Emission spectroscopic investigation of the spark discharge used for Cu nanoparticle production

A. Kohut[1], A. Metzinger[2], G. Galbács[2], L. Ludvigsson[3], B.O. Meuller[3], M.E. Messing[3], Zs. Márton[4], K. Deppert[3], and Zs. Geretovszky[1]

[1]Department of Optics and Quantum Electronics, University of Szeged, 6720 Szeged, Hungary
[2]Department of Inorganic and Analytical Chemistry, University of Szeged, 6720 Szeged, Hungary
[3]Department of Physics, Lund University, Lund, 22100, Sweden
[4]Department of Environmental Physics and Laser Spectroscopy, University of Pécs, 7624 Pécs, Hungary
Keywords: nanoparticles, spark discharge generator, spectroscopy
Presenting author email: linus.ludvigsson@ftf.lth.se

Copper nanoparticles (NPs) were generated by means of a spark discharge ignited between two copper electrodes in a flowing N_2 environment. The electrodes were powered by the simplest bipolar, capacitor charging layout. In these spark discharge generators (SDG) the particle formation is driven by the local melting and evaporation of the electrode material under the impact of the spark plasma followed by adiabatic expansion.

In order to obtain fundamental information on the NP formation process in an SDG, we carried out extensive time-resolved emission spectroscopic measurements of the electrode gap. To this end, a high sensitivity light collecting spectrometer system consisting of an Echelle spectrograph equipped with an intensified CCD detector (Andor Mechelle 5000 + Andor iStar 734-18F-03) was added to the SDG setup. Spatially integrated light was collected in a direction perpendicular to the electrodes' axis, via an optical fiber. Spectrometer operation was triggered from a passive high voltage probe (Tektronix P6015A) connected to the anode. The electro-optical setup allowed for the collection of the 300-800 nm spectral and 100 ns – 15 µs temporal ranges with an overall time delay of 95 ns and time resolution of 100 ns. Each spectrum was measured on separate sparks and 11 spectra were averaged at each delay.

The acquired emission spectra indicated the presence of atomic and ionized nitrogen (N^{2+}, N^+, N) and copper (Cu, Cu^+) species in the spark gap. N_2 and N_2^+ bands were not detected in the studied temporal window. Fig. 1 shows that after the ignition of the discharge, the emission of doubly ionized nitrogen peaks first at very early times (ca. 100 ns), followed by the emission from ionized nitrogen (at around 1 µs) already in a broader distribution. Emission from the atomic species of the electrode material and gas environment starts later and lasts significantly longer (10-12 µs in duration).

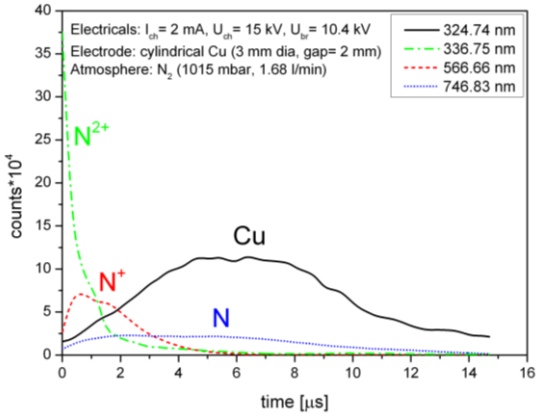

Figure 1. Temporal evolution of the emission of the species detected in the spark discharge.

We also collected time-resolved electrical data on the spark plasma, with the goal of exploring the influence of the settings at the capacitor charger (charging voltage and current) on the plasma and particle characteristics. The data in the present system in a N_2 environment clearly indicate that *i)* as long as the charging voltage is equal or higher than the breakdown voltage, the charging voltage has no influence on the plasma characteristics, *ii)* the charging current can not only influence the discharge frequency, but also the breakdown voltage and hence also the electrode material evaporation. These observations were also supported by the spectroscopic and particle characterization data, which will be discussed in detail in our presentation. For example, an increasing charging current decreased the breakdown voltage, indicated by a decrease in the intensity of all observed emission lines (equivalent with a drop in the number concentration of the related species in the discharge gap).

This work was supported by the European Union´s Seventh Framework Program (EU FP7) under Grant Agreement No. 280765 (BUONAPART-E) and by the TÁMOP programme of Hungary (No. 4.2.2.A-11/1/KONV-2012-0060).