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Preparation and characterization of UV-LED curable composite systems based on carbon fillers

Abstract

In the present dissertation, UV-LED curing technology is exploited to design coating composites with advanced properties. As eco-friendly, inexpensive and high operating efficiency process, UV-LED curing technique represents a valid alternative to conventional thermal curing methods. In fact, UV-LED photo-induced polymerization shows several advantages, such as low operational costs and time and energy saving, notwithstanding that UV-LED units emit "cold" radiation. Since its innovative features, UV-LED curing technology is exploited for producing added-value composite coatings obtained by the incorporation of carbon fillers in epoxy-acrylate curable resin containing a specific photo-initiator. Thanks to their physical and chemical characteristics, carbon fillers provide advanced properties to insulating acrylic resin. Among carbonaceous materials, Biochar and multi walled carbon nanotubes (MWCNTs) are selected to improve the rheological, thermal, electrical and optical properties of the thermosetting matrix. As bio-sourced product, Biochar is an inexpensive and environmentally- friendly material that has a remarkable importance within the circular economy, based on recovery and reuse of biomass wastes at the end of their life. Among biomass residues, spent coffee grounds are the main industry waste worldwide. Besides, as the most popular beverage in the world, its consumption increases year by year with a consequent huge amount of generated solid waste. Spent coffee ground constitutes about 90% of brewed coffee: because of its high lignocellulosic composition, exhausted coffee residue may become a resource when it is converted into Biochar through pyrolysis. The use of the Biochar as a filler in polymeric composites is due to its high carbon content that has a significant effect on the mechanical, thermal and electrical properties of the host material. Furthermore, thanks to its morphology and structure, the Biochar is suitable to promote the dispersion of MWCNTs in a polymer matrix. As the low level of dispersion of MWCNTs in thermosetting resin limits the

application of these nanofillers, the shuttle effect of Biochar was exploited for obtaining acrylic composite coatings. The combination of Biochar and MWCNTs in acrylic resin may results into a synergistic effect: the Biochar promotes the dispersion of MWCNTs, hence allowing the optimization of the overall performances of the composite materials.

In order to design the UV-LED composite films, a suitable curable mixture, containing the photo-initiator and the epoxy acrylic resin, was prepared. Then Biochar and/or MWCNTs were incorporated, both as single and mixed fillers, through sonication at different loadings, ranging from 0.01 to 1.0 wt.%. The liquid dispersions, coated on a glass plate, were subjected to the UV-LED curing to obtain a three-dimensional fully cured network in few seconds.

The UV-LED composite films were characterized to investigate the effect of the filler type and loading on the effectiveness of the UV-LED curing process and on the rheological, thermal and optical properties of the cured composite films. While the fillers did not compromise the effectiveness of the curing process, leading to the obtainment of fully cured composite networks, the properties of the UV-LED composite films were strictly dependent on the filler size and shape. In particular, the morphology of Biochar and MWCNTs affected the filler-polymer interface, which the properties of composite films depend on. For this reason, in this dissertation, the morphological and rheological analyses were fundamental to investigate the correlation between the structure and properties of the UV-LED composite films, as well as the shuttle effect provided by Biochar.