A Controlled Spark Generator for Increased Nanoparticle Production

T.V. Pfeiffer[1], P. Keijzer[2] and A. Schmidt-Ott[1]

[1]Department of Chemical Engineering, Delft University of Technology, Delft, 2628 BL, the Netherlands
[2]Electrical and Mechanical Support Division, Delft University of Technology, 2628 CD, the Netherlands
Keywords: Spark discharge, gas phase synthesis of nanoparticles, scale up.
Presenting author email: t.v.pfeiffer@tudelft.nl

Spark generators allow the production of high purity nanoparticles, without the need for precursors or solvents. The particles form through ablation of target electrodes by repetitive sparks of constant energy. Current spark generators still follow the original design (Schwyn, 1988), and give poor production rates on the order of 1 mg/hour per electrode pair. An important limiting factor is the repetition rate of the sparks: above ~300 Hz the well-defined spark regime transitions to a chaotic, quasi-continuous discharge. Here, we present a novel approach to increase the production rate, by increasing the repetition rate with constant spark energy.

The distinguishing feature of spark discharge is the short, high intensity oscillating capacitive discharge. This results in high temperatures (10^4 K) and fast quench rates (>10^7 K/s), allowing unique phases to be produced. Up to ~300 Hz, the production rate of a spark generator is proportional to the repetition rate (Helsper, 1993). However, suitable capacitor charging power supplies for higher repetition rates are expensive. Regardless of the power source, residual space charge from a previous spark lowers the gas breakdown voltage at higher frequencies, giving erratic behaviour and strong variations in spark energy. To properly scale up the production rate of a spark generator, constant spark energy has to be maintained also at higher repetition rates

To achieve this we decoupled the charging and discharging cycles of the spark generator circuit, as schematically shown in figure 1. The capacitor is charged while the gap is disconnected (S_2 open), which allows the spark energy to be set without causing premature breakdown in the gap. The spark is initiated by connecting the fully charged capacitor to the spark gap (S_1 open, S_2 closed). Repetition rate, spark energy and gap spacing can be set independent of gas properties and each other, which is a significant improvement over the standard design. The upper repetition rate of this method is limited only by the duration of the spark, ~100 kHz for a typical <10 µs spark.

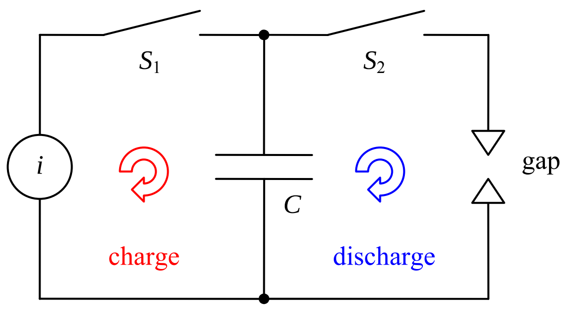

Figure 1. New spark generator concept

On the concept of figure 1, a 1.25 kW prototype was developed and built based on readily available 1.5kV IGBTs (Insulated Gate Bipolar Transistor). The prototype provides up to 50mJ sparks with an upper repetition rate of 25 kHz. Ar and He were used as quench gases. Large gas flows of 100-1000 SLM, in closed loop configuration to limit gas consumption, are necessary to prevent melting of the electrodes at power inputs >~250W. Niobium electrodes were used because of the high melting point of Nb. The impurities in commercial grade gas result in Nb_2O_5 as product (XRD).

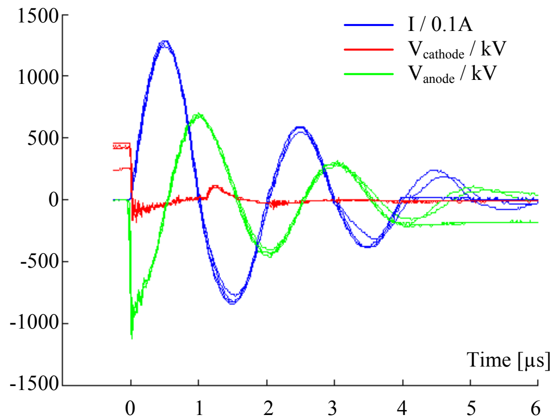

Figure 2. Oscilloscope traces of 9 consecutive 1.2 kV, 32 mJ sparks at a 6.6 kHz repetition rate.

The discharges show the familiar RLC-like oscillations with resonance frequencies around 1 MHz. TEM shows the characteristic fractal-like agglomerates of spark generated nanoparticles, with primary particles of 6 nm (σ_g = 1.6). For Nb, the yield (mass per energy) at high repetition rates is identical to that in the classic system at low repetition rates (Tabrizi, 2009). Mass output scales linearly even at repetition rates well above 1 kHz. We conclude that the production of nanoparticles by spark discharge has been successfully scaled up by two orders of magnitude, while retaining the well-defined, repetitive identical sparks.

Work funded by Agentschap NL, grant EOS-LT07052.

Helsper, C., Mölter W., Löffler F., Wadenpohl C., Kaufmann S., and Wenninger G. (1993) *Atmospheric Environment A.* **27** 1271-1275.

Schwyn, S., Garwin E. and Schmidt-Ott, A. (1988) *Journal of Aerosol Science* **19,** 639-642.

Tabrizi, N. S., Ullmann, M., Vons, V. A., Lafont, U. and Schmidt-Ott. A. (2009) *Journal of. Nanoparticle Research.* **11**, 315-332.