Detection of metallic nanoparticles in water activated by air plasmas

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1. Introduction

Aqueous solutions treated by cold atmospheric plasmas - plasma activated water (PAW) are nowadays of a great interest. Thanks to the synergistic effects of the plasma action and induced chemical changes in water (via formation of reactive species), PAW possesses bactericidal or therapeutic effects [1]. In addition to the plasma agents and induced aqueous chemistry, plasma may sputter metallic nanoparticles from the electrode to the treated liquids. This effect has not been much studied but may contribute to the bactericidal effects of PAW [2, 3]. Our focus was here is to detect and examine metallic nanoparticles in the PAW.

2. Experimental set-up and methods

A DC-driven transient spark discharge in air was applied between the high-voltage hollow hypodermic needle and the grounded metallic mesh electrode [4]. The needle enabled us to electrospray the water directly through the active zone of the discharge. After the plasma treatment of the deionized DI water, we used the scanning electron microscopy (SEM) to observe the tip of the needle and the presence of particles in the treated DI water; examined their size and volume distribution by dynamic and static laser scattering (DLS, SLS) and nanoparticle tracking analysis (NTA), and their elemental composition by the electron dispersive X-ray spectroscopy (EDS).

3. Results

We observed the time-progressive instability of the discharge electrical parameters, which is probably due to the changes of the stainless, chromium-nickel steel needle tip electrode. SEM analysis showed morphological changes of the plasma treated needle in comparison with the untreated one. The treated needle lost it sharpness and specific patterns of "melted areas" we observed on its surface. SEM observation of the treated DI water showed the presence of particles with the size from nano- to several micrometers. More detailed analysis of the DI water by DLS, SLS and NTA shows wide distribution of particles mainly below 500 nm (Fig. 1). The EDS analysis of particles confirmed that the elemental composition of the particles was identical with the needle composition (Fe, Cr, Ni, O).

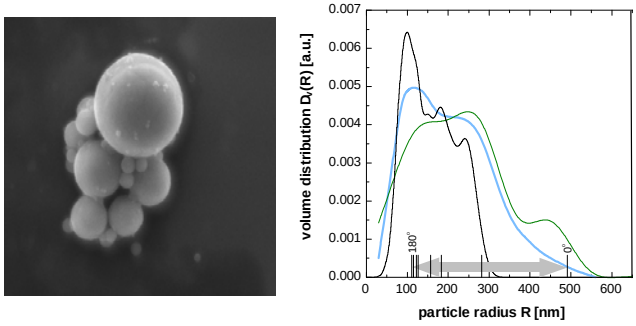

Fig. 1 SEM pictures (10,000x mag) of metallic particles in the PAW (left). Volume distribution of nanoparticles analyzed by various methods (right): black (NTA), green (SLS), blue (optimal combination of NTA and SLS). Vertical lines show DLS for various scattering angles.

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