New applications of arc discharge source

M. Chen, Z. Y. Zou, J. M. Huang, B. N. Ye, and W. G. Qian

Citation: Rev. Sci. Instrum. **65**, 1340 (1994); doi: 10.1063/1.1145004
View online: http://dx.doi.org/10.1063/1.1145004
View Table of Contents: http://rsi.aip.org/resource/1/RSINAK/v65/i4
Published by the American Institute of Physics.

New applications of arc discharge source

M. Chen, Z. Y. Zou, J. M. Huang, B. N. Ye, and W. G. Qian
Shanghai Institute of Nuclear Research, Academia Sinica, Shanghai 201800, People's Republic of China

(Presented on 1 September 1993)

We describe some details of the production of ^{57}Fe and C_{60} ions by the Nielsen source. Some application results are also given.

The arc discharge source (Nielsen source) is generally used on EMIS or other ion facilities. We have modified some parts and carefully chosen the discharge materials of the source for some new ion beam applications. All the parameters of the source can be telecontrolled and telemetered precisely by a microprocessor-based multichannel remote control system with optical fibers. High precision ($\pm 2\%$); good anti-interference ability; digital display; and mass calculating function are the features of the system.

An ion beam transport system which is matched to the source has wide ion energy range, accurate mass resolution, and excellent beam properties.[1] The source can provide numerous kinds of ions, including gas, metal, and molecular or compound state ions for different applications. Some typical results for those applications are given as the following:

(1) ^{57}Fe Mössbauer sample and nanocrystalline preparations by ion implantation:

^{57}Fe is one of the most usual and conveniently used isotopes to measure Mössbauer effects at room temperature. ^{57}Fe isotopes can be separated and implanted into a given sample by the isotope separation, then one can measure the Mössbauer spectrum of the interconverted electron (or x, γ rays) emitted from the excited iron atoms in the sample. This is the new Mössbauer experimental technology which was developed in recent years. Because ^{57}Fe can be implanted into the samples which did not contain the Mössbauer nuclide and the undamaged measurement could be carried out, the application fields of the Mössbauer effect could be extended. Because this EMIS system has large mass dispersion and resolving power, for example, $D_{m\perp} = 2.7$ cm for $^{56}Fe^+$, $^{57}Fe^+$, we can easily separate ^{57}Fe from other Fe isotopes and implant it into Cu, Si, or SiO_2 substrates to prepare Mössbauer samples.

In the preparations, we did not use the expensive and enriched ^{57}Fe isotope but the natural iron chemical compound $FeCl_2 \cdot 4H_2O$. Because the chloride contains some crystalline water, we should take some steps to eliminate the water from the chloride at a certain temperature of the source before the separation. About 1 μA $^{57}Fe^+$ (natural abundance is 2.19%) ion current after separation could be collected on the target. Generally, the ion dose is $\sim 5\times 10^{16}$–1×10^{17} $^{57}Fe^+/cm^2$, and the preparation time for one sample is about 3 h. A LN cold trap was used before the target to eliminate the contamination of carbon atoms in the system and good results were obtained. An electroscanning system was used to make a homogeneous ion dose distribution. Experiments proved: the separation efficiency is relatively high, the implantation homogeneity is good. The samples prepared by the way mentioned above, were successfully used in practical Mössbauer effect research. This is also a novel method, by using an ion implantation and subsequent heat treatment, to prepare Fe nanocrystalline in SiO_2. The formation process of Fe granules was monitored by means of the conversion electron Mössbauer spectroscopy and the size of which was determined by TEM.[2] For example, the SiO_2 with an area of 10 mm diameter was implanted by $^{57}Fe^+$. The dose and energy of the ions were 5×10^{16} atoms/cm^2 and 60 keV, respectively. After annealing treatment of the Fe–SiO_2 system, the iron atoms could be precipitated in the substrates. A typical TEM micrograph is shown in Fig. 1, where the iron granules are clearly displayed and the particles are separated and have a size distribution. An average size estimated is about 25 nm. Figure 2 is the magnetic hysteresis loop of a Fe–SiO_2 system with the same condition as in Fig. 1. The coercive force (H_c) of the system is two orders of magnitude higher than the value ($<0.8\ O_s$) of the normal bulk α-Fe and has an unusual relation with the temperature compared with the normal α-Fe.[2]

(2). C_{60} cluster ion production and mass spectrum analysis of C_{60} cluster series:

C_{60} which was discovered in recent years is the third isomer of pure carbon besides graphite and diamond, so-called soccer-ball-shaped C_{60} molecules (fullerene). C_{60} series, not only in superconductive material preparations but also in electronics and new chemical compound synthetizing have an immeasurable applied future. Because this facility has large mass resolving power (RP) and great mass-energy product (ME=39.0 amu MeV), we can use it for

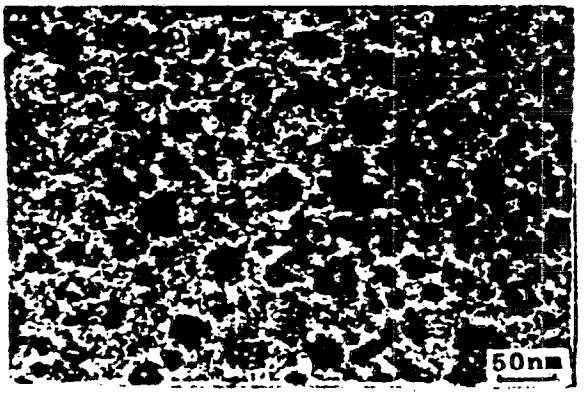

FIG. 1. TEM micrograph of a SiO_2 sample with an energy of 60 keV and a dose of 5×10^{16} Fe/cm^2 implanted after annealing at 650 °C for 90 min.

 0034-6748/94/65(4)/1340/2/$6.00

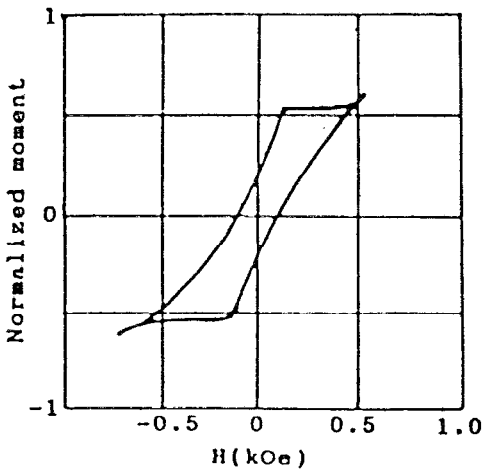

FIG. 2. Magnetic hysteresis loop of a Fe–SiO_2 sample with a same condition as in Fig. 1.

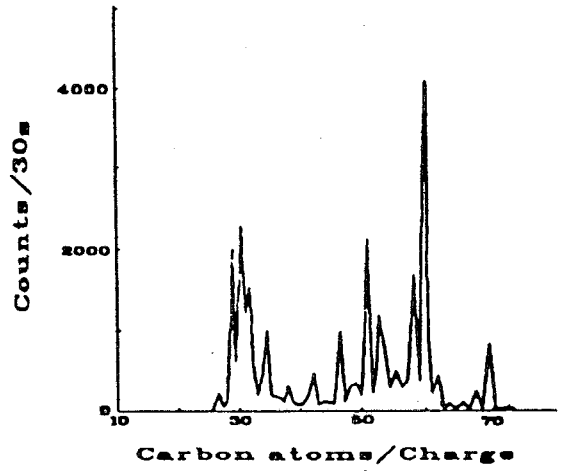

FIG. 3. Mass spectroscopy of C_{60} cluster series.

mass separation of large molecular ($M \geqslant 720$) series. If a postdeceleration system is matched to the facility, it could be used to prepare C_{60} films by ion deposition or make special electronic or optical devices by C_{60}^+ ion implantation. Using the high mass *RP*, EMIS and very sensitive MCP detector (microchannel electron multiplier), we have obtained the first mass spectrum of C_{60} cluster series by this electromagnetic analyzing method. And then about 1.6×10^{-12} A pure C_{60}^+ ion current was obtained at a source temperature $\sim$400 °C. The soccer-ball-shaped C_{60} molecular arrangement on the optical glass surface was observed with SEM (scanning electron microscope) at C_{60}^+ dose $\sim1.05\times10^{10}/cm^2$. Figure 3 is the spectrum of C_{60}, C_{70} mixed samples which were chemically purified. The optimum yield for a certain mass is strongly related to the discharge temperature of the source and the ionization potential of the charge material. This is a direct way for C_{60} series mass spectrum analysis and it could be used to provide an effective way for C_{60} film preparation and C_{60}^+ ion implantation.

[1] M. Chen and Z. Y. Zou *et al.*, Ann. Rep. SINR **10**, 72 (1990); **11**, 82 (1991).
[2] G. L. Zhang *et al.*, Appl. Phys. Lett. **61**, 2527 (1992).