Low Power Polysilicon Sources for IR Applications

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ABSTRACT

We have designed and fabricated polysilicon thin film infrared (IR) sources by micromachining technology. These sources are made with a lightly doped middle region for light emission and heavy doping of the supporting legs. The sources are fabricated on a 10 mm thick, low temperature silicon dioxide layer. Different doping levels were used to achieve various source resistances. From the power requirement to reach the required light emission versus source resistance curve it is seen that there exists a resistance value which minimizes the necessary input power.

I. INTRODUCTION:

Incandescent light sources have many applications. They are used in wideband spectral analysis of chemicals. Other potential uses are in infrared scene generation and calibration of photodetectors. Typically, the light emission from these sources ranges from the visible to far infrared region.

The conventional infrared calibration source [1] are made using tungsten filament suspended from a glass substrate. They have disadvantages such as; they require high input power, delicate handling, they are expensive and have low maximum operating temperature. Recently, [2], [3] miniature light sources have been fabricated using polysilicon thin film resistors. The resistors are heated by applying current to make the source glow in desired wavelength regions. These sources can glow in air or vacuum however the power requirement is far less in vacuum and the lifetime in ambient is severely reduced due to oxidation. Mastrangelo et al [4] reported the fabrication of vacuum sealed polysilicon filaments using IC technology. However, such types of sources are no longer produced. We have undertaken the development of polysilicon IR sources for the NASA Space Infrared Test Facility (SIRTF) flight project. These devices are to be used as the calibration sources for the focal plane infrared detectors. The requirements from this project are low power, long lasting, stable, and reliable sources. We designed various types of structures and used different process parameters in the fabrication of these sources. In this paper we describe the fabrication process and test results of low power polysilicon sources capable of operating at liquid helium temperature (4.2K).

II. FABRICATION OF POLYSILICON IR SOURCES:

The fabrication process of the polysilicon sources starts with deposition of a 10.0 mm thick low temperature oxide (LTO) on a silicon substrate. A thick oxide layer is required to ensure that the polysilicon film will not touch the silicon substrate when the LTO is removed from underneath the structured for the bridge fabrication. Undoped polysilicon of 1.0 mm thickness was deposited by LPCVD method followed by a low dose blanket implantation on the polysilicon film. This low dose implant is critical as it determines the resistance of light emitting region. In our experiments we varied this implant dose to tailor the IR source resistor value. After the first implant, the polysilicon film was patterned and etched to form the resistor strip. Then a heavy dose boron implant (2E16/cm2) was carried out with the photoresist as the masking material in the light emitting region. Implantation is followed by a high temperature anneal. Aluminum metallization was carried out after contact windows were opened. Aluminum was patterned and etched from all the areas except the contact areas. Finally, a long oxide etch in buffered HF was carried to remove the oxide from the exposed area of the wafer and under the bridges. The fabrication process is completed by alloying at 490 C for 20 min. .

III. RESULTS AND DISCUSSION

Fig. 1 shows the SEM picture of the bridge suspended between two pad islands. The bridge is 200 mm long and 6 mm wide with middle lightly doped rectangular light emitting region of 30 X 40 mm. It is clearly seen that the bridge bends downwards. The light emitting region is at lower than the supporting polysilicon pad islands which are on the 10.0 µm thick oxide layer. Fig.2 shows the magnified view of the light emitting middle rectangular (30X40 µm) region. The picture is the edge-on view of the source. The source is approximately 6.0 µm above the silicon surface. In order to get the light emission, the bridge has to be completely unattatched from the underneath silicon dioxide layer. A long oxide etch in buffered HF is required for complet removal of silicon dioxide.

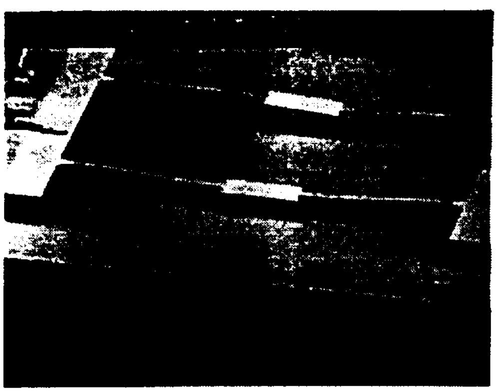

Figure 1. SEM of bridge hanging by two islands of low temperature oxide

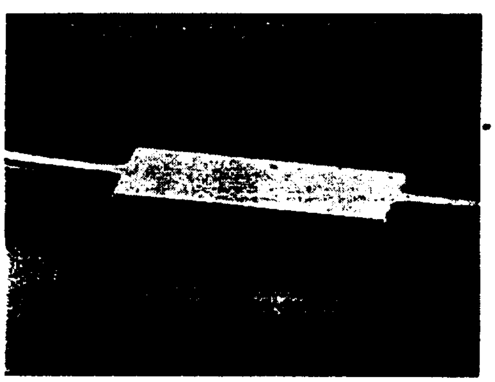

Figure 2. SEM of bridge portion where light emission occurs

The polysilicon sources are wire bonded into a TO-5 header. The I-V curve were generated while the sources are in vacuum . The vacuum chamber has a glass window through which the light emission was observed. The polysilicon sources behaves as a linear resistor for low bias values. As seen in Fig. 3, as the applied voltage is increased a saturation characteristic in the I-V curve is seen. This is followed by a non-linear increase of current with applied voltage. Our results agree with

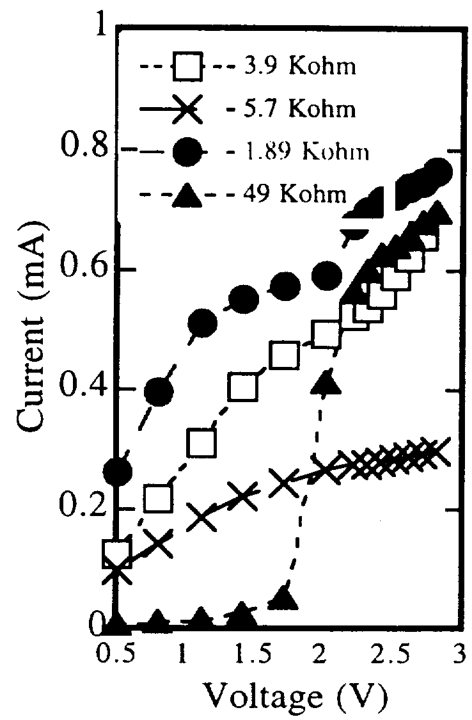

Figure 3., I-V curve for different polysilicon resistor

previously reported non-linear behavior of polysilicon resistor values [5]. Plots of four resistance values of polysilicon sources which give different I-V characteristics are shown in the figure. For a 49 Kohm resistor, very little current flows at low biases. However, at approximately 1.75 volt, a large increase of current occurs. Again at about 2.1 V the increase in current is less in comparison to the range between 1.75 and 2.15 V. We believe this sudden increase in current is due to thermal breakdown of polysilicon resistor [6]. The increase in resistance values beyond 2.1 V is similar to those of low resistance sources such as the 1.89 or 3.9 Kohm devices. The light emission occurs for 49 Kohm resistor at 2.25 Volt and the power required is 2.2 mW. Though the I-V curve for both 1.89 or 3.9 Kohm are similar, the I-V curve for 5.7 Kohm is different. Within the applied bias range, a nonlinear resistance change occurs for 5.7 Kohm resistor. We did not see any kink in I-V curve for 5.7 Kohm resistor which is seen for other resistors.

We have measured the power required for a particular radiation temperature for different resistance values. The results are shown in Fig. 4. Power required for light emission ofparticular

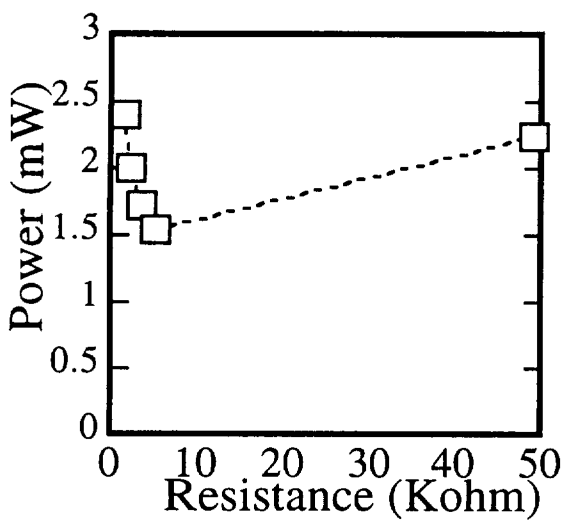

Figure 4, Power required for 1000K radiation versus polysilicon resistance

temperature decreases with increase of resistance values. However, after attaining a minima, the required power increases. We believe the temperature of the sources are approximately 1100 K. The fact that the power requirement goes through a minima with increase in resistance values implies that more than one mechanism is responsible for light emission in polysilicon resistor. It has been reported that the change in resistance values beyond the kink point in Fig. 3 (from which light emission is observed) is due to current induced resistance decrease [7] and filamentation [8]. The optimum value of 5.7 Kohm polysilicon resistance was chosen for the SIRTF project which requires minimum input power.

IV. Conclusions:

We have successfully designed and fabricated low power polysilicon sources for SIRTF flight project. Optimum polysilicon resistance value was chosen to achieve least power for IR radiation.

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