Development of Smart Self-Healing Polyurethane Microcapsules Utilizing an Enhanced ZnO/TiO2 UV-Shielding Shell for Spacecraft Applications

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Spacecrafts endure harsh environmental factors, such as space debris, thermal cycling, and intense UV radiation that induce the formation of microcracks in spacecraft coatings during long-term flight. This could cause deterioration of the external structure, instruments, communication systems, and protective systems. Advanced self-healing polymer composite protective coatings have drawn great attention for their many advantages, such as lightweight, tunable flexibility, and easy processability. There is still a challenge to develop a coating with self-healing efficiency and stronger UV shielding capacity to extend the service time of the coatings in an intense UV irradiation environment. This research addresses these challenges by introducing microcapsules designed with a polyurethane core for self-healing efficiency and a ZnO/TiO2 nanoparticles hybrid shell for enhanced UV protection. Polyurethane microcapsules were synthesised by interfacial polymerization then the nanoparticles were dispersed by in-situ polymerization using a prepolymer solution. Scanning Electron Microscopy confirms the release of polyurethane when a microcapsule ruptures into the damaged area which undergoes crosslinking reactions healing a microscratch in 24 hrs. Furthermore, the ZnO/TiO2 hybrid shell demonstrates excellent UV-shielding properties with absorbance ranging from 0.7 - 1 to alleviate negative consequences of intense UV radiation assessed by the UV-Vis spectroscopy. The integration of self-healing systems could ensure mass cost savings, as well as increased reliability and safety leading to longer operational life and missions. Their promising characteristics are paving the way for novel space applications with reduced maintenance that can replace expensive traditional solutions.