## Green bioactive nanoparticles for Cultural Heritage applications

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Biodeterioration represents a problem in the field of stone preservation [1]. Different classes of microorganisms can be responsible for several degradation processes, which affect especially historic limestone monuments. Metal and metal oxide nanoparticles (NPs) are receiving increasing attention as they can inhibit the growth of several pathogens, ranging from bacteria to fungi [2]. In recent years, we have demonstrated the feasibility of copper and zinc oxide NPs as bioactive materials for stone artworks protection [3-5]. Thanks to their biocompatibility and low toxicity, ZnO NPs are particularly appealing for cultural heritage applications. Their activity is typically associated to the release of Zn2+ and reactive oxygen species formed at ZnO nanoparticle surface [6]. Moreover, their shape and size can influence their bioactivity. However, it is important to use safe and environmentally friendly methods to prepare such nanomaterials. As a result, we have developed a hybrid electrochemical-thermal green process to synthesize ZnO NPs with different morphologies [7]. By tuning the synthesis parameters and selecting the proper stabilizer, we have synthesized spheroidal and flower-like ZnO nanostructures using sodium polystyrene sulfonate [7] and cetyl trimethylammonium bromide [8] as capping agent, respectively. Novel hybrid coatings have been prepared loading the as-synthesized ZnO NPs into commercial consolidating agents and applied on stone monuments as antimicrobial films [4, 5]. In this communication, we will provide an overview of this alternative approach for the synthesis of ZnO NPs highlighting the role of the stabilizer. The case of benzyl-hexadecyl-dimetylammonium chloride or poly-diallyl-(dimethylammonium) chloride will be reported and compared to previous results. Morphological and spectroscopic analyses carried out on these ZnO nanomaterials will be presented. Moreover, their application in combination with water-repellent organosiloxane oligomers as advanced protective agents will be shown as well.

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