274
doi:10.1017/S1431927617002057

Microsc. Microanal. 23 (Suppl 1), 2017

Comparison of Characteristics of Neon, Argon, and Krypton Ion Emissions from Gas Field Ionization Source with Single Atom Tip

Hiroyasu Shichi[1], Shinichi Matsubara[1] and Tomihiro Hashizume[1]

[1.] Research & Development Group, Hitachi, Ltd., Kokubunji, Tokyo, Japan

A scanning ion beam instrument equipped with a gas field ionization source (GFIS) has been developed and commercialized using helium and neon ions [1]. Helium ions have been used mainly for observation, while neon ions have been mainly used for fabrication. The GFIS can emit different ion species by changing its ionization gas, but other noble gas ion species have not been used commercially yet. Heavier noble gases than neon are expected to be suitable for faster fabrication because the sputtering yields of heavier noble gas ions are higher than that of neon ions. On the other hand, the ion currents from a GFIS become larger at lower ion emitter temperatures. Although xenon gas is the heaviest, its boiling point of about 165 K is so high that large ion currents are not expected. In this study, the characteristics of neon, argon, and krypton ion emissions from a GFIS were investigated and compared from the viewpoint of practical fabrication.

The instrument for characterization of ion emissions from a GFIS is a field ion microscope (FIM) that has been developed for this study. The FIM is equipped with a double cold-stage Gifford-McMahon (GM) refrigerator. The first cold stage of the GM refrigerator is connected to a radiation shield, and the second cold stage is connected to an ion emitter tip holder. The tip can be cooled down to about 24 K with the GM refrigerator. Two sets of temperature controllers with ceramic heaters were installed at the first and second cold stages. The temperatures of the radiation shield and the tip holder can be set independently. A single-crystal tungsten wire was used as the ion emitter material. First, the tungsten wire was electrochemically etched; then the emitter tip was etched to a single atom tip in the FIM chamber using a nitrogen gas etching method [2]. The ionization gas, namely neon, argon, or krypton, was introduced into the vacuum chamber individually. The appropriate voltage required for field ionization was then applied to the tip. The ion emission patterns were observed on a multichannel plate (MCP), and the ion emission currents were detected with a Faraday cup. The emission currents were measured at various temperatures, gas pressures, and ion extraction voltages. The ion emission characteristics were thus investigated and compared.

Figure 1 shows the current-voltage characteristics of the neon, argon, and krypton ion emission at a gas pressure of 0.03 Pa. The neon ion emission was stable and maximum at 30 K. The neon ion emission current reached approximately 400 pA at 30 K, which was two orders of magnitude higher than that at about 200 K. The krypton ion emission was maximum at 40 pA at 65 K, which was one order of magnitude lower than that of neon. The current-voltage characteristics of argon were between those of neon and krypton. Figure 2 shows the pressure dependence of the neon, argon, and krypton ion currents. The temperatures were set so that the maximum ion emission currents were obtained at the fixed gas pressures. As the pressure was increased, the ion currents increased for all the ion species. At a gas pressure of 0.06 Pa, the maximum ion current is about 600 pA for neon ions. Table 1 shows a comparison of the characteristics of neon, argon, and krypton. By comparing the values obtained by multiplying the emission current by the sputtering yield, we found that the value for argon is highest. This means that argon ions are expected to be suitable for faster fabrication. On the other hand, the layer damaged by krypton ions in a sample is expected to be much thinner than when using neon or argon ions, and the well-known problem of creating noble gas bubbles in a sample can be suppressed by using krypton ions. We conclude that the argon or krypton GFIS ion beam instrument will be an attractive tool for nanofabrication [3].

References:

[1] B. W. Ward, John A. Notte, and N. P. Economou, J. Vac. Sci. Technol. **24** (2006), p. 2871.
[2] M. Rezeq, J. Pitters, and R. Wolkow, J. Chem. Phys. **124** (2006), p. 204716.

[3] We thank Dr. Y. Sugiyama and Mr. Y. Kawanami of Hitachi High-Tech Science Corporation for our valuable discussions. This research was supported by Hitachi High-Tech Science Corporation.

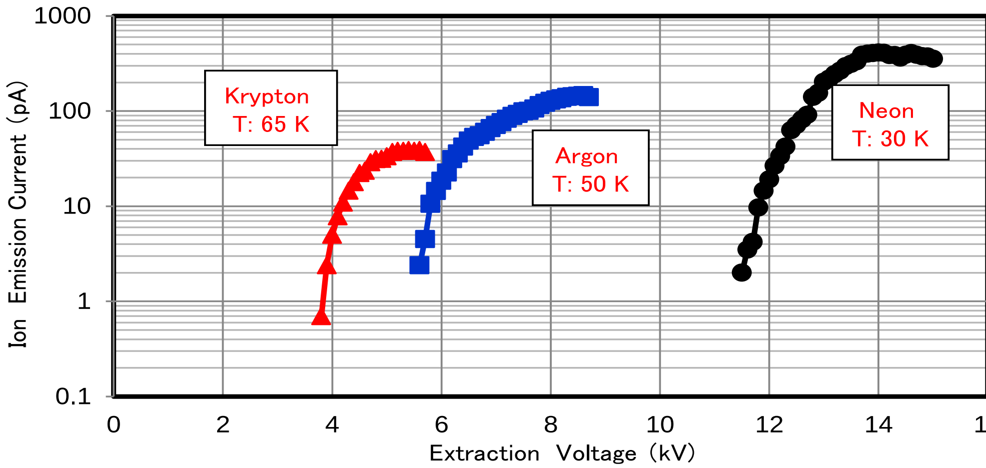

Figure 1. Current-voltage characteristics of neon, argon, and krypton.

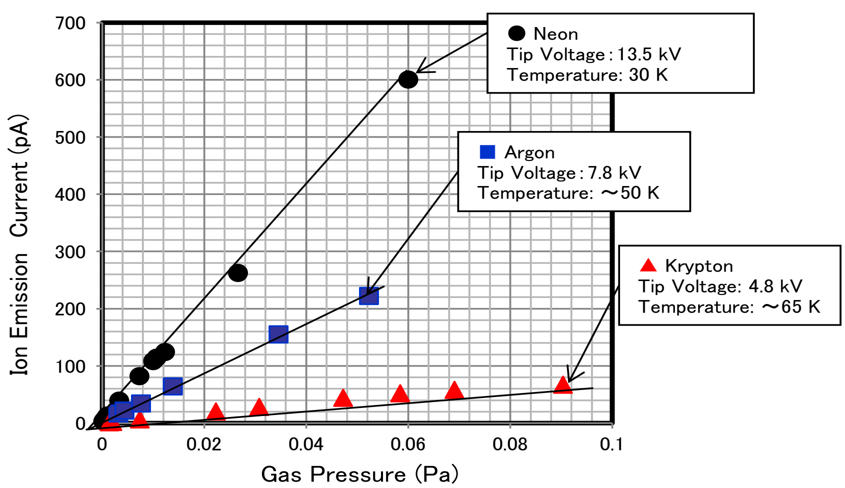

Figure 2. Ion emission current versus gas pressure of neon, argon and krypton.

Table 1. Comparison of characteristics of neon, argon, and krypton for GFIS.

	Boiling Point (K)	Atomic Weight	Tip Temperature for Maximum Current (K)	Maximum Current (nA/Pa)	Sputtering Yield (Si/10 kV)	Maximum Current x Sputtering Yield
Neon	27	20	30	10	0.6	6.0
Argon	87	40	50	4.4	1.5	6.6
Krypton	120	84	65	0.8	2	1.6

https://doi.org/10.1017/S1431927617002057 Published online by Cambridge University Press