Generation of alloyed nanoparticles by spark discharge

A. Muntean[1], M. Wagner[2], J. Meyer[2], M. Seipenbusch[1]

[1]Department of Chemical Process Engineering, University of Stuttgart, Germany
[2]Department of Mechanical Process Engineering and Mechanics, Karlsruhe Institute of Technology, Germany
Keywords: Nanoparticles, Spark Discharge, Copper, Nickel, Alloy
Presenting author email: alex.muntean@icvt.uni-stuttgart.de

Bimetallic nanomaterials are of great interest due to their size, composition and structure-dependent properties. In recent studies it has been reported that bimetallic nanoparticles possess outstanding characteristics when compared to monometallic nanoparticles, especially as catalysts for certain chemical reactions.

To ensure the use of a suitable catalyst for a given application, it is necessary to control the bimetallic particle generation and thus tailor the nanocatalyst composition. The particles were produced in the gas phase in a spark discharge generator (SDG). The advantages of nanoparticle generation via the aerosol route are the well-defined morphology of the product particles as well as the purity of their chemical composition.

Table 1. Comparison of the calculated and measured Cu/Ni-ratios

Sample	Feedstock Cu/Ni ratio, specified (mass ratio)	Nanoparticle Cu/Ni ratio (mass ratio)
Cu/Ni 80/20	4.33	4.83
Cu/Ni 60/40	1.624	1.684
Cu/Ni 40/60	0.722	0.744
Cu/Ni 20/80	0.27	0.28

The generation of copper, nickel and copper-nickel alloy nanoparticles by spark discharge was investigated, using different bespoke alloy feedstock. Roughly spherical particles with a primary particle Feret diameter of 2 to 10 nm were produced and collected in agglomerate form. The copper to nickel ratios determined by ICP-MS, and therefore averaged over a large number of particles, matched the nominal copper content quite well. Further investigations showed that the electrode compositions influenced the evaporation rate and the primary particle size. The evaporation rate decreased with increasing copper content, which was found to be in good accordance with the Llewelyn-Jones model.

However, the particle diameter was increasing with an increasing copper content, caused by a decrease in melting temperature due to the lower melting point of copper. Furthermore, the alloy compositions on the nanoscale were investigated via EDX. The nanoparticles exhibited almost the same composition as the used alloy feedstock, with a deviation of less than 7 percentage points between the individual particles. Therefore, no segregation could be detected, indicating the presence of a true alloy even on the nanoscale.

This result shows that nanoparticle compositions can be tailored to the needs of specific catalytic reactions.

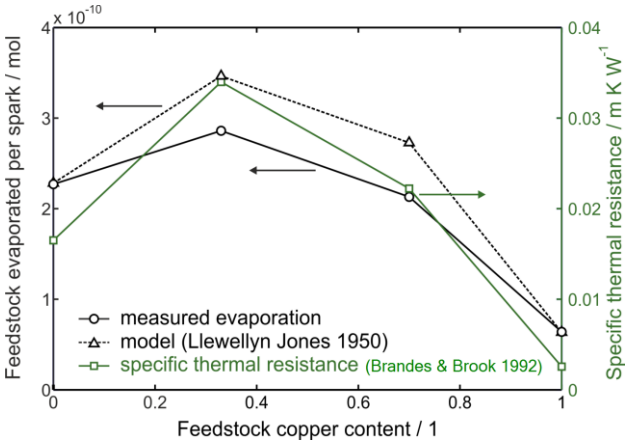

Figure 1. Measured evaporation rate per spark compared with the Llewellyn Jones model and the specific thermal resistance

The authors would like to express their gratitude to Dr. Gábor Galbács from the University of Szeged/Hungary for the ICP-MS measurements and to PD Dr. rer. nat. habil. Reinhard Schneider from the Karlsruhe Institute of Technology (KIT) for the EDX measurements.
The research leading to these results has received funding from the European Union's Seventh Framework Programme under Grant Agreement No. 280765 (BUONAPART-E).