III-E Structures and Reactivities of Metal Clusters

Clusters of metal atoms constitute a new class of material whose properties deviate significantly from those of isolated atoms and condensed matters. Our research group, started in January 2000, has been developing an experimental setup to study the size and shape dependent catalytic behavior of the metal clusters. The motivation of our research is to understand detailed mechanism of the chemical reactions involving the metal clusters based on the correlation with geometric/electronic structures.

III-E-1 Construction of Apparatus for Mass Analysis of Metal Clusters

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We have designed a plan to exploit a synthetic method of the metal clusters having a well-defined size before studying the chemical reactivities. The metal cluster ions are prepared by reduction of the relevant metal ions in the presence of ionic surfactant molecules which prevent coalescence of the clusters. We have constructed a new apparatus that allows us to monitor mass distributions of the nascent clusters in liquid phase. Figure 1 shows a schematic diagram of the apparatus with 7 stages of differentially pumped vacuum chambers. The apparatus consists of an electrospray ion source and a reflectron time-of-flight (TOF) mass spectrometer. Liquid sample containing the cluster ions is pumped through a fused silica capillary, whose end is supported in a stainless steel needle. Charged aerosol droplets are electrosprayed by means of an electrical potential between the needle tip and a counterelectrode (+3–5 kV). The cluster ions in the droplets are evaporated into the gas phase and further desolvated by collision with an inert gas such as nitrogen. A portion of the ion flow is skimmed and introduced into the acceleration region of the TOF mass spectrometer. In order to increase the detection efficiency for the ions having a mass-to-charge ratio above ~10^4, the ions are accelerated by applying a pulsed output of 30 kV from a homemade pulse generator (rise time ~30 ns, on time ~200 μs). The ions are guided by several sets of ion optics and detected by microchannel plate located at the end of the flight path of 3.1 m. Surface induced dissociation, a powerful diagnostics for structural characterization of large and complex systems, can also be performed with this machine. Cluster ions of interest are mass-selected by pulsed beam deflectors and allowed to collide with a solid surface mounted at the end of the reflectron. Collision energy can be varied by changing the voltage applied to the surface. Secondary ions scattered off the surface are detected by secondary TOF mass spectrometer.

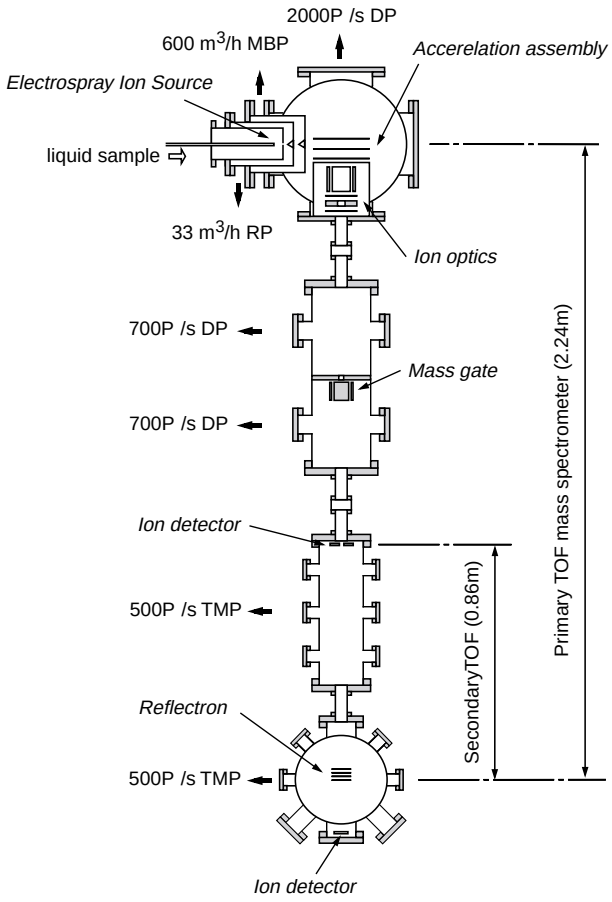

Figure 1. Schematic of experimental apparatus shown in cross section as viewed from above. RP: rotary pump; MBP: mechanical booster pump; DP: oil diffusion pump; TMP: turbo molecular pump.