High-power pulsed hollow cathode sputtering for high-rate growth of complex nanoparticles and nanostructures

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The production of nanoparticles in the gas phase is controlled by two factors, nucleation and growth. Here I focus on growth rate which is determined by the capture of particle forming species in the gas. The capture probability and rate are determined by a range of factors such as the path length and impact cross-section of the forming species. For neutral atoms or molecules, the path length through the reactor, and thereby their time in the nanoparticle growth zone, can be increased by increasing the operation pressure, but the cross-section of the species contributing to the particle growth will still be small and limited to the physical size of the growing nanoparticle. However, in a plasma the situation can change dramatically since nanoparticles in a plasma will attain an electric potential slightly lower than the plasma potential. This means that ionizing the source material can have a dramatic effect on the trapping cross-section since the nanoparticles can electrically attract positive ions in the plasma. The electrical interaction between ions and the charged particles can further enhance the trapping probability by lengthening the path-length of the ion through the reactor. This occurs if the nanoparticles electrically scatter the ions. The total result of these factors is estimated to increase the trapping probability with two orders of magnitude. [1] For these reasons, it is of great interest to efficiently ionize the particle forming species during nanoparticle synthesis. We do this by combining two methods that yields a high ionization rate, HiPIMS and hollow cathode target sputtering and are efficiently synthesising nanoparticles of a range of materials, with the only limitation that a conducting hollow target can be fabricated. However, with the use of reactive gases, compound nanoparticles, also insulating, can be grown. [2,3] One example of this is illustrated in the figure, showing Ni-O nanoparticles with different amount of oxygen incorporated in the synthesis. The growth and collection of alloyed and magnetic nanoparticles is also shown and discussed.

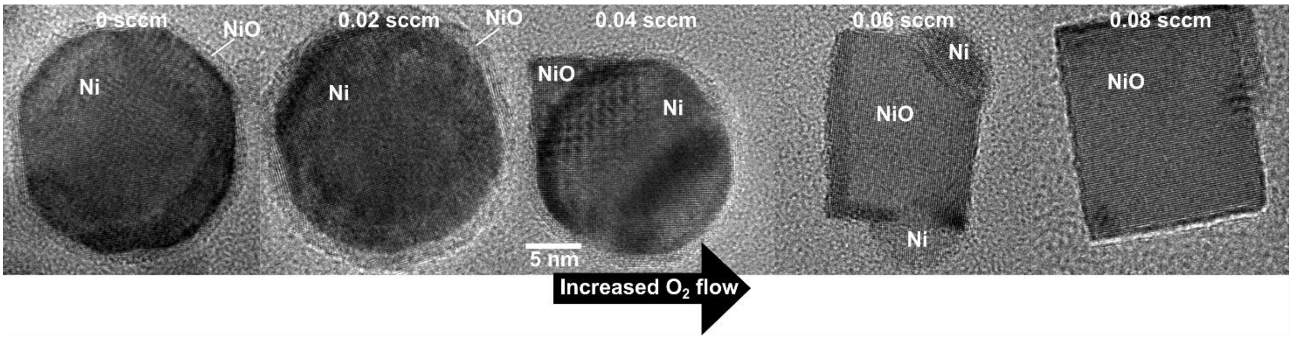

Fig. 1 Growth of Ni/NiO nanoparticles at different O_2 flow rates

[1] Pilch, I., Söderström, D., Hasan, M. I., Helmersson, U., Brenning, N., Appl. Phys. Lett. 103 (2013) 193108

[2] Gunnarsson, R., Helmersson, U., Pilch, I., J. Nanopart. Res. 17 (2015) 353

[3] Ekeroth, S., Ikeda, S., Boyd, R. D., Shimizu, T., Helmersson, U., J. Nanopart. Res. 21 (2019) 37