플레나 및 이방성 에칭 구조를 갖는 실리콘 p-i-n 광 스위치

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Optically-Triggered Silicon P-I-N Switches with Planar and Anistropically-Etched Structures

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Abstract - Two kinds of optically-triggered p-i-n switches with planar and V-groove structures have been fabricated with gold-doped silicon. The V-groove device exhibits a higher threshold voltage and is more sensitive to light. The minimum optical power indicates that a certain minimum illumination is required to optically turn on the silicon p-i-n devices.

I. INTRODUCTION

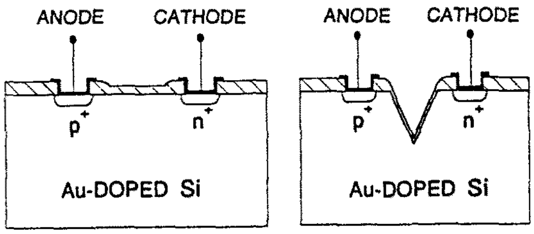
Optically-triggered semiconductor switches ,for either high-speed or high power switching, have been studied theoretically and experimentally, by many workers for over two decades[1-5]. Various new types of optically activated switching devives are developing, such as a bulk-type photo-conductive switch, vertical or lateral p-i-n diodes, an opto-GaAs MESFET, and an optothyristor. Recently silicon p-i-n diode switches have been reported to deliver high electrical pulse power[5-10].

This paper describes the steady-state characteristics of the optically-triggered silicon p-i-n devices with planar and anistropically- formed structures.

II. EXPERIMENT

The device geometry is detailed in Fig. 1. The starting n-type, (100) silicon wafer has a resistivity of 10 Ω·cm. The V-groove was etched by EDP and KOH. The anode was formed by p^+ diffusion using BN wafers as the source, and the cathode was formed by n^+ diffusion using $POCl_3$ as the source. Gold diffusion was then performed from the back of the wafer, using commercially available gold silica film on a source wafer. After gold diffusion, the resistivity of the sample was 50~80 kΩ·cm. The channel length of these devices is 4 mils and the size of the electrode is 1 × 10 $mils^2$.

Optical measurements of optically-triggered p-i-n devices were made using a LED as the light source. The LED was driven by a DC or pulse generator. The absolute incident power on the device was measured by placing the thermopile in the normal position of the test device. The low noise micro power OP amplifier (gain= 1000 V/V) was used with the detector.



(a) Planar (b) V-groove

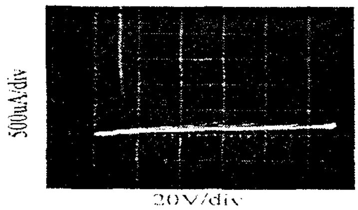
Fig. 1 Optically-triggered p-i-n switches

III. RESULTS and DISCUSSION

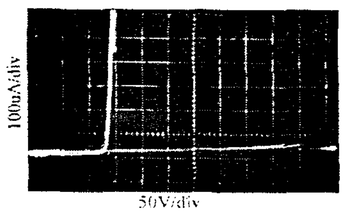
The general nature of the current-voltage characteristics of optically-triggered p-i-n devices was first explored by using a transistor curve tracer and different illumination intensities. Figures 2(a) and

(b) shows the effect of illumination on the current-voltage curves of two different devices. These figures show clearly the optical gating effect of p-i-n switch. The light illumination decreased the threshold voltage and increased the off-state currents in the prebreakdown region.

As shown in Figs. 2 (a) and (b), the on-state characteristic of the device depends weakly on the illumination and the on-state current remains almost unchanged. The latter fact is due to the fact that the concentration of optically-generated carriers is not much higher than the dark carrier density in the on-state.



(a) Planar device



(b) V-groove device

Fig.2 I-V characteristics of p-i-n switches for different illumination levels

The threshold current increased slowly when the illumination level was increased. However, the dependence of the threshold current on the illumination is much weaker than that of the threshold voltage. In Fig.2, in fact, it remained equal to the dark threshold current value in a wide range of the illumination levels, until close to the holding voltage. The off-state and threshold currents near the holding voltage increase considerably because of the higher light power.

Figure 3 shows the comparison of experimental light dark threshold voltage ratio, with numerical calculations from the single level model[11]. Although the correspondence in the magnitude is very poor, the general features or trend of these curves are roughly similar.

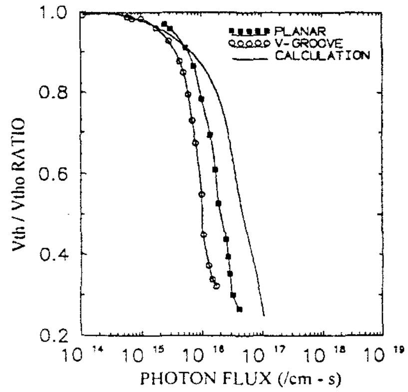
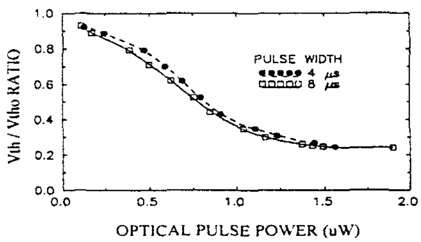
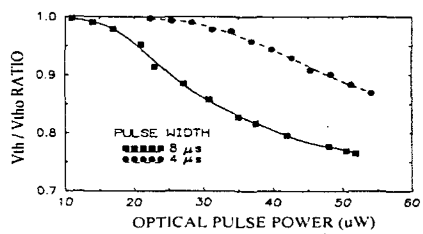


Fig.3 Comparison of the experimental and calculated Vth / Vtho ratios.

Figures4(a) and (b) show the variations of threshold voltage with optical pulse power for two different pulse widths of 4 μs and 8 μs. The threshold voltage is less sensitive to pulsed light than to DC light and more optical power is required for switching. This is may be due the fact that the average optical power in the pulsed case is much lower than that of DC light.



(a) Planar device



(b) V-groove device

Fig.4 Vth/Vtho ratio vs. optical pulse power.

For a 8 μs light pulse, the light sensitivity is improved and the curve becomes close to those for DC light in Figs. 3(a) and (b).

Figure 5 compares the experimental and calculated V_{Th}/V_{Tho} ratios for two different optical pulse widths, showing only a slight difference compared to the curve for DC light application (Fig. 3).

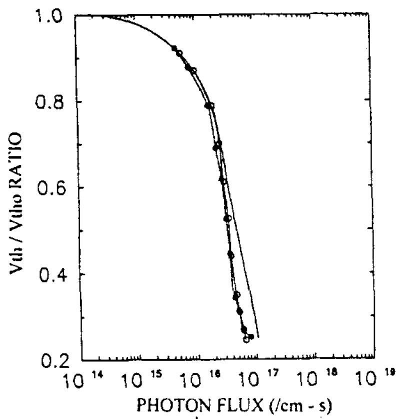


Fig.5 Comparison of the experimental and calculated Vth/Vtho ratios.

Figures 3 and 5 show a good fit between the experimental and calculated data at low optical power corresponding to high bias voltage. This is may be due to that in high injection level the donor gold level becomes always saturated and thus the single level model presented in Ref.[11] becomes more valid.[11].

Figure 6 shows the pulse width dependence of the minimum optical power required to switch the $(DI)^2$ device to the on-state. As the pulse width increases, the minimum pulse power $(P_{ph})_{min}$ decreases and seems to approximately approach the DC power effrect.

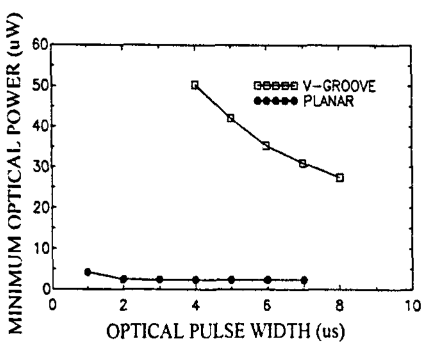


Fig.6 Minimum optical switching power as a function of pulse width.

IV. CONCLUSIONS

The steady-state characteristics of the optically-triggered silicon ṗ-i-n devices with planar and anistropically-formed structures were investigated under DC and pulse power levels. The threshold voltage decreased rapidly when the illumination level was increased. When biased more closely to the dark switching voltage, the p-i-n switch is more sensitive to light and less optical power is required. The V-groove device exhibits a higher threshold voltage and is more sensitive to light. The minimum optical power indicates that a certain minimum illumination is required to optically turn on the silicon p-i-n devices.

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