Synergetic effect of metal-ceramic composite coatings and metal-polymer composite bond coating on LPCS metallization of CFRP composite structures

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Abstract

Cold spray is a straightforward method to produce coatings and is recently investigated for metallizing polymeric substrates. A current issue is the poor adhesion of metallic particles onto carbon fibers reinforced structure, that causes some difficulties of coating build-up during. Herein, this study proposes two methods to enable a good bonding between a metal coating and a carbon fiber reinforced polymer (CFRP) substrate, with the use of ceramic/metallic powders mixture, and a metallic-polymeric composite bond coating (BC) on the CFRP substrates.

In this work, thermoset epoxy (TS) and thermoplastic polypropylene (TP) polymer-based continuous carbon fiber-reinforced composite laminates were manufactured using the standard vacuum assisted infusion process, co-cured with a biphasic BC made of copper powders and corresponding TS or TP polymer. These systems, namely ***Cu-BC-TS_CFRP and Cu-BC-TP_CFRP*** respectively, as well as the control of the ***TP_CFRP*** system were used as substrate for a low-pressure cold spray (LPCS) deposition. ***Al, Sn, Cu and Zn+Al powders pre-mixed with hard ceramic Al_2O_3*** particles were used to develop composite coatings on the substrates. By means of deposition efficiency (DE) evaluation and microstructure analysis, the varied deposition results among different scenarios were discussed, and the deposition mechanisms of mixed powders and the synergetic effects of introducing a BC were investigated.

Experimental results

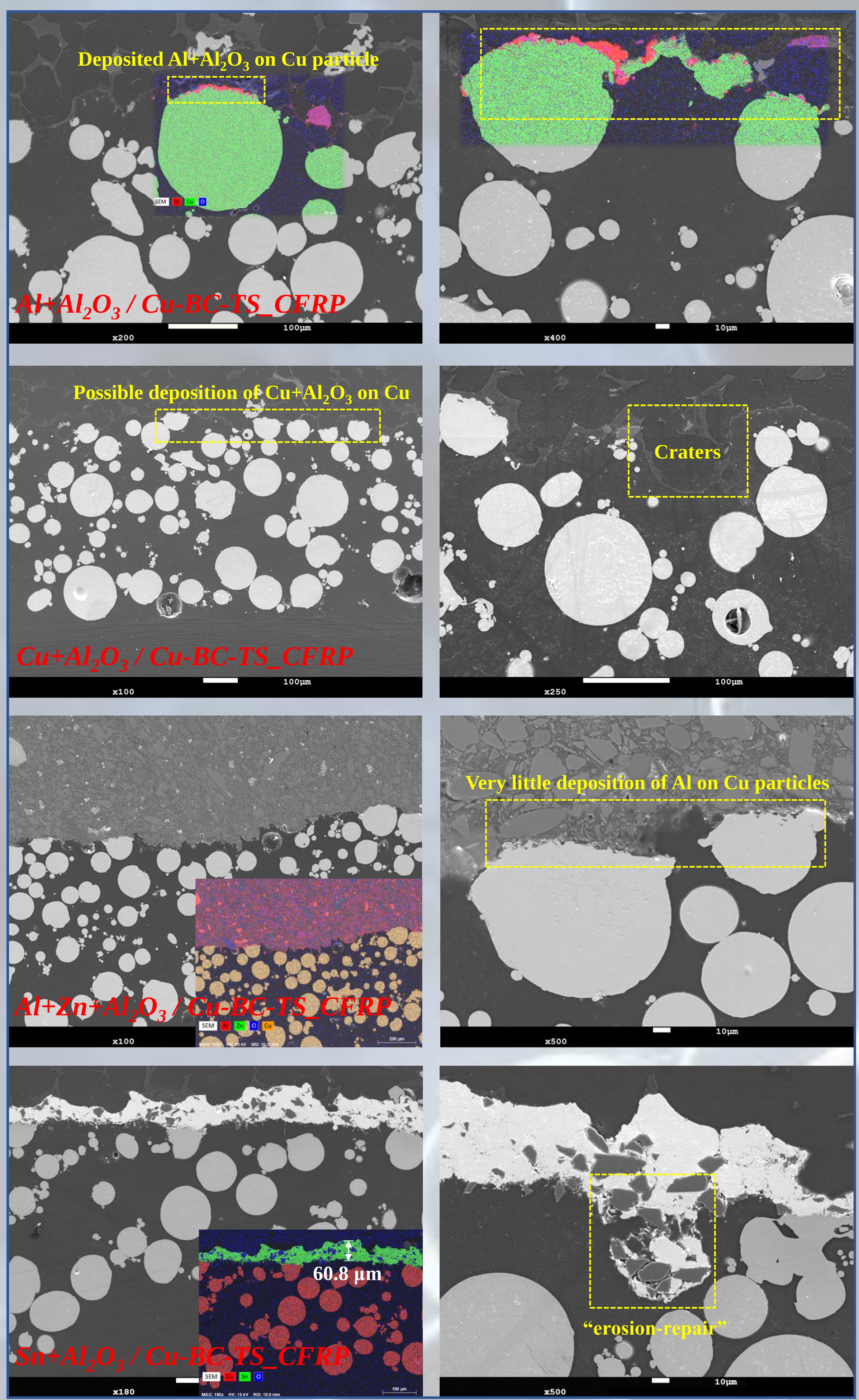


Fig. 1 Results of mixed powders cold sprayed on the substrates of Cu-BC-TS_CFRP

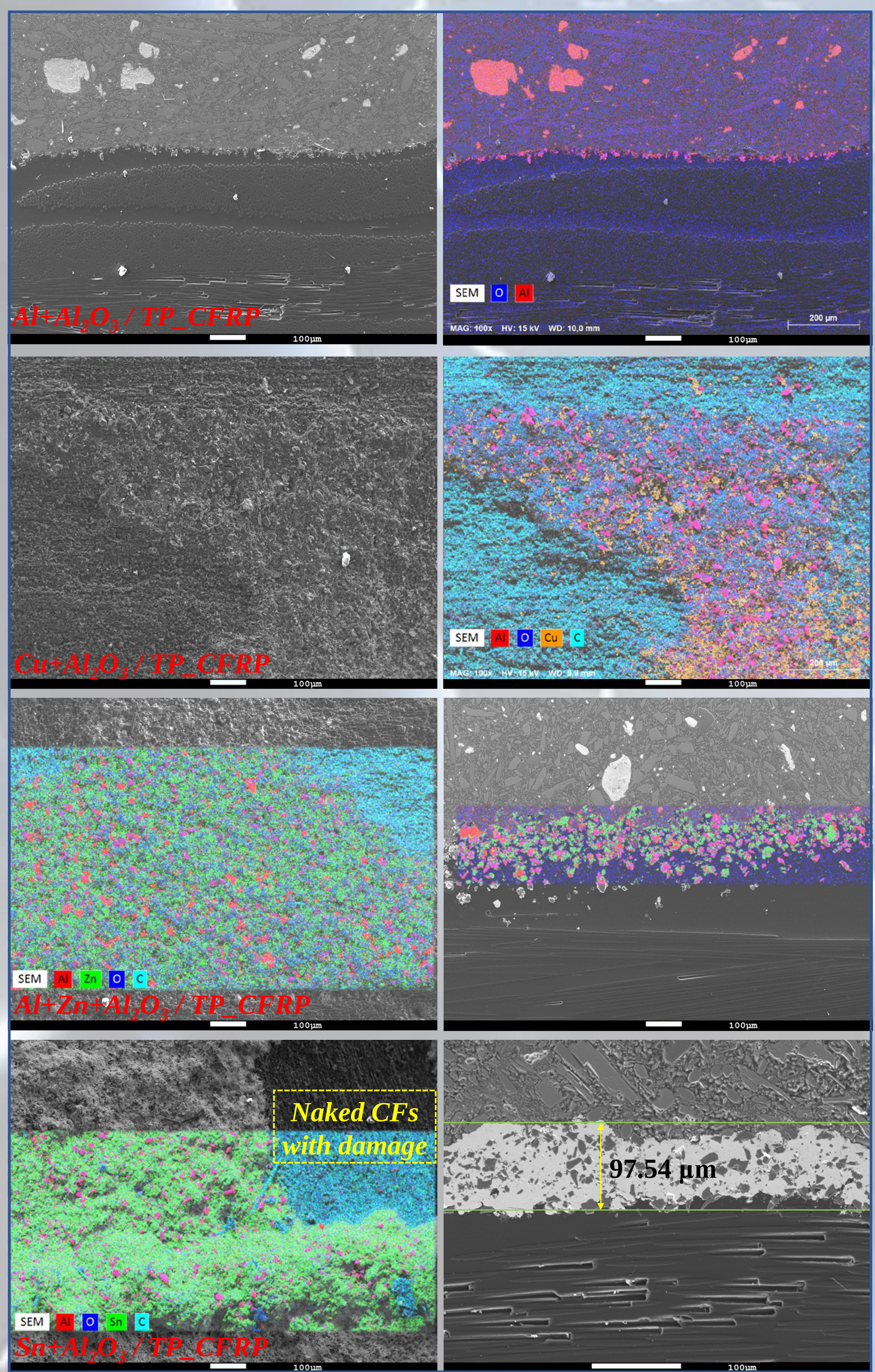


Fig. 2 Results of mixed powders cold sprayed on the substrates of TP_CFRP

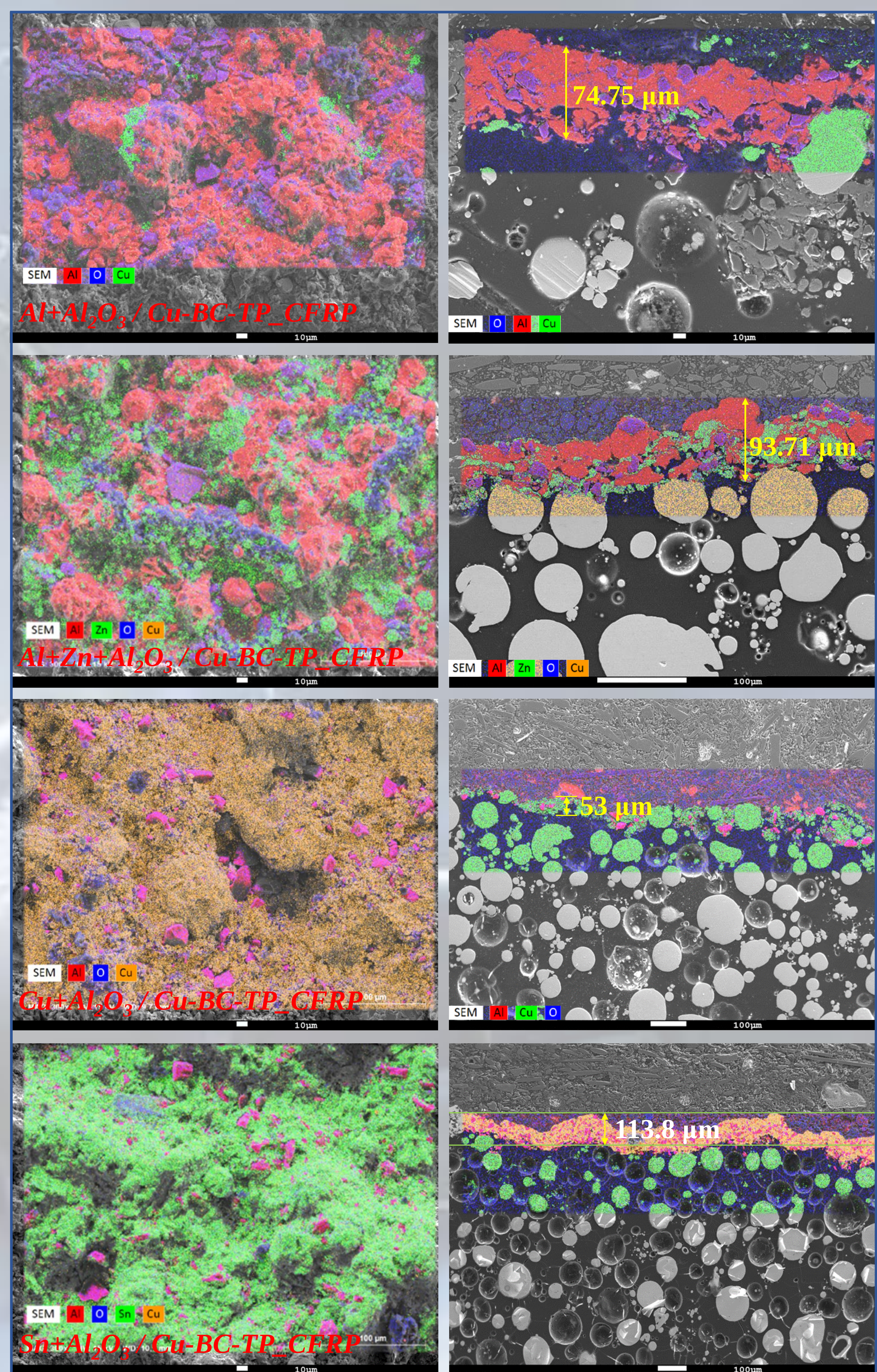
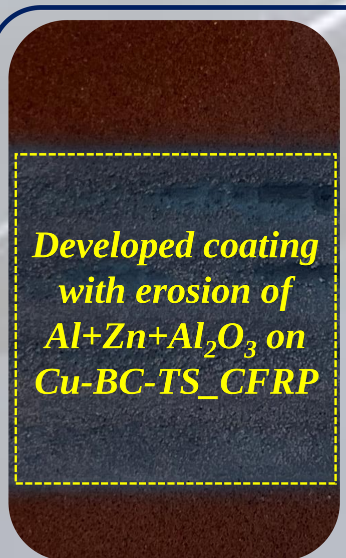


Fig. 3 Results of mixed powders cold sprayed on the substrates of Cu-BC-TP_CFRP



The deposition traces of each scenario of low pressure cold spraying multi-component powder systems onto Cu-BC-TS_CFRP were shown according to the morphological analysis along with EDS results, where the growth of Cu-Al_2O_3, Al-Zn-Al_2O_3, and Al-Al_2O_3 composite coatings have been prevented due to an erosion of matrix. The roughened copper particles in the sublayer have indicated one of the important functions of secondary components as the abrasive particles. A particular "erosion-repair" mechanism was found in the successfully-developed Sn-Al_2O_3 composite coatings, due to the synergistic effect of ductile Sn and brittle Al_2O_3 particles.

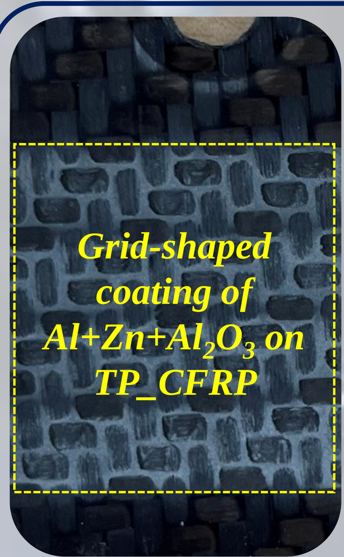
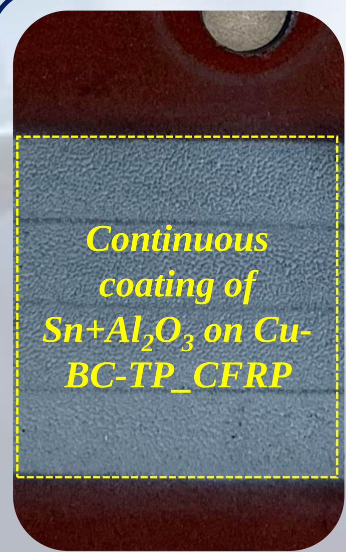


Fig. 2 shows the deposition results of cold spraying mixed powders systems on TP_CFRP substrates. It was observed that the deposited metallic and ceramic particles were partially attached on the resin-rich region of CFRP substrate, leading to a grid-shaped (as shown in the left picture) discontinuous coating on the surface. Fig. 2 shows that deposits of Al+Al_2O_3, Cu+Al_2O_3, and Al+Zn+Al_2O_3 were individually embedded into the matrix part of CFRP, accompanied with a depth. And the SEM observations have suggested that Sn+Al_2O_3 powder system showed the most promising results among the tested combinations, with a thicker and nearly continuous coating compared to the others.



Since the trials of cold spraying multi-component powders on TP-CFRP substrate were demonstrated failed along with the discontinuous coatings, the feasibility of cold spraying mixed powders on the compatibilized sublayer of Cu-BC-TP_CFRP substrate was explored and the results are shown in Fig. 3. From both the top surface and cross section view, the impacting powders were all successfully deposited on the Cu-BC-TP_CFRP substrate systems, forming a continuous coating. And the developed coatings of Al+Al_2O_3, Cu+Al_2O_3, Al+Zn+Al_2O_3, and Sn+Al_2O_3 powders were of the thickness of 75 µm, 53 µm, 94 µm and 114 µm, respectively.

Conclusion

In conclusion, the sublayer mixture of Cu-BC-TS_CFRP has prevented the growth of Cu-Al_2O_3, Al-Zn-Al_2O_3, and Al-Al_2O_3 composite coatings due to the erosion of thermoset epoxy matrix. The configurations of Al-Al_2O_3, Cu-Al_2O_3, Al-Zn-Al_2O_3, and Sn-Al_2O_3 powders have exhibited discontinuous deposits within some localized regions on the substrate surface of TP_CFRP. To obtain the qualified coatings, the compatibilized thermoplastic based sublayer of Cu-BC-TP_CFRP was introduced, which was proved to be a promising method to achieve a better deposition efficiency as it limits the cracking propagation in the matrix, then allowing a plastic deformation and the build-up of a coating. Soft powders could facilitate the deposition by easing an onset of bonding, ceramic particles played a role of abrasive particles and peening agents for the accompanying powders and the roughened substrates. Therefore, the mixed powders of Sn with Al_2O_3 was demonstrated as a feasible condition to form a successful coating with a desirable electrical conductivity onto the Cu-BC-TS_CFRP (60 µm) and Cu-BC-TP_CFRP (114 µm) structures, which allows to provide a referential value for the metallization of CFRPs.

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