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Non-equilibrium atmospheric pressure plasma synthesis of copper-based nanostructures in liquid environments

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The surfactant and capping-free synthesis of copper-based nanostructures in liquids by means of cold atmospheric pressure plasmas is here presented. The process was performed (i) with an atmospheric pressure microplasma, driven by a DC generator, to synthesize nanostructures in pure ethanol and (ii) with a non-equilibrium atmospheric pressure plasma jet, driven by a nanopulsed generator, to produce nanostructures in two electrolyte solutions. The synthesis was achieved by using the plasma source as cathode and a copper foil as anode. Regarding the synthesis in ethanol with the microplasma, non-agglomerated CuO quantum dots (QDs) with a size of 2.2±1.3 nm were produced. Purity and homogeneity of the obtained system were evaluated through FTIR and XPS spectroscopies, underlining the formation of pure CuO. As a further step, the energy-band diagram was also evaluated in order to investigate the properties of the synthesized CuO QDs for their eventual application in photovoltaic devices. The potentialities of the nanopulsed plasma jet for synthesis of nanostructures was tested on two electrolyte solutions, named SOL1 and SOL2. SOL1 was composed of distilled water in which NaCl and NaOH were dissolved. SOL2 consisted in distilled water containing only NaCl. TEM images showed the formation of nanostructures: nanorods and nanoparticles were obtained from SOL1, while nanoparticles were produced from SOL2. The d-spacing and XPS analysis underlined the presence of pure Cu phase for nanostructures obtained from SOL1 and of CuO phase when SOL2 was subjected to plasma; so highlighting how the composition of the solution affects the morphological and chemical characteristics of the nanostructures produced in liquid. Finally, mechanisms leading to the synthesis of nanostructures are also proposed and discussed.

Keywords
plasma-induced synthesis
microplasma
nanopulsed plasma jet
CuO
quantum dots