Nanotip-Enhanced Microplasma Devices

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***Abstract*—Nanotip-enhanced microplasma devices have been successfully fabricated and operated with neon gas at room temperature. The panel-type microplasma device included nanotip and metal electrodes on the rear panel, which provided low discharge voltage, strong emission, and stable discharge phenomena. The nanotip with a radius below 10 nm enhances the electrical field distribution density. The electrical properties of neon discharges have been examined with pulsed waveforms from 2 to 20 kHz in neon with pressures from 4×10^4 to 10^5 Pa.**

***Index Terms*—Microdischarge, nanotips.**

OVER THE past few years, microplasma phenomena had been investigated in microcavity-plasma and glow-discharge devices, [1]. Microplasma devices are providing a great deal of interest for possible applications such as liquid crystal display backlighting, emitters, and molecular emission detectors [2]–[4]. There are some disadvantages in the existing microcavity-plasma devices including lifetime limitation.

In this paper, we investigate a nanotip-enhanced microplasma device with panel-type geometry. The devices have been fabricated by conventional photolithographic techniques and wet chemical processes. The nanotip was manufactured with a tip radius below 10 nm with a 30-nm-thick coated aluminum layer. The nanotip is attached on the rear panel to enhance the local strength of the electrical field. The advantages of the nanotip-enhanced microplasma devices are high resolution patterns with nanotips, low discharge voltage, long life time, strong emission, and stable discharge phenomena. The indium tin oxide (ITO) transparent electrodes on the front glass have been fabricated by conventional photolithographic techniques and wet etching processes with a mixture of $HCl/HNO_3/H_2O$. The thickness and the sheet resistance of the ITO electrode are 1 nm and 150 Ω/Υ, respectively. Sputtering deposition was used to deposit the chromium (Cr) electrode. The nanotip was attached on the chromium electrode with silver paste (4922N, DuPont). After sealing, the devices were evacuated to less than 1.33×10^{-5} Pa by a turbomolecular pump (Leybold Vacuum) and then backfilled with a research vacuum grade of neon gas from 4×10^4 to 1.066×10^5 Pa. The electrical properties of the device were examined in neon gas. A dc-pulsed excitation waveform, having a duty ratio of 20%, was applied at frequencies from 2 to 20 kHz between the ITO and metal electrodes by a pulse dc-power controller (SPIK 2000A, SHENCHANG ELECTRIC CO., LTD). The charge-coupled-device (CCD) images and photographs were acquired by an optical magnification system (Navitar, Inc.).

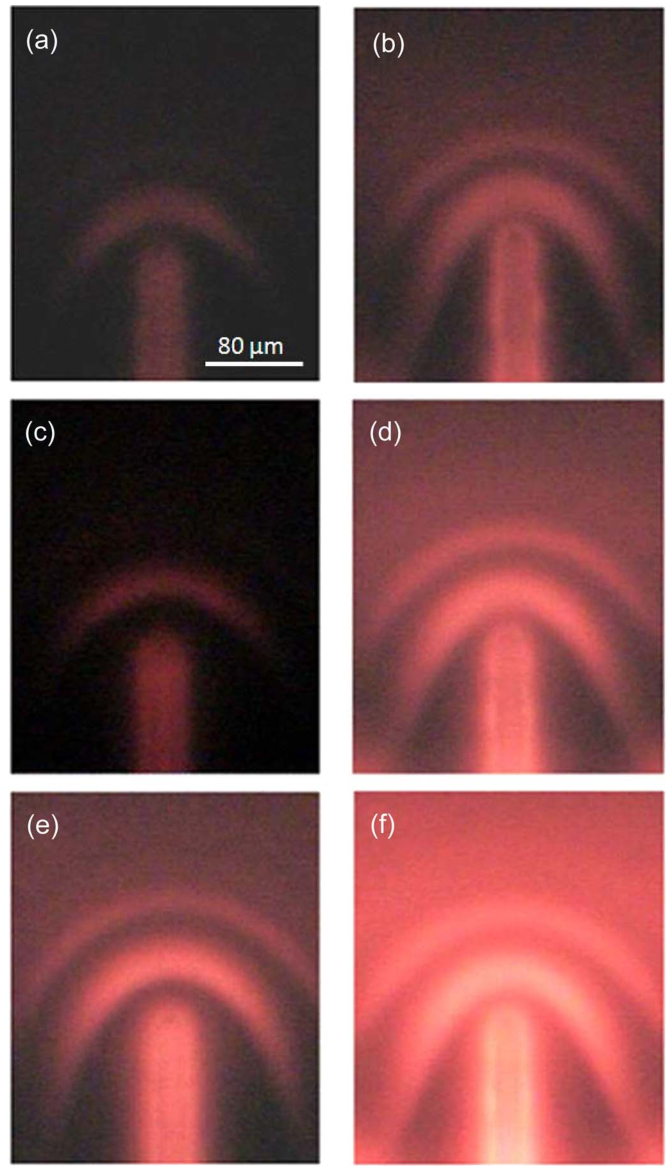

Fig. 1. CCD images of the glow discharge for the device operating under 400-torr neon gas at (a) 20 kHz, 300 V; (b) 20 kHz, 600 V; (c) 10 kHz, 280 V; (d) 10 kHz, 600 V; (e) 4 kHz, 400 V; and (f) 4 kHz, 600 V.

Fig. 1 shows the images of the device operation in neon gas with excitation frequencies of 2, 4, 10, and 20 kHz for a pressure of 5.3×10^4 Pa. The nanotip microplasma devices show

Manuscript received September 19, 2007; revised February 13, 2008. This work was supported in part by the Ministry of Economic Affairs, Technology Development Program for Academia, The Republic of China, under Contract 96-EC-17-07-S1-046 and in part by the National Science Council under Contract NSC96-2221-E009-079-MY3.

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Digital Object Identifier 10.1109/TPS.2008.922941

abnormal glow-discharge properties discharge voltages were possible due to the local electrical field distribution density being enhanced by the nanotips. The field emission on the nanotips decreases the operating voltage by about 200 V. The simple fabrication of the devices is an obvious advantage to procure the larger area panel-type nanotip-enhanced microplasma devices.

The nanotip-enhanced microplasma device technology provides advantages, which are discharge voltage, long life time ($> 50\,000$ hrs), brightness (7 500 lm), efficiency (35 to 44 lm/W) and high resolution patterns.

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