Nanoparticle beam deposition methods for functional electronics

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Owing to their high surface-to-volume ratio, their small size and the high number of intrinsic defects, nanoobjects such as nanoparticles exhibit properties that go beyond typical bulk materials. In particular, nanogranular systems with nanoparticles as their fundamental building units exhibit electronic and optical properties that differ from their atom-assembled counterparts. As such, nanoparticles are promising building units for applications in catalysis, optics and functional electronics.

In the field of sensors, noble metal nanoparticles are readily used to cover surfaces of semiconducting metal oxide micro- and nano-structures, which consequently tailors sensor properties such as sensitivity, selectivity and response times. On the other hand, in the context of memristive devices and neuromorphic hardware, noble metal (alloy) nanoparticles can be applied to localize and enhance the electrical field and realize highly localized resistive switching processes. In addition, such nanoparticles can act as functional building units for self-arranged networks, which are poised at the threshold of electrical percolation and show criticality and avalanche dynamics.

Common to all of the abovementioned applications is the high demand on a precise control over nanoparticle composition and deposition process. In this contribution, nanoparticle beam deposition via a Haberland-type gas

aggregation cluster source will be showcased as a versatile method that meets these demands. Nanoparticle beam deposition methods based on gas phase synthesis of nanoparticles offer the benefit of a high purity, surfactant free deposition that is compatible with a broad range of substrates. The fundamental processes of nanoparticle formation and trapping inside gas aggregation sources are highly dynamic and require a better understanding.

This contribution highlights the importance of in-operando diagnostic methods for the development of a deeper understanding of the nanoparticle formation processes inside a gas aggregation source. The applicability of in-operando UV-vis and OES to control the functional properties of nanocomposite thin films will be demonstrated at the example of AgAu alloy nanoparticles with tuneable alloy composition. Furthermore it will be demonstrated how laser light scattering techniques can be applied to comprehend the dynamic trapping processes of nanoparticles inside the nanoparticle source, in particular under consideration of different gas inlet geometries.