Design and elaboration of lignin based anti-corrosion hybrid coatings

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In the current context of Aluminum alloys anti-corrosion technological developments in the aeronautical sector, new alternatives to the traditional hexavalent chromium-based coatings are being studied to be more eco-sustainable, as required by the REACH legislation. A new approach to the protection of 2024 aluminum alloys was initiated with the development of an innovative hybrid coating combining an interconnected silica matrix with kraft lignin from the Gascogne forest.

Although it is the second most abundant biopolymer on Earth and has a rich molecular structure, lignin is unfortunately little used in high value-added technological applications; indeed, its main use is as a source of heat and energy in factories by simple combustion.

The context of the work is the design of a bio-coating which is based on the natural self-organization of the phases in presence allowed by the technique of "Evaporation Induced Self-Assembly (EISA)". The process does not require any external energy to activate, is environmentally friendly and very easy to transfer to industrial level. The bio-resource/silica mixture is applied to the substrate using the easy-to-implement Dip Coating method, in which important parameters such as relative humidity (RH) and shrinkage rate have been optimized. The alloy protection process was then enhanced by SF_6 plasma post-treatment of the coating surface, which induced a very clear increase of the hydrophobicity of the elaborated materials.

Technically, two different ways of preparation of the coatings were evaluated in this work: a "direct route" (DR) and a "non direct route" (NDR) for which a preliminary functionalization of the surface of the metallic substrate to be protected was carried out with an organo-alcoholic agent, the TESPSA. The results showed that the "non-direct" coatings presented a more homogeneous coverage on the surface of the Al2024 alloy and that their hydrophobicity was naturally much higher than that of the "direct" coatings. Besides, the physico-chemical characterizations achieved with SEM microscopy and XPS spectroscopy have highlighted the tendency of the lignin to organize itself onto the silicic phase, playing a major role in the final protection. Moreover, the results show that it seems appropriate to carry out the deposits with slower speeds of withdrawal of the baths while operating in a rather dry environment (Relative Humidity around 10%). These conditions would indeed ensure a better homogeneity of the coatings, also significantly reducing their wettability and making them thicker, which are the requirements expected by the aeronautical industry certifications. For the materials developed, the adhesion tests carried out indicated a very good degree of coating adhesion on the aluminum alloy in accordance with the industrial requirements. Finally, some corrosion tests were carried out to test the behavior of the hybrid coatings and demonstrated a higher protective effect than all actual sustainable solutions commercialized in the world for the best NDR developed system.

Considering the valorization of a BioSource derived from pine tree wood (Lignin market will represent USD 1222 Million in 2027), open a large field of perspectives for the protection of metallic parts in the Aeronautics industry in an ecofriendly way.

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