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Size control, transport and collection of nanoparticles grown in pulsed hollow cathode discharge: Experiments.

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The experimental progress and challenges are reported in a broad project, in which different types of nanoparticles (NPs) are produced in pulsed hollow cathode discharges. The key to the pulsed power technique is a NP growth environment built up of a sequence of partially overlapping high density plasma clouds, in which the sputtered growth material has a high degree of ionization. This technique opens new opportunities, but also adds new challenges. In particular, electric fields and NP charging become important in all phases: the growth, the transport, and the final collection of NPs on substrates. In the reported project the production goals are defined by three different applications: we aim at Fe-oxides as MRI tracers which need to have a radius 2-4 nm and narrow size distributions, CuZr NPs for catalysis which requires deposition structures with a large effective surface area, and InAl-nitrides and Zn-oxides for high-efficiency light-emitting electrochemical cells. In this case the NPs need to have radius 2-4 nm, narrow size distributions, and a uniform spread-out deposition without agglomeration. The state of the project is as follows.

Productivity can be influenced by seeding the discharge gas, argon, with trace oxygen, probably through stimulating nucleation. With optimized discharge conditions a high fraction of the available growth material can be transformed to NPs.

Size control is demonstrated by various alternative control parameters: pulse frequency, pulse amplitude, pulse length, discharge geometry, gas pressure, and gas flow speed. A size dispersion below 10 % is shown to be achievable.

Transport and collection is a challenge. We need to operate in a complicated regime where Brownian motion, electric fields, gas flow drag and substrate bias all play a role, depending on NP size and charge. We present experimental observations that identify some problems with transport and discuss involved mechanisms.

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