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Selective oxidation of metal nanoparticles generated by spark ablation

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The generation of metal nanoparticles of high purity, with high throughput, and high control of the particle composition, is interesting for applications in many fields including catalysis, medicine, and gas sensing. Spark ablation produces an aerosol of particles in a carrier gas and is a potential technique where such synthesis conditions could be implemented (Efimov, 2016).

For most applications, the surface of the particles is of great importance since it highly affects the particle properties. Changes such as surface oxidation can negatively influence the properties of e.g., catalysts and magnetic nanoparticles. For some applications, complete oxidation of the particles is desired, and for others, a thin surface oxide to protect the particle core is of interest. Therefore, the understanding of particle generation and associated oxidation is vital.

Recently, the prevention of surface oxidation of particles by the addition of a reducing agent (such as H_2) in the carrier gas was discovered (Hallberg, 2018), and is today frequently used when pure unoxidized metal nanoparticles are desired. However, there are few investigations of how the choice of carrier gas affects the composition and crystal structure of particles, which greatly influence particle properties (Ternero, 2023).

Figure 1 shows that a reducing atmosphere of 95% N_2+5% H_2 (N_2+H_2) affects particles of Tin and Aluminium differently. For Sn, a reducing atmosphere (orange) results in the lowest particle yield compared to when only nitrogen (green) or air (blue) is used. For Al, a reducing atmosphere produces the highest particle yield.

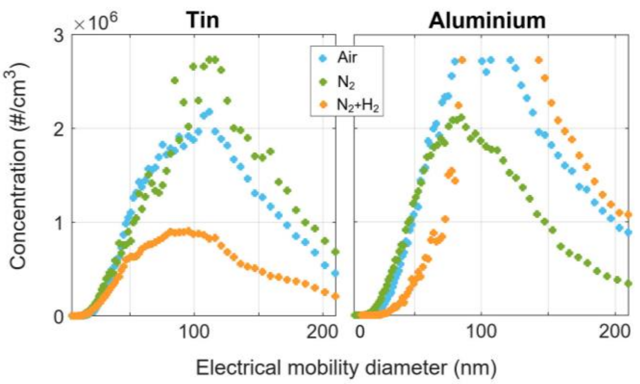

Figure 1. *Size distribution of Sn and Al particles produced using identical production parameters in three different carrier gases, see figure legend*.

Figure 2 shows a HR-TEM image of Sn particles generated in a reducing atmosphere. From the fast Fourier transform (FFT) it could be concluded that the particle core is crystalline while the shell is amorphous. In contrast, Sn particles generated in N_2 and air seems to consist of primary particles of Sn, SnO, and SnO_2.

This work aims to investigate how particle yield and crystal structure of different easily oxidized materials are affected by the choice of carrier gas in spark ablation. We will present results from both online (tandem DMAs and pulsed XRD using an XFEL) and offline (HR-TEM, XPS, and XRD) techniques showing differences and similarities between how particles of 4 material systems (Al, Sn, Ti, and Zn) are affected by the carrier gas. This will help optimize the type of carrier gas for producing particles with properties that are desired for specific applications.

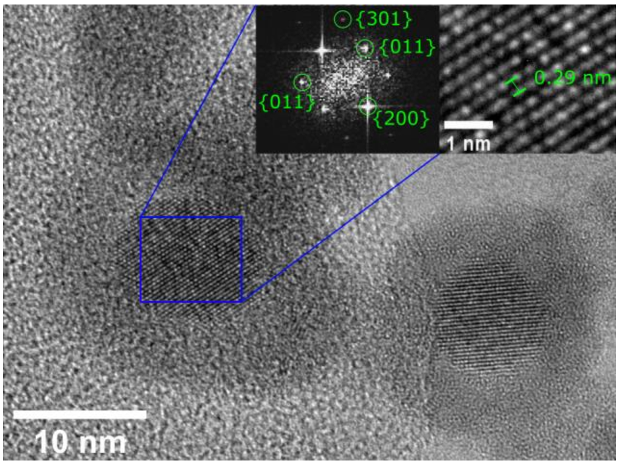

Figure 2. *HR-TEM image of an Sn particle produced with N_2+H_2 as carrier gas. The particle has a core of Sn and a shell of amorphous SnO_x. Left inset: FFT of a particle core, confirming the Sn crystal structure. Right inset: close-up of the core showing its lattice distance.*

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Efimov, A. et al., (2016). *Oriental Journal of Chemistry*, *32*(6), 2909-2913.

Hallberg, R. et al., (2018). *Aerosol Science and Technology*, *52*(3), 347-358.

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