TFTs as Photodetectors for Optical Interconnects

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Abstract—In this work we are looking at the prospect of using poly-silicon based Thin Film Transistors (TFTs) as photodetectors for optical interconnects that can detect light effectively at 1100nm wavelength from silicon based Light Emitting Diodes (LEDs). These TFTs were fabricated from laser crystallized silicon and were characterized under darkness and illumination. The photosensitivities of these devices were limited due to the presence of aluminium as their gate electrode but have shown us the possibility of a new approach to photodetection.

Index Terms—Laser Crystallization, Optical Interconnect, Photodetector, Silicon, Thin Film Transistor (TFT).

I. INTRODUCTION

In recent years there has been a lot of focus on replacing metallic interconnects with much faster optical interconnects for intra-chip communications. The optical interconnects have the advantage of providing higher bandwidth for data transfer while consuming less power [1].

One of the basic components of an optical interconnect is a Photodetector. The important properties of a photodetector are quantum efficiency, responsivity and speed. It is also important to have a lower leakage current. The optical absorption coefficient $a$ of the material chosen greatly influences the responsivity of the photodetector [2].

There are different varieties of photodetectors namely p-n diode, p-i-n diode, Avalanche photodiode and Metal-Semiconductor-Metal (MSM) photodetector [3]. Many have addressed different approaches for these photodetectors [4]-[5]-[6]. In this paper we are looking at the novel approach of using TFTs for detecting light from silicon based LEDs at 1100nm wavelength [7]. One of the unique advantages of this approach is in using low temperature processing techniques in its fabrication compatible with CMOS post processing. We have also demonstrated in this paper that these TFTs were quite sensitive to light albeit having aluminium as its gate electrode.

II. EXPERIMENTAL

For this work we employed both p-Type TFTs and n-Type TFTs fabricated from laser crystallized silicon. The laser crystallization process involved a controlled lateral crystallization of the material. This was done by using pre-patterned a-Si lines prior to the deposition of a-Si layer using Low Pressure Chemical Vapour Deposition (LPCVD) at 550°C which was laser crystallized using a green (515nm) laser as shown in Fig. 1 [8].

This resulted in the formation of grain boundaries which were preponderantly location-controlled thus making it possible to pre-define them.

The n+ and p+ regions were formed using ion implantation of dopants and activated using laser anneal. The bottom gate oxide was grown using thermal oxidation while the front gate oxide was deposited using Inductively Coupled Plasma Enhanced Chemical Vapour Deposition (ICPECVD) at 150°C [9]. All the TFTs had Aluminium as their front gate electrode which limited their direct illumination.

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III. MEASUREMENTS

Output and Transfer Characteristics were measured under darkness and illumination covering different wavelengths using a Karl Suss Probe station.

An external light source was used for illumination. A wavelength carousel filter was fitted along with the light source in order to choose different wavelengths for the characterization of the devices.

IV. RESULTS AND DISCUSSION

Aluminium as a front gate electrode limited the direct illumination of the TFTs. The response of these TFTs could be attributed to the stray light entering the channel because of the light getting scattered along the edges of the metal as well as due to the back scattering of light via the oxide layer beneath it.

These TFTs were not fabricated with the intention of photodetection and so was the use of Aluminium as the gate electrode. They were instead used as test devices to look into the prospect of using them as photodetectors.

Under illumination the Drain current ($I_d$) decreased for both p-type and n-type $\perp$ TFTs whereas it increased for p-type $\parallel$ TFTs whilst the change in the Drain current ($I_d$) for n-type $\parallel$ TFTs were relatively insignificant as shown Fig. 4 and Fig. 5.

These effects diminished with the increase in the Gate voltage ($V_g$) i.e. the influence of light on $I_d$ were significant only in the sub-threshold region. With respect to wavelengths, infrared spectrum gave a predominant effect on p-type $\perp$ TFTs while the white light had an upper hand on both n-type $\perp$ TFTs and p-type $\parallel$ TFTs as shown Fig. 4 and Fig. 5.

As seen from the output characteristics of these TFTs, it can be clearly stated that the orientation of the major grain boundaries along the channel plays a crucial role in determining the type of response under illumination. The increase in $I_d$ for $\parallel$ TFTs can be attributed to the minimal influence of the grain boundaries as they are oriented in parallel to the path of the movement of the carriers though n-Type $\parallel$ TFTs have registered a very minimal change in $I_d$ under illumination. In general $\parallel$ TFTs have higher Drain current ($I_d$) when compared to $\perp$ TFTs as seen in Fig. 4 and Fig. 5. The decrease in $I_d$ for the $\perp$ TFTs cannot be well accounted. Many previous studies have claimed for an increase in the conductivity of poly-silicon under illumination [10]-[11]. In the present case the responses of $\parallel$ TFTs and $\perp$ TFTs are complementary to each other. This needs further analysis in order to well document the effect of illumination in $\perp$ TFTs with an applied gate voltage.
V. CONCLUSION

The above measurements have shown the possibility of using TFTs as Photodetectors but their performances were limited due to the presence of the aluminium as their gate electrode. These TFTs will be further redesigned in order to better understand their characteristics. True compatibility with CMOS post processing can be achieved with silicon by depositing a-Si using Plasma Enhanced Chemical Vapour Deposition (PECVD) instead of LPCVD.

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REFERENCES