Arrays of microdischarge devices having 50–100μm square pyramidal Si anodes and screen cathodes


Microdischarge devices having (50–100μm)² pyramidal Si anodes and metal screen cathodes have been operated continuously at Ne gas pressures up to 1350Torr and voltages below 95V. More than 34μW of output power is produced by a single device in a solid angle of ~5 x 10⁻⁴sr for a Ne pressure of 500Torr. 3 x 3 arrays of these devices have been fabricated.

Although microdischarges were first investigated in 1959 by White [1], the fabrication of devices in Si was reported only recently [2, 3]. Since then, microdischarge devices and arrays in flexible, metal/polymer structures [4], the excitation of a microdischarge by a reverse-biased pn junction [5], and a multistage ceramic microdischarge device [6], have been demonstrated. The integration of microdischarge devices in Si is of particular interest, since the introduction of a plasma of mesoscopic dimensions into a microelectronics environment results in a hybrid discharge/solid state device offering exciting opportunities for displays, chemical sensors, and microlasers.

The fabrication and operation of arrays of microdischarge devices, having square Si inverted pyramid anodes with a cross-sectional area of (50–100μm)², and metal screen cathodes, are described in this Letter. Combining Si pyramidal and metal screen electrodes results in a reduction of a factor of almost three in device operating voltage, contrasted with previous devices [7], and an increase in radiant output power of an order of magnitude of approximately one. 3 x 3 arrays of these devices have been fabricated and stable glow discharges produced on a continuous wave basis at Ne pressures up to 1350Torr and voltages below 95V.

The fabrication procedure for the Si pyramidal anode(s) is similar to that described previously [7]. Briefly, inverted pyramidal microcavities, either 50 or 100μm square at the base and 35 or 70μm in depth, respectively, were produced in p-type, 300μm-thick, Si (100) substrates by anisotropic wet etching with KOH. After spin-coating a 7.5 to 8μm-thick film of polyimide onto the substrate, the polymer was cured at 300°C in an N₂ atmosphere, and a 0.15μm-thick Ni film was evaporated onto the polyimide. Channels, 50 or 100μm square, were then defined photolithographically with a Cr mask, and the polyimide in the pyramidal cavities was removed by etching in an O₂ plasma. Finally, a 17μm-thick Ni screen, having 22μm-wide hexagonal openings, was chemically bonded onto the surface of the device and the finished device or array was soft-baked for eight hours under vacuum. After evaporating the devices to a base pressure of ~10⁻⁷Torr, they were back-filled with research grade Ne. Absolute measurements of output power in the 300 to 800nm spectral region were made with a calibrated pin detector. Also, although the devices reported here operated well without ballast, I-V measurements were facilitated by inserting 207kΩ into the discharge driver circuitry.

Fig. 1 I-V characteristics for (50μm)² Si pyramidal microdischarge device having 8μm thick polyimide dielectric film and Ni screen cathode

Fig. 2 Comparison of radiant output power produced by (100μm)² Si pyramidal device when screen electrode serves either as cathode or anode

All data were obtained for p_Ne = 500Torr. The linear least-squares fit to the screen cathode data is shown. Also, vertical arrow associated with screen anode data denotes device failure in this region

Fig. 3 Optical micrographs of (50μm)² device operating in 1100Torr of Ne

Si pyramid is the anode
Operating conditions:
- 103.6V, 0.078mA
- 110.2V, 0.196mA
- 153.3V, 0.36mA

Fig. 4 Photographs of 3 x 3 array of (50μm)² Si pyramidal electrode devices showing the screen electrode, and of array operating in 700Torr of Ne (353V, 1.3mA)

Fig. 5 Photographs of 3 x 3 array operating in 700Torr of Ne

I-V characteristics for a (50μm)² device, in which the Si pyramid and the Ni screen serve as the anode and cathode, respectively, are shown in the lower right-hand portion of Fig. 1 for Ne gas pressures between 600 and 1350Torr. Operation of 50μm devices at pressures below 600Torr is unstable and the device is rapidly damaged by cathode sputtering. The highest pressure studied is presently limited by our vacuum and gas handling system. The device operating voltages of Fig. 1 (94–332V) are at least a factor of two smaller than those reported in [1] (260–370V) for devices having a Si pyramidal cathode and an Ni film anode.

If the polarity of the device is reversed (i.e. the screen serves as the anode), the I-V data displayed in the upper left-hand part of Fig. 1 are obtained. The operating voltages rise between 240 and ~330V (for p_Ne = 500–900Torr) and currents range from 0.3 to 8μA. Both sets of data in Fig. 1 exhibit positive differential resistance. On the basis of these results, we conclude that the screen electrode is primarily responsible for the steep decline in operating voltage and concomitant increase in current but that the pyramidal electrode also plays a role. Indeed, devices having a pla
PolymERIC digital optical modulator based on asymmetric branch

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A digital optical modulator based on an asymmetric Y-branch waveguide is proposed and fabricated using an electro-optic polymer. The operating point is initially shifted to the off-state utilizing the asymmetry in the branch to provide an initial zero-state with no electrical bias. It has been confirmed that the high extinction ratio can be obtained with a low drive voltage. An extinction ratio of 25 dB is demonstrated for a drive voltage of 20 V using a polymer, PMMA-DRI with $r_2 = 5$ pm/V at 1.3 μm.

Introduction: The digital optical modulator (DOM) based on the modal evolution effect has attracted much attention because it has a step-like response to the applied voltage, a potential for the polarization- and wavelength-insensitive operation, and a relaxed fabrication tolerance [1]. Unlike interferometric modulators, it requires no precise control of the bias and the drive voltage because of its digital response. It is desirable for an optical modulator array. Recently, we demonstrated a polarization-independent digital optical switch with a symmetric branch by using an electro-optic (EO) polymer [2]. EO-polymer-based devices allow a small velocity mismatch, featuring high-speed operation. However, the DOM based on the switch with a symmetric branch requires a high drive voltage to obtain a high extinction ratio. In this Letter, we propose and demonstrate an EO polymer DOM using an asymmetric Y-branch waveguide. The narrow arm of the branch is used for the output, while the wide arm can be used for monitoring the output characteristics. The operating point was initially shifted to the off-state due to the asymmetry in the branch. As a result, it provides an initial zero-state without any electrical bias, unlike other interferometric devices. Furthermore, it has been confirmed that the high extinction ratio can be obtained with a low drive voltage.

Fig. 1 Configuration of proposed DOM

Device configuration and design: The proposed DOM consists of an asymmetric Y-branch waveguide and a push-pull type electrode that reduces the drive voltage and provides a controllable chirp [3]. The schematic diagrams of our DOM and its cross-section are shown in Fig. 1. The width of the output arm is smaller than the width $W$ of the other arm by $\Delta W$. The optical output with no applied voltage is determined by the asymmetry factor $\alpha$, which is...