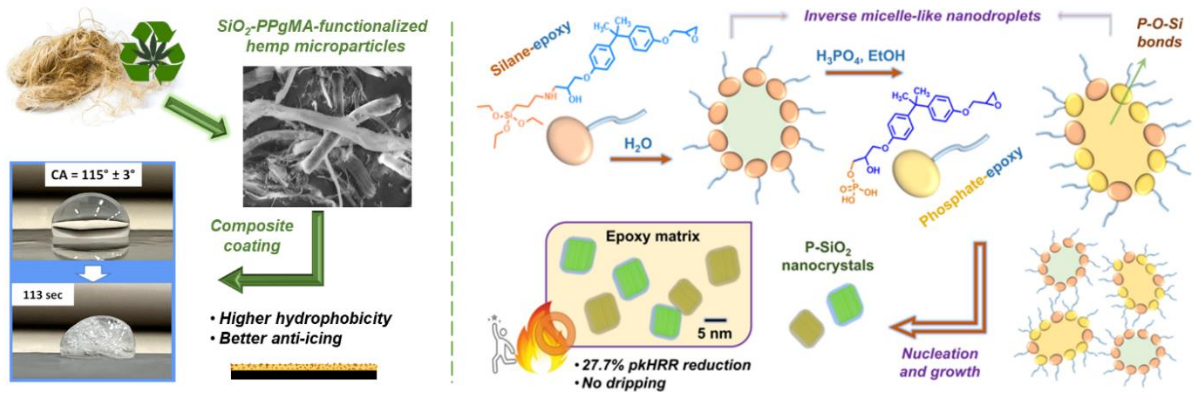

Figure 1. Schematic representation of epoxy-based composite coatings with functionalized hemp particles for tailored surface wettability (left) and Si-P-epoxy nanocomposites with improved fire behaviour (right).

Results and Discussion

The evaluation of the wettability and anti-icing performances of epoxy coatings containing 2 wt.% hydrophobic HMPs, cast on aeronautical carbon fiber-reinforced panels, showed up to 30° higher water contact angle at room temperature and doubled icing time at -30 °C than unfilled epoxy resin coatings. This behaviour is promoted by the surface functionalization of the HMPs and by the hierarchical rough structure induced by the fillers on the surface of the coated panels [3].

The hydrolytic synthesis route of the hybrid Si/P–epoxy nanocomposites enabled the growth of P-modified silica lamellar nanocrystals. This peculiar morphology of the organic-inorganic co-continuous phase allows for the absence of dripping during vertical burning tests, the production of abundant coherent char after combustion and a marked reduction (up to 27.7%) in the peak of heat release rate, even with about 1 wt.% Si and P. Moreover, the modification of the polymer matrix did not cause significant adverse effects on its thermomechanical properties [4].

Conclusions

Through the presented routes, waste natural fibers can be turned into valuable fillers to tailor the surface morphology and wettability of composites, and green low-cost compounds can provide epoxy resins with intrinsic fire resistance. These results may inspire the development of new hybrid nanocomposites and phosphate-based recyclable epoxy vitrimers for various industrial areas.

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Biography

Claudio Imparato is an Assistant Professor of Chemical Foundations of Technology at the University of Naples Federico II, where he obtained his PhD in 2019. His research topic is materials chemistry, including the synthesis and characterization of catalytic materials and functional composites and coatings.