Quantifying the Multi-Element Composition of Single Nanoparticles with the icpTOF

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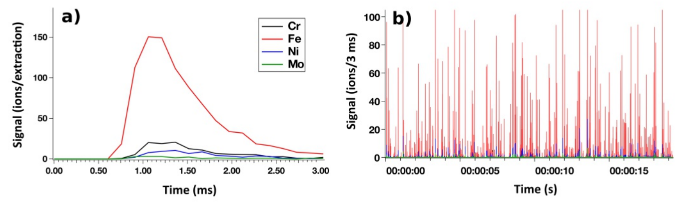
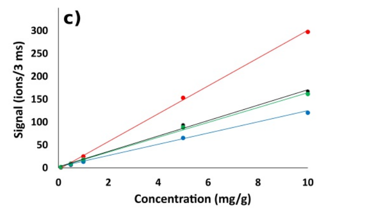
icpTOF

Single particle inductively coupled plasma mass spectrometry (sp-ICP-MS) has established itself as a robust and sensitive method for the measurement of nanoparticle size and number concentration at environmentally relevant levels. A single particle transmitted into an ICP- mass spectrometer generates a ~1 ms pulse of ion signal (e.g., Figure a). Most ICP- mass spectrometers use sequential mass analyzers that can measure only one or two isotopes during this rapid single-particle detection event. This is insufficient for the detection of complex multi-element particles, which represent a substantial portion of manufactured nanomaterials used as additives in consumer products or which are formed by chemical modifications of pristine single-element particles after they have entered the natural environment.

The TOFWERK icpTOF simultaneously measures all isotopes, enabling determination of the complete chemical composition of single nanoparticles. In a previous application note (Multi-element Detection of Nanoparticles with icpTOF, 2016), we demonstrated the ability of the icpTOF to record all elements in single particles and compared multi-element icpTOF data to what can be recorded with modern sequential mass analyzers. Here, we show that the elemental composition of single steel nanoparticles in a polydisperse population can be quantified based on a simple multi-element solution calibration.

Simultaneous measurement of all isotopes enables quantitative determination of the multi-elemental composition of complex single particles.





Element	expected values	icpTOF results
Fe	67-72%	68±5%
Cr	16-26%	19±4%
Ni	10-14%	11±3%
Mo	2-4%	1.3±0.4%

Determining the elemental composition of single steel nanoparticles. Steel nanoparticles (IRMM-383) synthesized in the frame of the NanoDefine Project (http://www.nanodefine.eu/index.php/project-overview) were provided by Steffi Böhme. Complete mass spectra (all isotopes) of single particles were recorded with the icpTOF using H_2 in the Q-cell to reduce the interference of ArO^+ and ArC^+ with $^{56}Fe^+$ and $^{52}Cr^+$, respectively. Figure a) shows the transient signal of Cr, Fe, Ni, and Mo from a single particle and figure b) the signals of many single particles recorded in a 20 second time period. The response of the icpTOF to individual elements (figure c)) was calibrated using standard solutions of Cr, Fe, Ni, and Mo in 1% nitric acid in the concentration range of 0.1-10 mg/g. This calibration was used to determine the concentration (c) of each element in every single particle, and element fractions for each particle were calculated using 100 % normalization method (c(Fe)+c(Cr)+c(Ni)+c(Mo)=100%). The table compares fractions used for synthesis of these particles to the mean molar fractions of 1900 single particles measured with the icpTOF.