Extended Abstracts of the 22nd (1990 International) Conference on Solid State Devices and Materials, Sendai, 1990, pp. 1055-1058

A Redundant Poly-Si TFT Shift Register Using Laser Repair Technique

H.Asada, K.Sera, F.Okumura, and S.Kaneko

Functional Devices Research Laboratories,
NEC Corporation
4-1-1 Miyazaki, Miyamae-ku, Kawasaki, 213 Japan

A novel redundant poly-Si TFT shift register using laser repair technique has been developed for high yield display and imaging devices with peripheral drive circuits. A pulsed YAG laser (1.06 μm) was used to exchange fault circuits for spare circuits. Ohmic laser connections (a contact resistance of about 100 Ω) between n^+-poly-Si and Al, separated by SiNx, were obtained by the irradiation to n^+-poly-Si through a glass substrate. The laser repair operation of the redundant shift register has been demonstrated.

1. Introduction

Poly-Si TFT drive circuits have been widely applied to display and imaging devices, such as active matrix liquid crystal displays (AMLCDs) [1),2)] liquid crystal shutter arrays [3)] and contact-type image sensors [4)], because these devices provide compact, low cost and high performance systems. However, with the increase of pixel number or the enlargement of device size, manufacturing yield is lower drastically, due to the process-induced defects. Particularly, defects in peripheral drive circuits are the most serious problem in AMLCDs, because they often cause area defects to the displays, while defects in pixel arrays with TFT switches cause point or line defects.

Therefore, it is essential to introduce redundancy and repair technique into the peripheral drive circuits. Redundant TFT circuits and laser repair systems for AMLCDs have been reported, however, they are not sufficient for repairing open-defects in the circuits. A laser connection technique is necessary for repairing them. This paper describes a new redundant poly-Si TFT shift register (S/R) using laser connection and disconnection technique. The redundancy and repair technique can be applied to not only TFT drivers but also other large area circuits including pixel arrays.

2. Construction

Fig.1 shows the block diagram of the redundant S/R, which is equipped with one or more spare S/Rs isolated from the circuit per each stage. The fault regular S/R on the n-th stage can be exchanged for the spare S/R on the same stage by disconnecting the input/output (I/O) lines of the fault S/R from the circuit and connecting the I/O lines of the spare S/R to the circuit with laser. Consequently, the redundant S/R operates correctly as a whole, if at least one of the S/Rs on the same stage has no defect. This new redundant S/R has the feature that both open- and short-defects of lines and TFTs can be repaired.

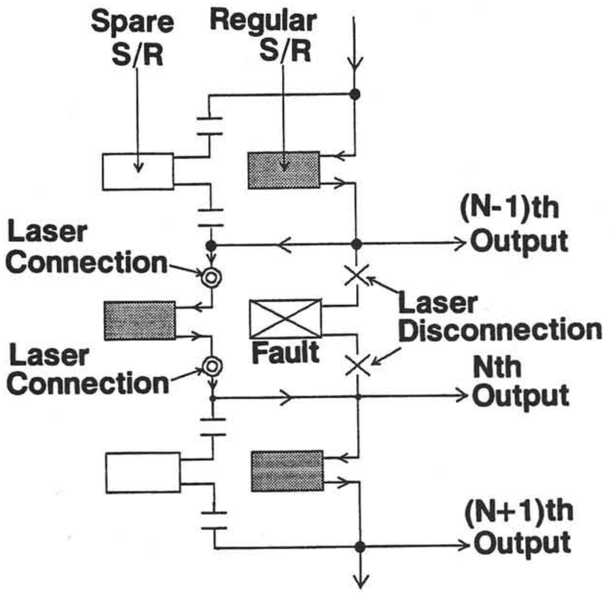

Fig.1. Block Diagram of the redundant shift register.

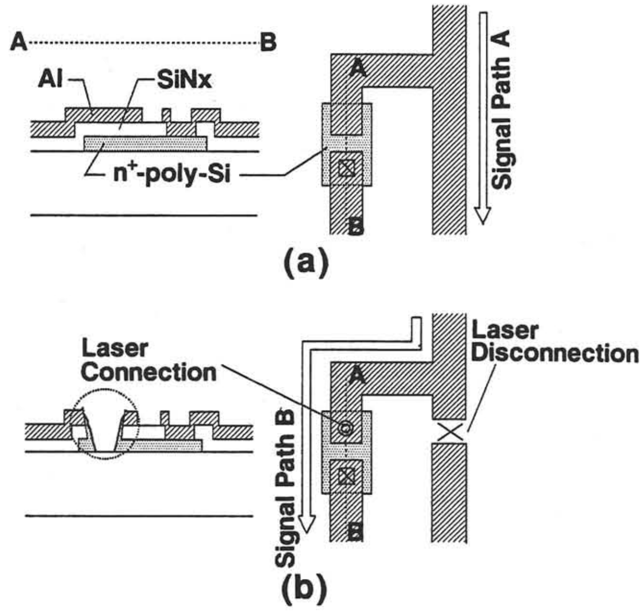

Fig.2. Plane and cross-sectional view of laser repair sites (a) before laser repairing and (b) after laser repairing.

3. Laser Repair Technique

A pulsed YAG laser, which operates at 1.06 µm with a pulse duration of 8 nsec, was used. The plane and cross-sectional view of laser repair sites are shown in Fig.2, where (a) and (b) correspond to the structure before and after laser repairing, respectively. The laser disconnection can be easily performed by irradiating YAG laser to the surface of Al lines.

A laser connection technique between metal layers has been reported [5]. It was confirmed that the connections were easy with several metal combinations, such as Al-to-Al, Al-to-Cr and Al-to-Mo. The probability of forming Ohmic connections was nearly 100 %. However, these combinations can not be always applied to poly-Si TFT circuits. Usually, it is necessary that they have an overlap structure of Al layer and a gate layer of doped-poly-Si, separated by an insulating layer, because the n^+-poly-Si layer is used as the circuit lines. In this work, the laser connections were formed between Al (3000 Å) and n^+-poly-Si (2000 Å) through SiNx (3000 Å) by irradiating YAG laser to the overlap site. The electrical signal path A can be changed to path B, as shown in Fig.2.

The laser connections were actually performed by one or more pulses at incident power densities ranging from 20 to 60 W/μm^2 in air. The irradiated pattern was 4 µm x 4 µm in size. In case of irradiating YAG laser to Al surface (front irradiation), the laser connections had diode-like or open characteristics. Although the diode-like connections approached Ohmic connections by annealing of the sites at 300 ℃ for 30 min, this method cannot be applied to AMLCDs after injecting liquid crystal materials into them. On the other hand, the irradiation to n^+-poly-Si through a glass substrate (back irradiation) formed Ohmic or diode-like connections. The probability of forming Ohmic connections was about 70 %, however, it became nearly 100 % by trying several times. The typical I-V characteristics is shown in Fig.3 together with illustrations of the laser connection sites. The Ohmic contact resistance was about 100 Ω. The value is sufficient for the proposed redundant S/R.

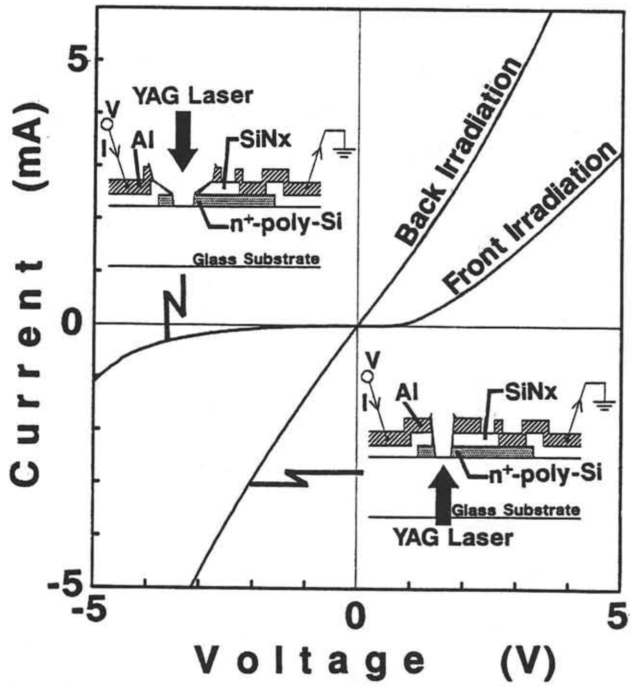

Fig.3. I-V characteristics of laser connection sites by the front and back irradiation.

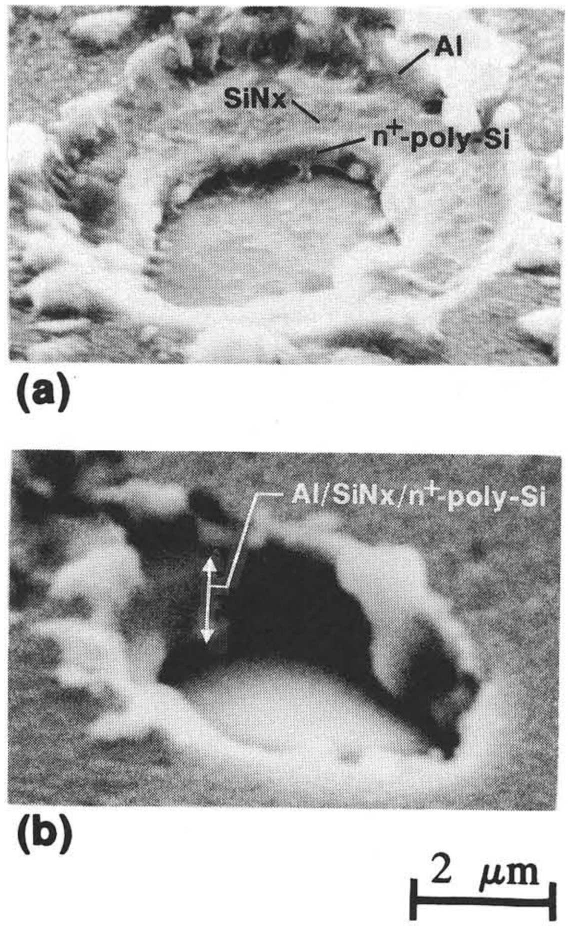

Fig.4. Scanning electron micrographs of laser connection sites formed by the (a)-front and (b) back irradiation.

The scanning electron micrographs of the laser connection sites formed by the front and back irradiation are shown in Fig.4-(a) and -(b), respectively. The site-structures are clearly different. In case of front irradiation, the passivation layer of SiNx is fractured and exploded conically and the Al layer is widely removed at the former site. In this repaired site, the probability of connecting n^{+}-poly-Si with Al, including diode-like connections, is low (less than 50 %). On the other hand, the columnar hole is formed through three layers of n^{+}-poly-Si, SiNx and Al at the latter site, where it is easier to connect n^{+}-poly-Si with Al. It was found that the site-structures have strong relation to the probability of forming Ohmic laser connections.

4. Device Performance

In order to demonstrate the effectiveness of the redundant circuitry and laser repair technique, a 320-stage redundant S/R was designed and fabricated on a glass substrate, using a conventional n-channel self-aligned poly-Si TFT process. The NMOS S/R is of the two-phase-clock dynamic type. Fig.5 shows a microphotograph of the redundant S/R, which consists of a regular S/R, two spare S/Rs and output buffers, has a length of about 67 mm.

Fig.6 shows a microphotograph of the laser repaired site in the redundant S/R. This is an example of exchanging the fault regular S/R on the 116th stage for the spare S/R using laser disconnection and connection technique mentioned above. In this case, the input signal to the 116th stage is turned to the spare S/R and its output signal is returned to the regular S/R on the 117th stage. The fault was detected by the output waveform monitored on an oscilloscope, however, in practice, the defects can be easily

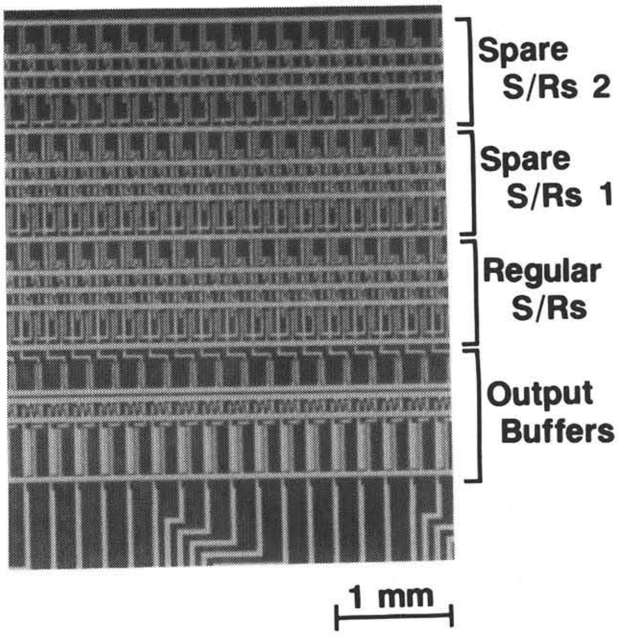

Fig.5. Microphotographs of the redundant shift register.

detected by the observation of defect patterns on a display image. The 100th, 110th, 120th and 130th output waveforms of the redundant S/R before and after laser repairing are shown in Fig.7- (a) and -(b), respectively. It can be seen that the redundant S/R operated correctly, with the 116th fault repaired.

5. Conclusion

This paper has presented a new redundant poly-Si TFT S/R using laser repair technique for high yield display and imaging devices with TFT drivers. The Ohmic connections of an Al layer and a gate layer of n^+-poly-Si, separated by a passivation layer of SiNx, was obtained by the back irradiation to n^+-poly-Si through a glass substrate. The effectiveness of the redundant circuitry and laser connection technique was demonstrated using a 320-stage poly-Si S/R. This new redundancy and repair technique is also expected to be useful for other large area circuits such as active matrix arrays as well as TFT drivers.

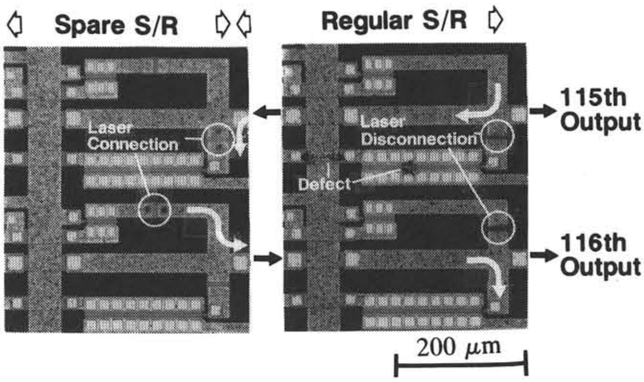

Fig.6. Microphotographs of the laser repair site in the redundant shift register.

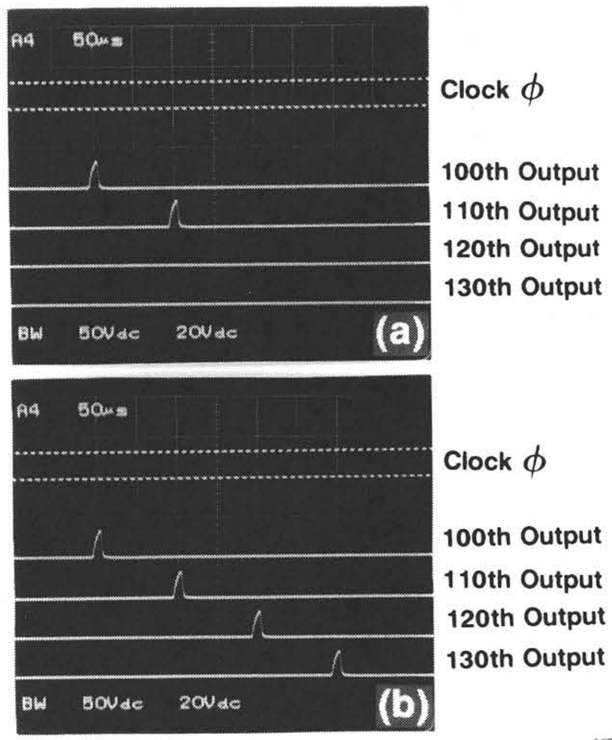

Fig.7. Output waveforms of the redundant shift register (a)before laser repairing and (b) after laser repairing.

Acknowledgement

The authors would like to thank Dr. S. Esyo, Dr. T. Saito, and C. Tani for their encouragement and support. Thanks are also due to H. Hayama for his valuable comment.

References

[1]S.Morozumi, et al.;JAPAN DISPLAY '86, pp196, (1986).
[2]A.Mimura, et al.;1988 IDRC, pp215, (1988).
[3]F.Okumura, et al.;1988 IDRC, pp174, (1988).
[4]T.Takeshita, et al.;1989 SID Digest, pp255 (1989).
[5]D.E. Castleberry, et al.; 1988 SID DIGEST, pp232 (1988).