High rate generation of size-selected metallic clusters in vacuum by magnetron sputtering

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Nanoparticles that are produced by a gas-condensation process in vacuum, have many advantages compared to those prepared via a conventional wet-chemistry route. Inherently these gas phase nanoparticles are very clean and pure, because there is no contamination from ligands, for example, which are often essential in other catalyst preparation methods, like precipitation or impregnation. As such, there is no need to carry out calcination processes afterwards to remove such organic materials, which could be a critical issue for some nanoparticle materials that are sensitive to high temperature.

The majority of the nanoparticles produced by magnetron sputtering are electrically charged, and this has made it convenient to employ a Time-of-Flight mass filter to select the particle size [1]. Although the particles produced in magnetron sputtering chamber have a relatively broad size distribution, they will have a very narrow size distribution, typically +/- 10% of diameter, after mass selection. This offers a powerful tool to investigate the influence of particle size on catalytic activity / selectivity, and thus can help to address many important theoretical questions.

We have also developed technologies to deposit nanoparticles on powders directly in vacuum [2], and this made it possible to evaluate catalytic performance using conventional fixed-bed reactors.

However, one currently limiting factor of this technology is that the amount of nanoparticle materials produced is small. To address the issue, we carried out aerodynamic simulation to understand better how the gas dynamic influences the clusters' formation and growth, and proposed new approach to improve the cluster throughput. By optimizing the gas dynamic inside the vacuum chamber, we were able to improve the cluster flux by 3 to 5 times. By adopting a different magnetron sputtering technology, we had another ~ 5 times flux improvement. Ultimately, we expect to improve the production rate by a factor of ~ 100. This will raise the possibility of mass-production of such high-purity and size-selected nanoparticles, which in turn will lead to many new and future commercially significant applications.

[1] S. Pratontep, S. J. Carroll, C. Xirouchaki, M. Streun, and R. E. Palmer, Rev. Sci. Instrum. 76 (2005) 045103.

[2] Peter R. Ellis, Christopher M. Brown, Peter T. Bishop, Jinlong Yin, Kevin Cooke, William D. Terry, Jian Liu, Feng Yin and Richard E. Palmer, The cluster beam route to model catalysts and beyond, Faraday Discuss., 2016, 188, 39.