Transparent Plastic Microplasma Flexible Light Sources

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Introduction

Microplasma devices (MD) have been studied for many years [1] and have been designed for operation as the illumination source for plasma display panels since the mid-1960s [2]. In the intervening years, the materials, design, and manufacturing methods used for plasma displays have evolved to enable the high resolution, long lifetime, and high brightness microplasma arrays for Plasma Display Panels (PDPs) that are in common use today [3].

We report on the first microplasma devices with cavities that are fabricated on both rigid and flexible transparent substrates by a polymer-based replica molding process. The process enables accurate and inexpensive production of plasma pixels with dimensions an order of magnitude smaller than conventional plasma television pixels, large uniform pixel arrays, and channels of arbitrary shape. The replica molding process may be performed over large surface areas for applications including video display, heads-up displays, medical phototherapy, photopolymerization, and photonic circuit light sources.

Devices operate with linear current-voltage relationships and may be operated at pressures near 1 atm. We demonstrate the operation of microplasma pixels over a wide size range, pixel arrays comprising up to one million pixels, plasma channels with widths 20-200 μm, structures, a 1 m long plasma channel, and microplasma Fresnel lenses.

Design and Fabrication Approach

A cross section of a representative transparent MD array is shown in Fig. 1. The substrate is either a glass or a flexible polyester (PET) film coated with a conducting Indium Tin Oxide (ITO) film. The ITO forms the bottom electrode of the MD device. The pixels are defined within a layer of UV-curable polymer (UVCP) material using a replica molding process [4]. A dielectric material such as TiO_2, SiO_2 or MgO is coated onto UVCP to protect the polymer cavity from exposure to the plasma discharge, which may result in gradual degradation of MD performance. The dielectric material also reduces the rate of outgassing from the polymer into the sealed cavity. The upper electrode is provided by attachment of an ITO-coated cover substrate. Narrow channels are provided to enable backfilling with any desired gas for discharge.

The fabrication utilizes a silicon mold of the plasma cavities made by conventional photolithography and etching. To produce the MD pattern, liquid UVCP was squeezed between the silicon mold and substrate. The liquid polymer flows into the mold shape, and is exposed to high intensity UV light to cure the liquid material into a transparent solid. After curing, the silicon mold was released from the MD cavity replica. The cured polymer preferentially and permanently adheres to the substrate and the silicon mold can be used repeatedly. Dielectric barrier films were deposited by e-beam evaporation. Finally, the cover was attached with adhesive.

Device Characterization

To validate our MD design and fabrication process, a 20×20 element array of discharge cavities (see Fig. 2) was studied. Fig. 3 shows the device illuminated in front of a one dollar bill where the device operated at 340 V_{RMS} and the Ne gas pressure was 700 torr. The current-voltage characteristics of device filled with Ne is plotted in Fig. 4 for pressure between 400 and 700 torr. The developed method is capable of making devices with geometric patterns besides square microcavities. Fig. 5(a) demonstrates emission in a folded 100 μm wide, 1 meter long channel; and discharge emission in more complicated structures, i.e. arbitrary letters, is demonstrated in Fig. 5(b). The operation voltage was found to be dependent upon channel dimensions, where narrow channels required higher voltage for ignition. For structures containing more than one channel width, the applied voltage could be selected so as to only ignite plasma in the wide channel regions. This is demonstrated in Fig. 5(b), where the 200 μm wide letters are joined by 20 μm wide channels, only the letter regions illuminated with an operating voltage of 200 V_{RMS}.

0-7803-9556-5/06/$20.00

Reference

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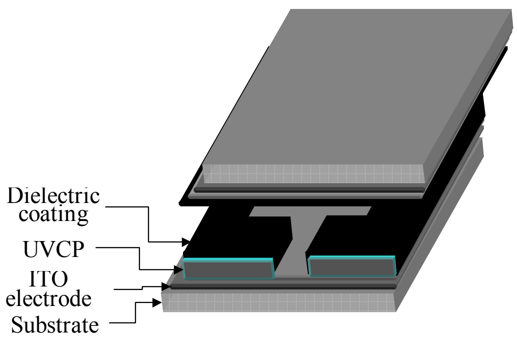


Fig 1. Generalized diagram of a discharge microcavity structure.

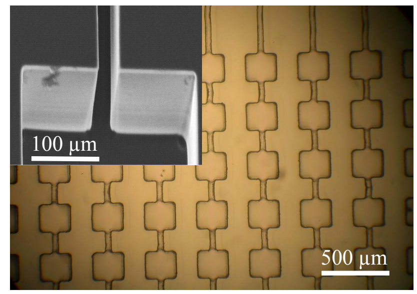


Fig 2. Optical micrograph of the 20×20 array. The cavities have 200×200 µm^2 cross section and the channels are 25 µm in width. SEM of the cross section of a single cavity with 76 µm is shown in the inset.

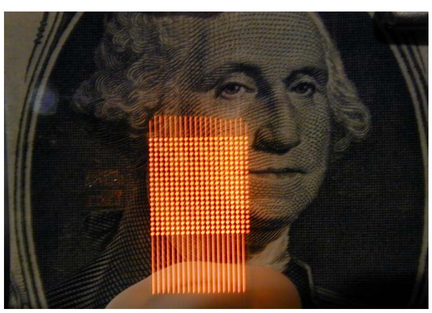


Fig 3. Photograph of a 20 × 20 array of cavities in front of a one dollar bill. The device operated at 340 V_{RMS} and the Ne gas pressure was 700 torr.

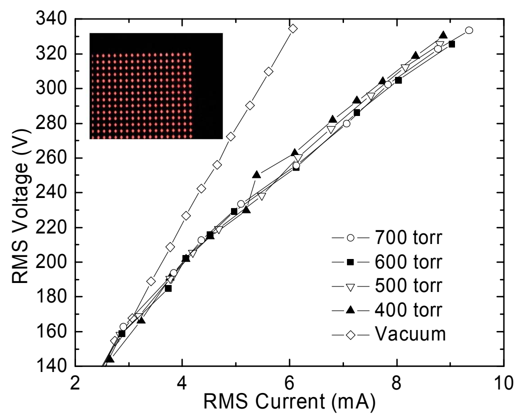
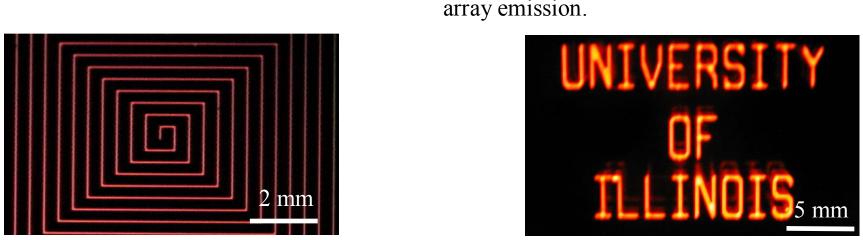


Fig 4. *I-V* characteristics for the 20×20 array of microcavities. Ne, pressures ranged from 400 to 700 torr and voltage increased from 140 to 340 V_{RMS}. The inset is a magnified view of a portion of the array emission.



(a) (b)

Fig 5. The microphotographies of different microdischarge structures. (a) Discharge in 20 µm channel array. (b) Discharge in folded 100 µm wide channels. The channel has a total length of 1 meter. Operation voltage is 248 V_{RMS} and the Ne pressure is 700 torr.