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Analysing the electrical behaviour of the Spark Generator in view of novel applications

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The spark discharge generator (SDG) is used to generate nanoparticles by evaporating electrode material using a repetitive discharge (Schwyn et.al., 1988, Tabrizi, Ullman et. al. 2008). Previous work (Tabrizi, Ullman et. al., 2008) has shown that the electrical behaviour of the spark can be modelled according to a simple RLC (resistance inductance capacitance) network. The inductance in the circuit is low, relatively small capacitances are used (20 nF), and the circuit resistance is negligeable. Since the resistance of the plasma quickly reaches a low and constant value (~2-5 Ω), this results in an underdamped oscillation of current and voltage (figure 1). In the same figure a fit of the data is displayed. Deviation between the fit and actual data at the onset of the discharge is due to the fact that the plasma resistance reaches a steady state value only after ~0.2 µs. This can be accounted for only in a numerical solution, not in the analytical form used here. For the remainder of the discharge however, the fit corresponds very well to the data. The same holds for the current.

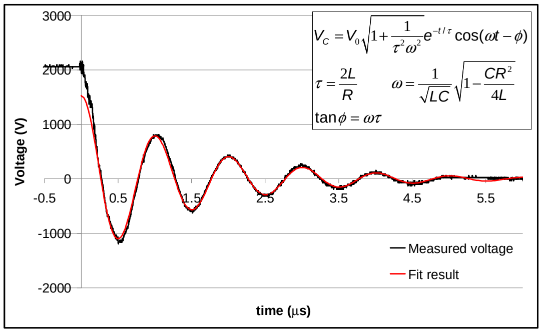

Figure 1: Voltage over capacitorbank. Mg electrodes, 2mm gap, 1 L/min Ar gas. Formulas used for the fit are given in the figure.

Results of applying this simple model to the production of particles using the SDG are presented here. Firstly, the SDG is exceptionally well suited for mixing different materials (Tabrizi, Xu et. al., 2008). One way of doing this is to use electrodes of two different materials. Normally the ratio between the two materials in the resulting nanoparticles cannot be altered except by switching high voltage and ground electrode materials, resulting in two fixed ratios. By adding external resistances to the discharge circuit however, we were able to change the waveform and thus the erosion rates of the electrodes and consequently the composition of the end product. The resultant waveforms again fit the model very well.

Secondly, the production rate for the semiconductor silicon in the SDG was disappointing so far. Analysis of the waveforms obtained for intrinsic silicon with the model showed that the resistance in the RLC network was very high (~140 Ω) due to the limited conductivity of the silicon rods, resulting in a non-oscillating overdamped discharge. Instead of a high current short duration discharge, a much longer lasting low current discharge is obtained. Visual observation confirmed this.

Doped silicon has a much lower resistance compared to intrinsic silicon. When doped rods were used instead, we were able to increase the production rate by a factor of 10^2-10^3, based on measurements using a TSI3071 Differential Mobility Analyzer (with a new TSI3077A Kr-85 neutralizer) and a Faraday Cup Electrometer or a TSI 3085 Condensation Particle Counter. This result is expected from the model. A comparison between two typical size distributions is given in figure 2. Clearly the production rate for doped silicon is much higher.

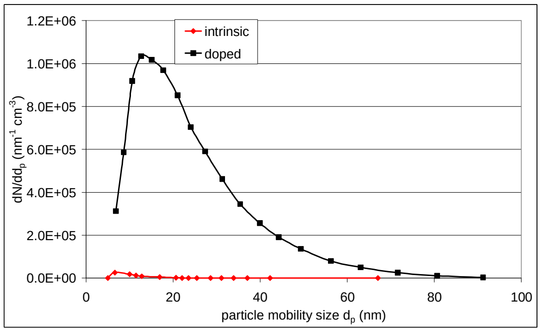

Figure 2: particle size distributions for intrinsic and doped Si. 2 mm gap, 1 L/min Ar.

Tabrizi, N.S., Ullman, M., Vons, V.A., Schmidt-Ott, A. (2008), *Generation of nanoparticles by Spark Dicharge*, J. Nanoparticle Res., 11, 315

Tabrizi, N.S., Xu, Q., Van der Pers, N.M., Lafont, U., Schmidt-Ott, A. (2008). *Synthesis of mixed metallic nanoparticles by Spark Dicharge*, J. Nanoparticle Res., accepted.

Schwyn, S., Garwin, E., Schmidt-Ott, A. (1988). *Aerosol Generation by Spark Discharge*. J. Aerosol Sci., 19, 639.