FT-ICR による金属・炭素混合クラスターの質量分析

FT-ICR Studies of Laser-Vaporized Carbon Clusters and Metal/Carbon Binary Clusters

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Atomic and molecular clusters are being recognized as playing an important role in the thin-film deposition process and phase-change phenomena. Furthermore, small clusters are the most adequate system for the verification of quantum molecular dynamics calculations such as the interference of light and matter. Hence, experimental treatments of such atomic and molecular clusters are now desired. In order to examine such clusters, we have implemented a Fourier transform ion cyclotron resonance (FT-ICR) spectrometer directly connected to a laser-vaporization supersonic-expansion cluster beam source.

The heart of the FT-ICR spectrometer was made of ICR cell cylinder centered in a strong homogeneous magnetic field of a 6 Tesla superconducting magnet. The atomic cluster beam was generated outside of magnetic field by the laser vaporization of a solid sample disk, followed by cooling with supersonic expansion of pulsed helium gas. The ionized cluster was carried by helium gas and directly injected to the magnetic field. By measuring the ion-cyclotron frequency, which was inversely proportional to the ion mass, a very high-resolution mass spectrum can be obtained.

The high mass-resolution was demonstrated for positive mass spectra of silicon, carbon, and metal-carbon binary clusters and negative mass spectra of metal-carbon binary clusters. For bare carbon positive clusters, we found the special condition where the odd-numbered clusters were observed in the range of C_{30} to C_{50} and the continuous change to C_{60}-dominant condition and 'normal' even-numbered distribution.

An example of mass spectrum measured by the direct-injection FT-ICR apparatus is shown in Fig. 1. Here, a graphite sample with about 1 % of Sc, which is the typical composition used for macroscopic metal-containing fullerene, was vaporized by the 2nd harmonics of Nd: YAG laser and the positive clusters were trapped and analyzed by the FT-ICR spectrometer. If we ignore the metal-composite clusters, the distribution of bare carbon clusters was almost the same as typical pure carbon clusters. One the other hand, almost all of Sc-carbon composite clusters had only one Sc atom and even number of carbon atoms: ScC_{2n} in the range of $36 \le 2n \le 76$, with special magic numbers of ScC_{44}, ScC_{50}, ScC_{60}. These magic numbers were reproduced for La-C and Y-C binary clusters, even though the relative amount of bare carbon clusters were much less for La and Y.

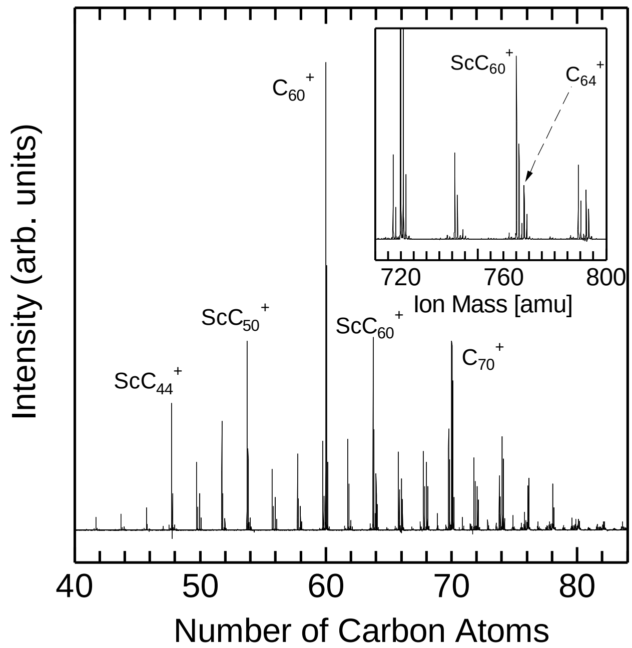

Fig.1　A FT-ICR mass spectrum of Sc carbon binary clusters generated by the cluster source.

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