Diamond-Shaped Microplasma Device Using Thick Photoresist as a Barrier Rib in Ne–Ar Gas Mixtures

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***Abstract*—The discharge characteristics of the diamond-shaped microplasma devices with pure neon, neon–1% argon, and neon–5% argon gas mixtures are investigated. The 5 × 5 arrays of diamond-shaped microplasma devices operating at pressures from 300 to 800 torr have been characterized. The diamond-shaped microplasma devices, offer advantages such as having a high yield process, low ignition voltage, stable glow discharge, and low cost. The electrical properties of neon discharges have been examined with different argon fractions. The diamond-shaped microplasma device operates at voltages as low as 190 V, at 800 torr.**

***Index Terms*—Glow discharge, microdischarge.**

FOR THE past few years, microplasma devices have been investigated because of their unique electrical and optical properties [1]–[5]. Much of the interest in microplasma devices stems from generating efficient vacuum ultraviolet to visible radiation. However, current fabrication processes for have not produced stable glow discharges and long lifetimes in large-size panels. Recently, microelectromechanical system (MEMS) processing technologies have addressed these issues. The reduction of the dimensions of conventional plasma devices afforded by MEMS, could be the solution for sequential driving liquid crystal display backlighting, high resolution plasma display panels, environmental sensors, lighting systems, and biomedical systems.

In this paper, we present a report on diamond-shaped microplasma devices using thick photoresist to solve a difficult issue; misfiring between the photodefinable glass barrier rib and the electrode. This problem resulted from the barrier rib being attached on the electrode and substrate. The diamond-shaped microplasma devices, which use a thick photoresist (SU-8), have addressed this issue. The thick photoresist (SU-8) is spun on the substrate, and affords the opportunity of realizing any geometry and high-resolution patterns by lithographic techniques.

The diamond-shaped microplasma device is shown in Fig. 1. The cross-sectional image of the microplasma device was taken with a scanning electron microscope. The silicon wafer substrate has a 1-μm thermal oxide coating, which has been used as a buffer layer. The Cr-interdigitated electrodes are fabricated on the silicon dioxide by the liftoff process. The pitch between two electrodes is 20 μm. The thickness and width of the Cr electrode are 1000 Å and 15 μm, respectively. After depositing a dielectric layer (HfO_2) by an e-gun evaporator, the 75 μm thick photoresist serves as a barrier rib on the dielectric layer. The diamond-shaped pattern (50 μm) was realized by lithographic techniques. The vacuum chamber was pumped down to 2×10^{-6} torr by a turbomolecular pump and back filled with research vacuum grade of pure neon, neon–1% argon and neon–5% argon gas mixtures between

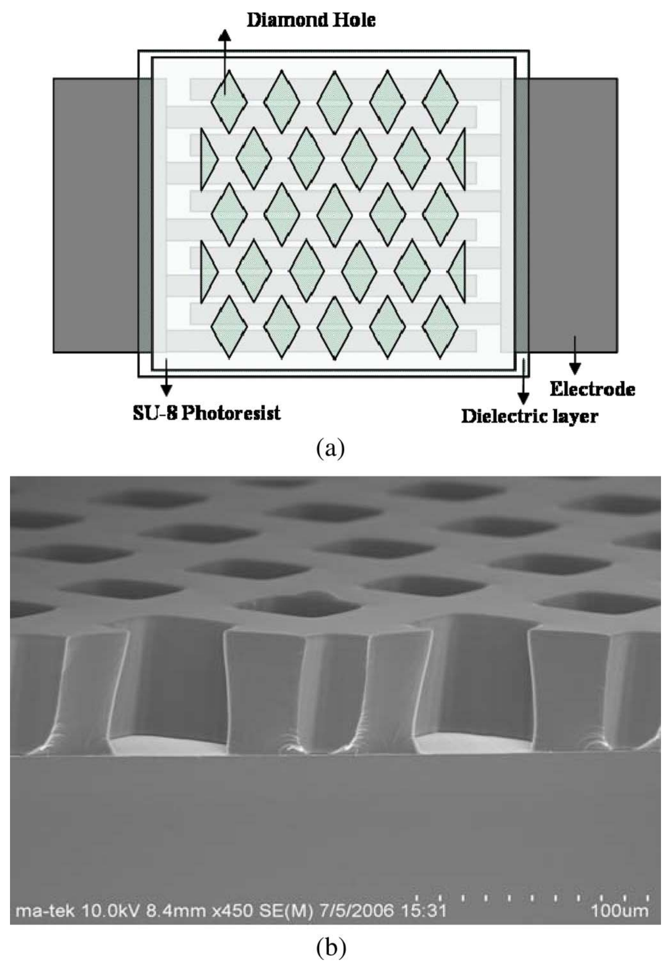

Fig. 1. Diamond-shaped microplasma device. (a) Schematic diagram of the top view. (b) SEM image of the cross section with a tilt angle.

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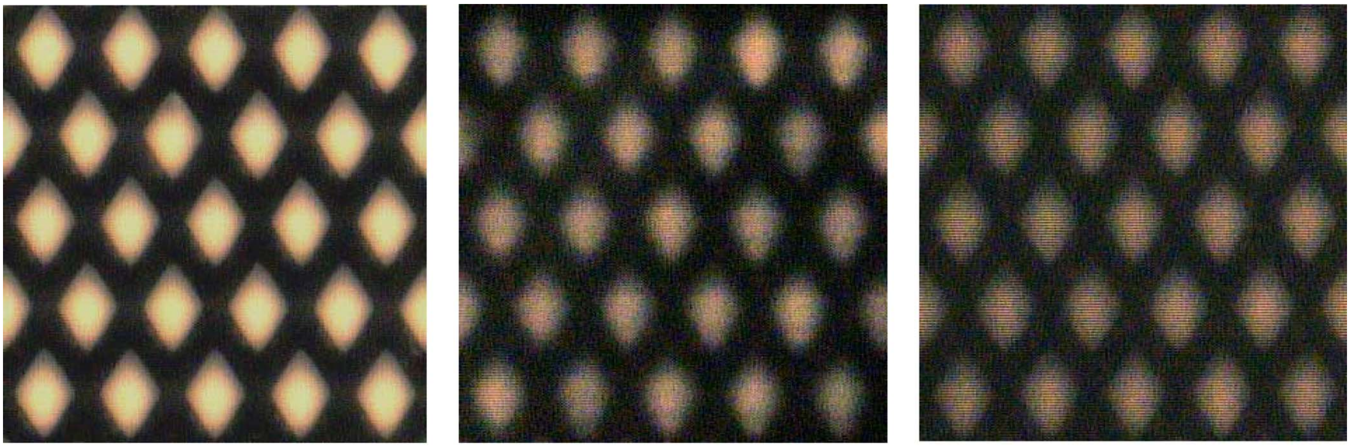

(a) (b) (c)

Fig. 2. Photograph of the 5 × 5 arrays of the microplasma device with a diamond structure operating at 300 torr of (a) neon gas, (b) neon–1% argon, and (c) neon–5% argon gas mixtures.

300 and 800 torr. The 10 kHz bipolar voltage waveform is applied between the Cr electrodes by a pulse dc power controller. The photographs of the microplasma device and glow image are captured by the optical measurement system (Navitar, Inc.).

The glow of the 5 × 5 arrays, which is shown in Fig. 2, is uniform and operates at 300 torr of neon gas. The driving voltage is 272 V and 10 kHz, respectively. Images are shown for Ne/Ar $= 100/0, 99/1$ and $95/5$. The diamond-shaped devices have provided stable plasmas in the diamond-shaped holes and solved a difficult issue, which is the misfiring of plasma between the glass barrier rib and substrate, of prior devices [5].

REFERENCES

[1] M. Kushner, "Modeling of microdischarge devices: Pyramidal structures," *J. Appl. Phys.*, vol. 95, no. 3, pp. 846–859, Feb. 2004.

[2] K. H. Becker, K. H. Schoenbach, and J. G. Eden, "Microplasmas and applications," *J. Phys. D, Appl. Phys.*, vol. 39, no. 3, pp. R55–R70, Feb. 2006.

[3] T. Callegari, F. Gegot, L. C. Pitchford, J. Galy, and J. P. Boeuf, "Experimental investigations of glow discharges in hollow cathode geometries at low pressure," *IEEE Trans. Plasma Sci.*, vol. 33, no. 2, pp. 384–385, Apr. 2005.

[4] S.-O. Kim and J. G. Eden, "Arrays of microplasma devices fabricated in photodefinable glass and excited AC or DC by interdigitated electrodes," *IEEE Photon. Technol. Lett.*, vol. 17, no. 7, pp. 1543–1545, Jul. 2005.

[5] S.-O. Kim and J. G. Eden, "Arrays of square cross-section microdischarge devices fabricated in glass and driven by interdigitated electrodes," *IEEE Trans. Plasma Sci.*, vol. 33, no. 2, pp. 566–567, Apr. 2005.