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Ignition Characteristics Relating with Shape of Floating Electrode in Micro ICP source
マイクロ誘導結合プラズマ源に導入した浮遊電極の形状と点火特性

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The micro-plasma can generate the local high-density plasma without using the vacuum system. MEMS technique will be applied for realizing the small plasma source. Inductively coupled plasma (ICP) is suitable, since its density is higher using the small number of elements. The difficulty is the ignition. We have reported that the floating electrode can enhance the ignition. Some electrode shapes in 2-different setups are examined with the feasibility of the combination with MEMS structures.

1. Introduction

Micro-plasma source is expected to match with MEMS devices since the atmospheric pressure decreases the characteristic length down to μm level. In addition, saving power and gas consumptions are also expected. Among many plasma setups, ICP is attractive since it can generate higher plasma density using the fewer number of elements. However, the ignition of ICP is troublesome. We have first reported that the ignition can be easier by introducing the floating electrode using a prototype setup of the glass epoxy substrate with the milled gas channel [1]. Although the effect of the floating electrode is clear, there are many unknown factors especially for introducing this technique in MEMS devices.

In this study, two different plasma setups with MEMS elements are examined especially relating to the floating electrode.

2. Experimental setups

Two different ICP setups are tried using 100MHz power source. The magnetic field occurs around the current path. The floating wire electrode receives this field and the inductively generated voltage is considered to triger the ignition. Figure 1(a) is the planer type. ICP coil is U-shaped one-turn coil. The center region is the trench of the gas channel, inside which MEMS floating electrode is introduced. Figure 1(b) is the tube type. The spiral coil is combined with the gas tube. The floating wire is place near to the spiral coil. The capillary and the floating wire are integrated to one MEMS element.

3. Devices

Figure 2 shows the fabricated floating electrode for the setup of Fig. 1(a). The original Si wafer is

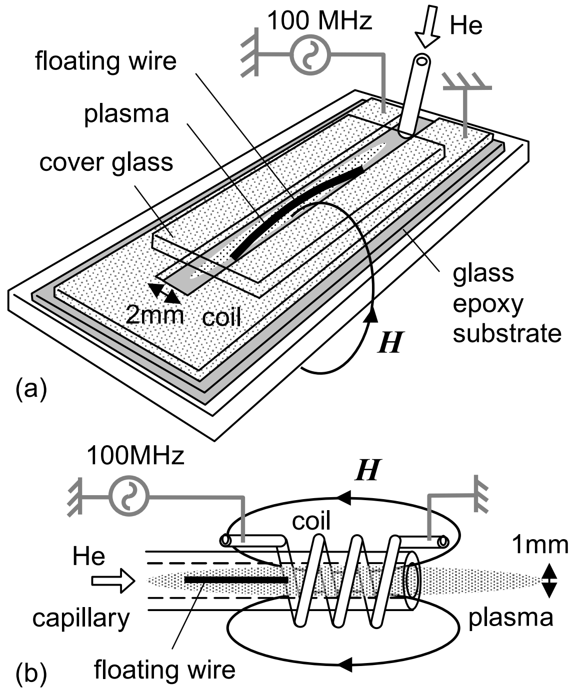

Fig. 1: Schematic drawing of setups for generating micro plasma. (a) Planer-type using U-shaped ICP coil. (b) Tube type using spiral ICP coil.

200-μm thick, and the through Si etching is carried out for the fabrication. The structures are 20-μm wide beams. About 900 nm-thick Al is deposited on Si for the electrical conduction. 18 different shapes are prepared being connected to thick Si frame. The electrode shape can be grouped with C-shape, spiral, and loop with bow-tie (two triangular tips facing each other). C-shaped electrode is neither stably obtained nor mechanically handled.

Figure 3 shows the device chip for the setup of Fig. 1(b) integrating the floating wire and the capillary tube. The size is 8x3 mm^2. The center

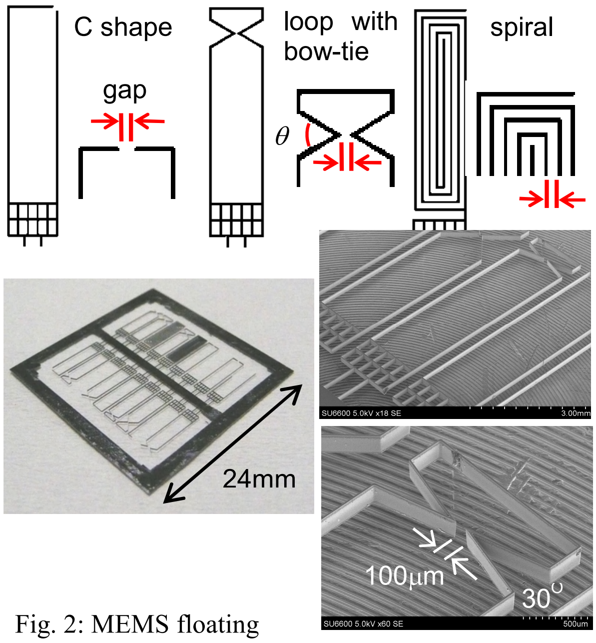

Fig. 2: MEMS floating electrodes for setting inside U-shaped coil in Fig. 1(a). The magnified image is the loop with bow-tie.

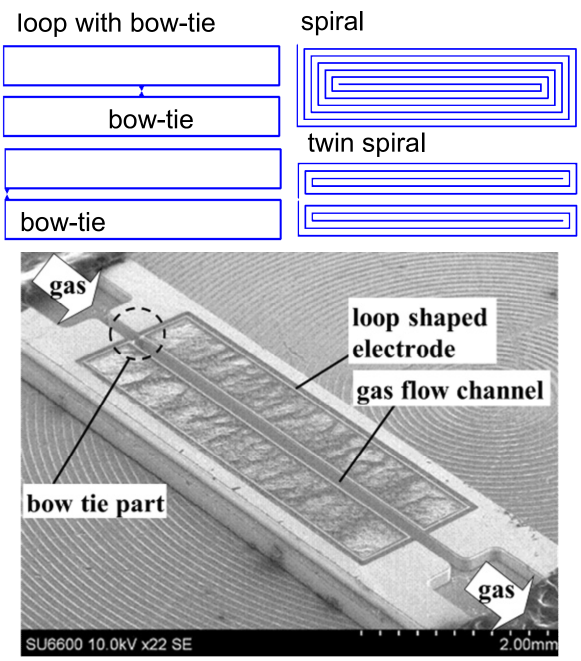

Fig. 3: MEMS device of the floating electrode integrated with the gas flow channel.

trench is the gas flow channel. The floating electrode is Al film pattern on the top surface faced to the gas channel. 8 different electrode shapes are designed. The floating electrode is grouped by loop with bow-tie and spiral. The bow-tie positions are at the center or the end of the loop.

4. Results

Figure 4 shows the ignition power using the electrode as shown in Fig. 2. The ignition power

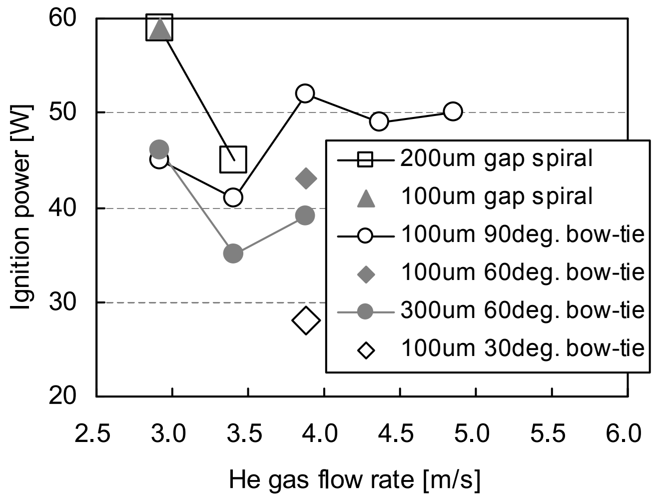

Fig. 4: Ignition power against 6 different electrodes changing He gas flow rate.

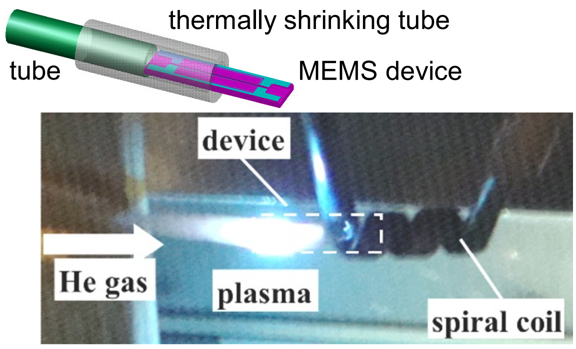

Fig. 5: Photo of the ignition. The ignition point is considered at the bow-tie.

has the dependence on He gas flow rate having its valley at about 3.5 m/s. The spiral electrode shows the higher ignition power compared with the loop electrode with the bow-tie. The minimum value in our experiment is 28 W. The gap between bow-tie is 100 μm and the cone angle is 30^{O}.

Figure 5 shows the photo of the ignition using the electrode shown in Fig. 3. The ignition is obtained only for the loop electrode with the bow-tie. The bow-tie is at the end of the loop at the upstream of the gas flow. The gap between bow-tie is 90 μm and the cone angle is 60^{O}. The ignition power is 138 W. He gas flow is 49 ml/min. The average gas flow speed is similar to that of Fig. 4.

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References

[1] S. Kumagai, H. Matsuyama, Y. Yokoyama, M. Hori, M. Sasaki, Jpn. J. Appl. Phys. **50** (2011) 08JA02.