High-yield synthesis of Al_2O_3 and SnO_2 nanoparticles by the multi-spark discharge generator

A. A. Efimov, I. A. Volkov, A. A. Lizunova, D. A. Mylnikov and V. V. Ivanov

Department of Physical and Quantum Electronics, Moscow Institute of Physics and Technology, Dolgoprudny, 141700, Russia
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Presenting author e-mail: efimov.aa@mipt.ru

At the present time, the aerosol nanoparticles are coming into use in printed electronics and photonics (Hoey *et al.*, 2012). In this connection, the development of various cost-effective methods of synthesis of nanoparticles in the gas phase is of particular importance. The spark discharge is one of promising methods allowing to produce high-purity ultrafine particles. The main drawback of this method is low production rate (less than 10 mg/h), which nevertheless can be overcome through increasing the repetition rate of discharges (Pfeiffer *et al.*, 2014) or the number of discharge gaps (Efimov *et al.*, 2013). In this work, both approaches have been embodied in the new multi-spark discharge generator (m-SDG) used for high-yield production of metal oxide nanoparticles.

The scheme of m-SDG is presented in Figure 1a. It consists of 12 pairs of electrodes connected in series, which are purged continuously by a clean air at a rate of 15 m/s. To apply high voltage between the electrodes, the 12-nF capacitor is used; the repetition rate of discharges is controlled by the pulsed generator. In order to produce alumina and tin oxide nanoparticles the following regime was used: 4.5 kV and 2.5 kHz.

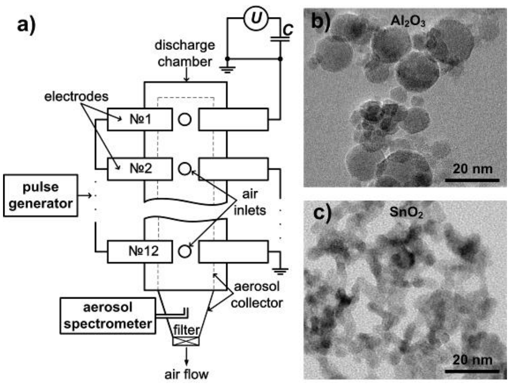

Figure 1. A scheme of the multi-spark discharge generator (a) and TEM images of Al_2O_3 (b) and SnO_2 (c) nanoparticles.

The as-synthesized airborne nanoparticles were characterized by using diffusion aerosol spectrometry (DAS 2702). The nanoparticles accumulated by a porous stainless steel implementing the role of aerosol filter were studied by transmission electron microscopy - TEM (JEOL JEM-2100) and X-ray diffraction - XRD (Bruker D8 DISCOVER).

It was found from the analysis of TEM images that size of primary Al_2O_3 and SnO_2 nanoparticles is mostly ranging from 5 to 10 nm (Figure 1b, c). These primary nanoparticles are combined into agglomerates with a size of about 50-80 nm that is in good agreement with the data obtained from aerosol analysis (Figure 2).

The estimated values of production rate of two types of nanomaterials are presented in the Table 1. The achieved production rate is found to be at least 100 times greater than that of conventional aerosol generators operating in the self-breakdown mode (Bau *et al.*, 2012).

Table 1. The production rate of nanoparticles obtained by m-SDG by using electrodes made of Al and Sn.

Electrode material	Production rate	Composition (XRD)
Al	0.3 g/h	γ-Al_2O_3 (46%) and amorphous Al_2O_3 (54%)
Sn	9 g/h	β-Sn (2%), SnO_2 (94%) and SnO (4%)

The proposed technology of high-yield synthesis of ultrafine airborne particles opens up fresh opportunities for their industrial application, for example, in electronics and precision engineering, by employing aerosol jet printing.

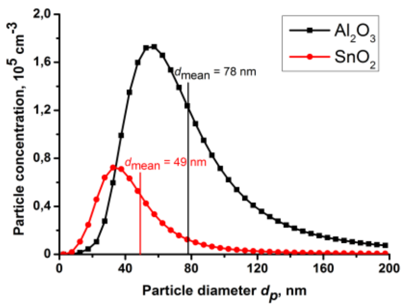

Figure 2. Size distribution of as-synthesized airborne Al_2O_3 and SnO_2 nanoparticles.

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