Controled synthesis of core-shell nanoparticles for functional applications

Oguz Han Asnaz[1], Jonas Drewes[2], Marie Elis[3], Franko Greiner[1,4], Franz Faupel[2,4], Lorenz Kienle[3,4], Alexander Vahl[2,4], and Jan Benedikt[1,4]

[1]*Institute of Experimental and Applied Physics, Kiel University, 24098 Kiel, Germany*
[2]*Chair for Multicomponent Materials, Kiel University, 24143 Kiel, Germany*
[3]*Chair for Synthesis and Real Structure, Kiel University, 24143 Kiel, Germany*
[4]*Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, 24118 Kiel, Germany*

Abstract: A novel combination of a gas aggregation source and a secondary radio frequency discharge is used to generate, confine, coat and extract nanoparticles. The process is monitored using *in situ* Fourier transform infrared spectroscopy and localized surface plasmon resonance spectroscopy. It is demonstrated that Ag@SiO_2 nanoparticles can be synthesized with a well-defined surface coating and that they can be extracted in a controlled way.

Keywords: Gas aggregation source, low-pressure plasma, Ag@SiO_2 core-shell nanoparticle.

1. Introduction

Due to their small size, noble metal nanoparticles have unique properties in comparison to their bulk counterparts. Applications range from photocatalysis, resistive switching, sensors, solar cells, to antibacterial coatings. Their properties can be further enhanced or controlled by means or surface modification for example in the form of thin layer on their surface, forming so called core-shell nanoparticles. Wett chemistry mehods can be used with the disadvantage that the nanoparticles have to be extracted from the solution after the process [1,2]. Plasma deposition on negatively charged particels trapped in the low-pressure plasmas is an alternative, which allow at the same time the *in situ* monitoring of particle properties and well defined particle extraction.

2. Experiment

In this contribution, the Ag nanoparticles are created in a Haberland type gas aggregation source [3] using magnetron sputtering of silver target at 170 Pa and then injected into a secondary radio frequency discharge (inductively coupled plasma reactor, however operated in the capacitive E-mode at 11 Pa) for further confinement and treatment [4]. The confinement is possible due to negative charge of the nanoparticles in plasma. This approach allows for treatments at much longer time scales than in traditional in-flight treatment setups and much finer control over the coating properties. The system is capable of confining particles over an hour without significant losses. The confined nanoparticles are monitored using multipass White cell with Fourier transform infrared spectroscopy (FTIR, 20 passes) to measure material of the shell or UV-vis absorption spectroscopy (4 passes) to follow the localized surface plasmon resonance of the metal nanoparticles.

The deposition of SiO_2 is achieved by admixter of highly diluted SiH_4 into the low-pressure chamber, where the oxidation is maintained through the impurities presented there (O_2/H_2O). The nanoparticles are extracted with the help of particle extraction system operated with pulsed positive bias [5].

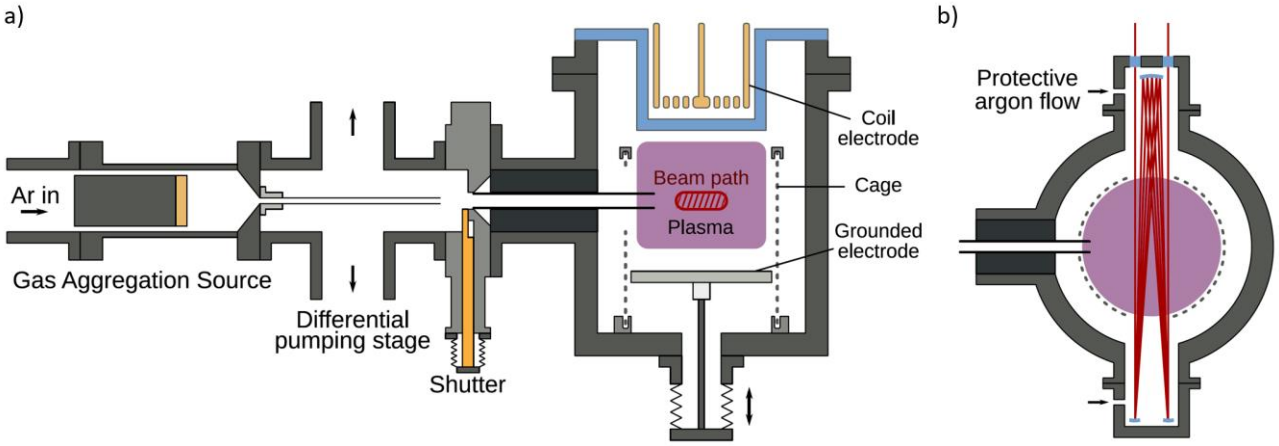

Fig. 1. a) Side view of the experimental setup with combination of the gas aggreagation source, differential pumping, and low-pressure chamber for particle trapping. b) Top view of the low-pressure chamber to show the beam path of the White multipass cell through the plasma used for UV-vis and FTIR spectroscopy.

3. Results

Ag nanoparticles with diameters between 5 and 60 nm have been generated by the GAS source and injected into the low-pressure argon plasma. Injection of SiH_4 gas (concentration below 100 ppm) into the argon plasma has resulted in the deposition of SiO_2 material on the silver nanoparticle. Homogeneous coating was achieved after 10 min of treatment, which was preceeded by the island growth as demonstrated by TEM images in Fig. 2. Closing of the coating is observed at around 5 min of treatment time.

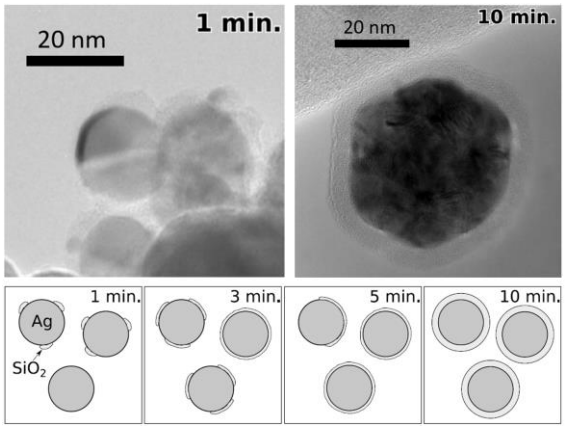

Fig. 2 TEM images of the Ag nanoparticels extracted after 1 minute (left) and 10 minutes (right) of treatment in Ar/SiH_4 plasma. The cartoon below shows the progress of the closing of the shells during the treatment. Data adopeted from [4].

The deposited layer is effectively etched away when hydrogen gas is admixed to the argon gas, where both *in situ* diagnostics provide the feedback about the progress of the etching.

4. Summary and prospects

The here presented method is very versatile and can be applied to many different nanoparticles ranging from different metals and metal alloys to inorganic material and even polymers. Furthermore, different coatings can be applied and even the fabrication of a gradually changing coating is possible. Moreover, the in situ diagnostics allow for the precise control of the synthesis process. The extraction process controlled over the duration of the applied voltage pulse allow on one hand the deposition of very thin layers with the nanoparticle density below the percolation threshold or, on the other hand, generation of over micrometer thick layers of loosly packed nanoparticles. This control allows the integration of these core-shall nanoparticles into functional layer with variety of electrical properties. The latest results achieved with this experimental setup will be presented at the conference.

5. Acknowledgements

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6. References

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