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Foreword

At first thought, mass spectrometry would appear to have little in common with nanotechnology—at least the nanotechnology of popular imagination. However, the basic premise/promise of nanotechnology, namely the massively parallel control of function at the nanoscale, requires reaching a level of understanding concerning the individual nanoscale objects, which is typically much beyond that presently available. Mass spectrometry as applied to the study of large molecular ions as well as to the development of new techniques for ionization, size selection, deposition and detection can be expected to play an increasingly important role in this emerging area.

This issue of IJMS contains a selection of papers which are not meant to be comprehensive or even representative. Instead the selection is meant to highlight a number of subdisciplines of mass spectrometry which are (or will hopefully become) of interest to the nanosciences/nanotechnology community. For instance, the development of more and more intense cluster ion sources has enabled experiments in which mass selected clusters up to several thousand atoms are soft-landed onto well defined surfaces to conveniently generate near monolayer coverages. This allows a study of metal-cluster/support interactions as a function of particle size, shape, orientation and charge state. Clearly, such information is relevant to the metal particles comprising the “granularity” of nanofabricated metal electrodes. Perhaps less clearly but no less importantly, understanding charge transfer through supported metallic nanoparticles requires a detailed knowledge of their physical properties as a function of charge state. Consequently, probes of isolated clusters and in particular production and characterization of multiply charged clusters are also of great current interest.

Mass-selective deposition in the sense of a “preparative scale mass spectrometry” is of course not just limited to (metal) clusters. Electrospray (ESI) sources are being continuously improved in intensity and can access most soluble substances. Deposition of extremely fragile biochemical species or even the dual beam co-deposition of cations and anions to generate novel salts is within reach. Seen in combination with methods to selectively position the deposited particles (e.g., via deposition into a solvent slush followed by dielectrophoretic trapping on prefabricated electrodes) the nanotechnological interest becomes apparent.

At higher impact energies deposition merges with scattering and implantation. In particular the latter can be used for surface nanostructuring much as in conventional focused ion beam (FIB) patterning. It is becoming clear that highly charged as well as high mass projectiles will allow unprecedented levels of lateral and vertical resolution.

A significant fraction of experiments in nanotechnology are done on a few particles or even on one individual nanoparticle—often in contact with surfaces. Ion traps have much to offer in this context because they also allow few-particle dynamical probes over long time scales much as in condensed phase but under rigorously matrix-free conditions (facilitating “reference state” determinations). In addition to the adaptation of existing trap technologies (Penning and Paul) to specific, high sensitivity experiments such as fluorescence or cavity ring down spectroscopy, new linear ion trap configurations provide exciting prospects for the future. Similarly, the perspective of being able to probe Wigner crystals of highly charged (oriented?) molecular ions at elevated trap temperatures is compelling.

It goes without saying that the primary outputs of any mass spectrometry experiment, namely the determination of particle mass to charge ratio and relative abundance, are also of great interest to those nanotechnologists who synthesize ever larger molecules. Fragment-free volatilization/ionization is the first goal here and MALDI and ESI ion sources are being routinely used. Biochemical species of mass $> 2\,\mathrm{MDa}$ are (nearly routinely) put into gas-phase using such methods. Still, given the limits to solubility of many macromolecules there is potential for further ion source development (e.g., desorption via highly charged ion impact). Another issue is heavy particle detection. Secondary electron emission eventually runs out of steam due to the required impact velocities. Charge or deposited energy sensitive detectors as well as non-destructive optical detection (e.g., via fluorescence excitation or light scattering) of trapped particles offer useful alternatives.

The larger the particle, the higher the mass resolution required in order to characterize or size select. In particular Penning trap spectrometers have been systematically improved over the preceding decade such that nanoparticle mass can now be determined routinely to one part in 10^7.

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Further improvement is to be expected although we are still a distance away from being able to weigh total nanoparticle binding energies.

Clearly, there are many synergies between mass spectrometry and the nanosciences. I hope that the papers in this volume serve to illustrate the point and would like to thank all authors for contributing.

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