Carbon Cluster output of Cesium-Sputtering Ion Sources with Modified Cathode Geometries

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The dependence of conical-angled graphite geometries on the carbon-cluster output from a Source of Negative Ions by Cesium Sputtering (SNICS) has been investigated. Seven different cathode geometries have been studied and it is reported that cluster ion output currents are independent of the geometry of the cathode in contrast to results reported by others.

1. Introduction

The surface impact and the implantation of cluster ions into materials are significantly different from those for monomer ions of the same element species and impact energy [1]. Surface sputtering with cluster ions can be drastically different than with monomer ions. The sputtering yield can reach two hundred molecules per impacting carbon cluster ion, which is two orders of magnitude higher than the sputtering yield obtained with carbon monomer irradiations at the same energy per atom [2]. The greater erosion ability of cluster ions has also been used for smoothing of surfaces [3, 4]. For the same ion beam current, ion charge and implantation time many more atoms can be implanted via cluster implantation than with monomer implantation. Importantly, more shallow implantations can be achieved with cluster ions than with the corresponding monomer at the same bombarding energy, since the energy deposition per implanted atom is reduced. This is relevant in the fabrication of ultra-shallow transistor junctions with nanometer dimensions, where the implantation energy of typical doping atoms, such as boron, has to be of the order of 1 keV or smaller [5].

In previous studies [6, 7, 8, 9, 10] the output of carbon-cluster ions by cesium sputtering sources has been studied using the SNICS designed by NEC. Both high density graphite powder and solid graphite rod was used as a cathode. Wang *et al.* [6, 10, 11] have extended this work by reporting that the ion current for C_n^- (and B_n^- clusters ions) ($1 < n < 11$) depends strongly on the opening angle θ of the conical recess. Their results suggest that a flat surface of the graphite results in significantly lower C_n^- output currents, when compared to cathodes with a conical recess with an opening angle of $\theta = 90^o$. This difference amounts to about an order of magnitude for carbon clusters, when the respective C_1^- monomer currents are normalized, i.e. the effect of the cathode recess is isolated.

The mean value of the previously reported [7, 8, 9] carbon negative ionic output currents for solid graphite cathode from SNICS are compared with the measured output currents from Wang *et al.* for different graphite cathode geometries [6] in Fig. 1. In order to exclude the effects of different operating parameters, the outputs have been normalized according to C_1 monomer current. The comparison, reveals that the Wang *et al.* 90^o conical geometry matches the mean of all the previous published data for solid graphite cathode whereas the other two geometries give very low output currents. Based on this comparison both the previous results and the odd-even effect are questioned:

(i) The $\theta = 0^o$ cathode is measured up to an order of magnitude smaller by Wang *et al.* [6] than previously reported [7, 8, 9].

(ii) The odd-even staggering of the output currents measured previously is not reported for n = 4, 8 for θ = 0°, 120° by Wang *et al.* [6].

(iii} The larger opening angle cathode (θ = 120°) produces currents smaller or equal to a flat cathode surface [6].

In order to produce larger clusters from a negative ion source and to understand the mechanism of their production and the effect of a recess or a conical cavity in the cathode, we investigated the effects of different cathode geometries on the production of clusters.

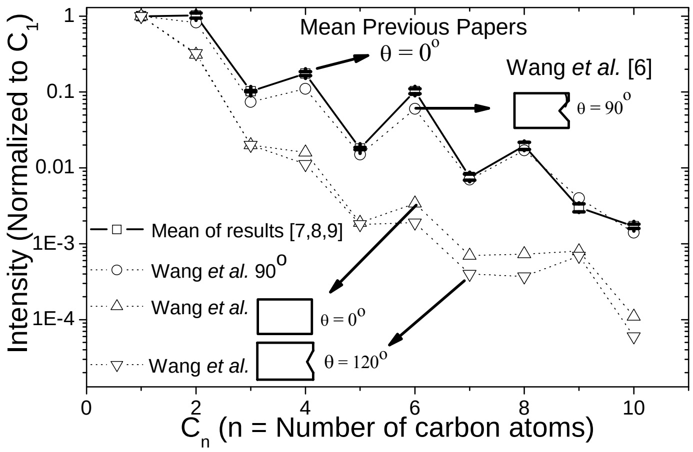

Fig. 1. Mean value of measured carbon cluster currents for solid graphite cathodes [7, 8, 9] compared with results by Wang *et al.* [6] results for three different cathode geometries including conical recess with opening angle of θ = 90° and θ = 120°.

2. Experimental Details

The schematic diagram of the ion implanter is shown in fig. 2. A SNICS source manufactured by National Electrostatics Corporation (NEC) is used to produce negative carbon-cluster ions. Solid graphite is sputtered by 5 keV Cs^+ ions and the resulting negative species is extracted by applying an extraction voltage of 15 keV. The extracted beam is accelerated to 100 keV and then passes through the first 3×3mm² slits which are located before Faraday Cup 1 to measure the output current of the beam. A set of quadrupole magnets is used for focusing the beam whereas a dipole magnet located between the two quadrupole magnets is used for the mass selection and transporting selected ions to Faraday cup 2. The cluster ion current is measured from the Faraday cup 2 which is located after the second 3×3 mm² slits.

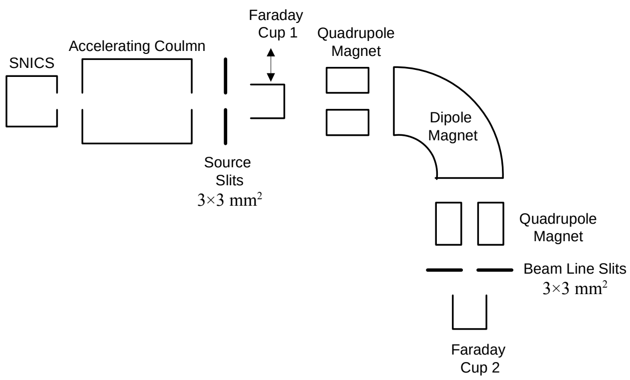

Fig. 2 Schematic diagrams of 150 KeV ion implanter and SNICS ion source.

Various geometries of solid graphite cathodes were used in which the cone angle varied from 20° to 120° plane geometry. A solid graphite cathode and a hollow graphite cathode were also used in addition to the conical geometries. Fig. 3 shows the geometries of all graphite cathodes used in which "θ" is the cone angle of the graphite. All these graphite geometries were used under the same conditions and the monomer as well as cluster output currents was measured from Faraday cup.

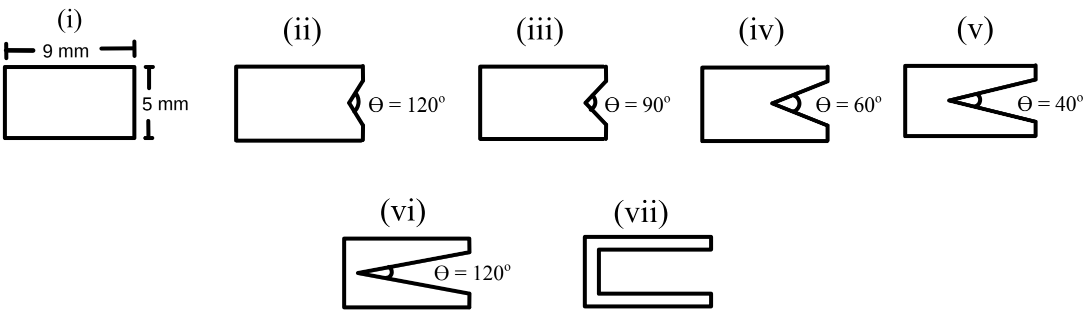

Fig. 3. Cross sectional drawings of the different graphite cathodes geometries studied in this work.

3. Results

In our experiments we measured the output currents from all the geometries given in Fig. 4. Before installing the graphite cathodes in SNICS they were backed for 24 hours in an electric oven at 100º C to eliminate moisture and minimize the effect of any adsorbed gases in the graphite. The vacuum during the running of each source was kept at ~ 10^{-6} mbar. A typical mass spectrum is shown in Fig. 4. It is obvious that odd numbered carbon clusters are less intense than even numbered clusters, in agreement with the earlier results [6, 7, 8, 9].

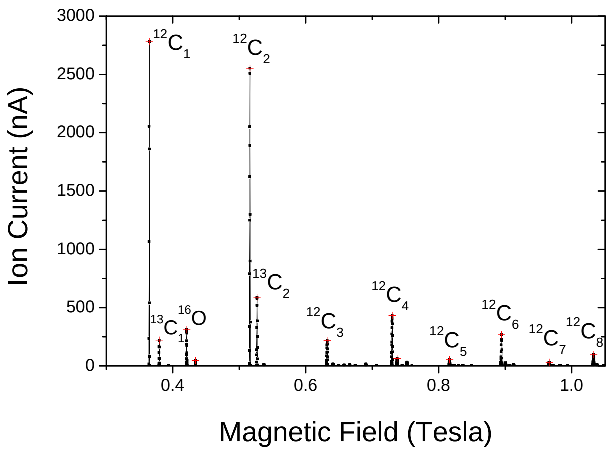

Fig. 4. A typical mass spectrum of carbon monomer and clusters from SNICS ion source. (The small peaks in the mass spectra are likely the clusters including ^{13}C).

In order to minimize the effect of changes in cathodes geometries after using in SNICS the operating time of each graphite cathode was limited to 3 hours and output currents were measured twice during the time in which the cathodes were used in SNICS. The comparison between our results for all graphite geometries and Wang *et al.* [6] results are shown in Fig. 5. Mean value of our initial and repeated data of the normalized output currents for all the seven graphite geometries used has been plotted against Wang *et al.* results [6]. Wang *et al.* 90º conical angle solid graphite geometry, which gave the maximum output, lies in the range of our mean data for all the geometries whereas the other two geometries give lower intensities.

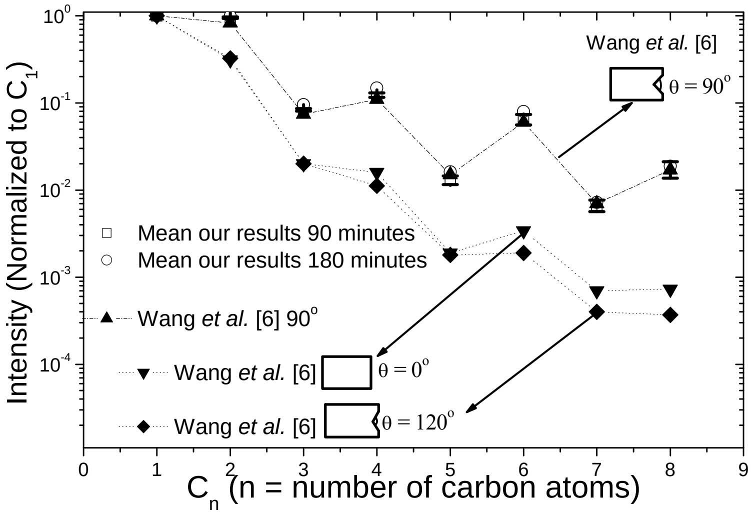

Fig. 5. Comparison of our data of all graphite cathodes with the Wang *et al.* data [6].

4. Conclusions

A possible dependence of the cathode geometry on cluster-ion output from a negative ion source has been studied. After using different graphite cathodes for three hours in the ion source no considerable increase in the cluster output was observed. On comparing our data with previously published results revealed no difference in clusters ion output currents. Our study of graphite cathodes with different geometries reveal that the shape of the cathode does not affect the cluster-ion current. Data from all the geometries gave almost same cluster-ion output.

Acknowledgements

The author would like to thank H. Timmers and L.G. Gladkis for their various contributions to this work and W.D. Hutchison for proof reading.

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