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Current Drive Silicidation Technology for High Speed Field Programmable Devices

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A low-resistivity antifuse for field programmable devices has been developed by using current-drive silicidation (CDS) technology in a metal-amorphous silicon-metal structure. Experimental data indicates that the programming of an antifuse is accomplished within 2nsec, and the resistance of programmed antifuse is lower than 150Ω. The R_{on} decreases as the programming current to power of about 1.6. This technology is suitable for low-power, high-speed, field-programmable devices such as FPGA's and PROM's.

1.INTRODUCTION

Recently, there has been a great need for field-programming technology because users demand short cycles time, low cost, and low risk. The field programmable devices such as FPGA and PROM can be programmed by users to obtain the required function. The field programmable devices can be programmed readily in a short time, so these devices will also develop the new application of LSI.

Antifuse technology is the key technology for field programming. Applying the specific voltage to the antifuse, the definition of the interconnections after the completion of the all production processes.

In poly-Si fuses, melted poly-Si particles tend to degrade the reliability of the circuit. Nitride films have been used in anti-fuse structures[1] but had high on-state resistance (R_{on}) and poor reliability.

Current Drive Silicidation (CDS) technology in a metal-amorphous silicon-metal antifuse structure can be realize the quite low R_{on} with high stability, because the programming of CDS anti-fuse involves the formation of silicide and no particle generation. The on-state resistance of anti-fuse extremely affect the delay time, so this technology provide the high speed field programmable device.

In this paper, we describe the characteristics of antifuse having the Ta/a-Si/Ta structure for high speed field programmable devices.

2. EXPERIMENTAL

The structure of the metal-amorphous silicon-metal antifuse is shown in Fig. 1. Tantalum(Ta) film and 100nm un doped amorphous silicon (a-Si) film were consecutively deposited using an UHV multi-chamber film deposition system. The a-Si was deposited by plasma enhanced CVD at substrate temperature of 300°C. After forming a 1-μm^2 contact hole and the upper Ta electrode, an aluminum film was deposited. In order to program the antifuse, a voltage was applied to the amorphous silicon through a series resistance, typically 2kΩ. The purpose of the series resistance was to regulate the programming current.

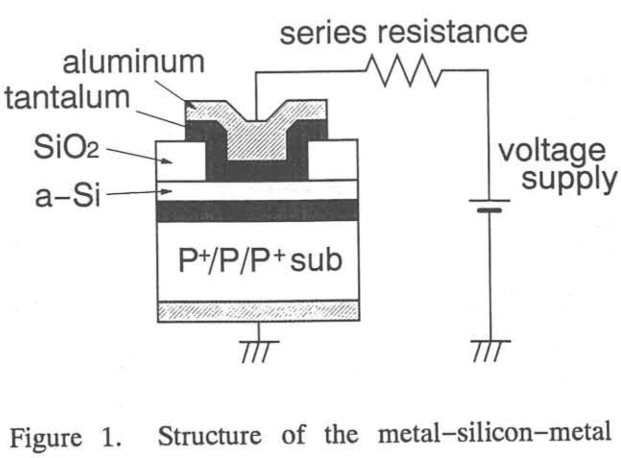

Figure 1. Structure of the metal-silicon-metal antifuse.

3. RESULTS AND DISCUSSION

Figure 2 shows the I–V characteristics of anti–fuse for the thickness of the a–Si film is 50, 100, and 150nm, respectively. The breakdown voltage decreases as the a–Si film becomes thinner. In the case of (a), the tunneling leak current remains high although the breakdown voltage is decreased, resulting in high power dissipation.

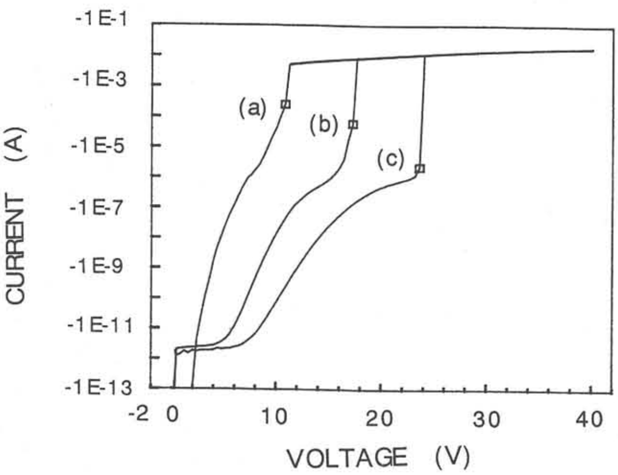

Figure 2. Dependence of I–V characteristics on varying a–Si film thickness. (a) 50nm, (b) 100nm, (c) 150nm.

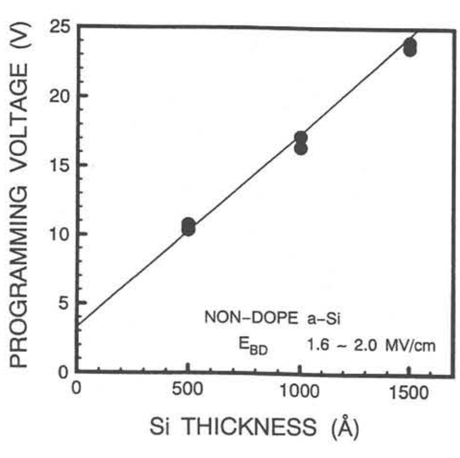

Figure 3. Dependence of breakdown voltage on amorphous Si thickness.

Figure 3 shows the dependence of breakdown voltage on varying a–Si film thickness of 50, 100, 150nm. The programming voltage of anti–fuse is determined by thickness and property of a–Si film. It is wellknown that the property of a–Si can be affect by the production process. According to the previous reports[2], a–Si formed by ion–implantation exhibits the breakdown field in the range of 0.8~1.3 MV/cm. In this experiments, the breakdown field intensity of the a–Si is 1.6~2.0 MV/cm.

Figure 4 displays the dependence of R_{on} on the programming current for the antifuses programmed by constant voltage with long duration. The programming current was regulated by series resistance of 2kΩ. The amorphous film of 50nm thick was used in this measurement. The increase of the programming current lead to the reduction of R_{on}. A low on–state resistance of 62Ω are obtained when the programming current of 20mA was applied. This dependence has been reported by the previous studies[2], shown by the following equation;

$$R_{on}=V_0/(I_p)^n$$

The data indicates on a decrease of R_{on} as the programming current to power of about 1.6.

A large parasitic capacitance exists on the experiments for Fig.4, The large discharge current flow through the anti–fuse at the moment of breakdown. The average discharge current of the parasitic capacitance can be estimated as

$$I_{AVR}=\frac{C_P(V_{BD}-V_F)}{t_d}$$

where V_{BD} is the breakdown voltage, V_F is the final

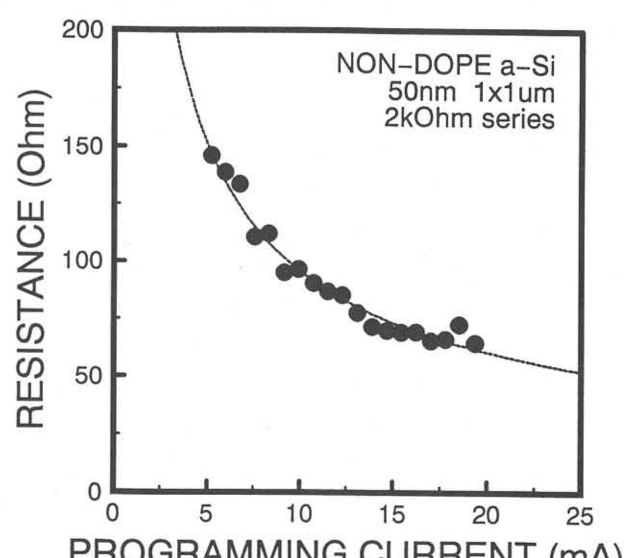

Figure 4. Dependence of R_{on} on the programming current in the programming by pulse with long duration.

voltage, and t_d is the discharge time of the parasitic capacitance. In this case, I_{AVR} can be estimated as 10mA or larger, but the R_{on} was reduced by the small DC current less than 10mA. The difference of the programming by the short pulse current, such as the discharge current, and the regulated constant current must be investigated to design the programming circuit with low power dissipation.

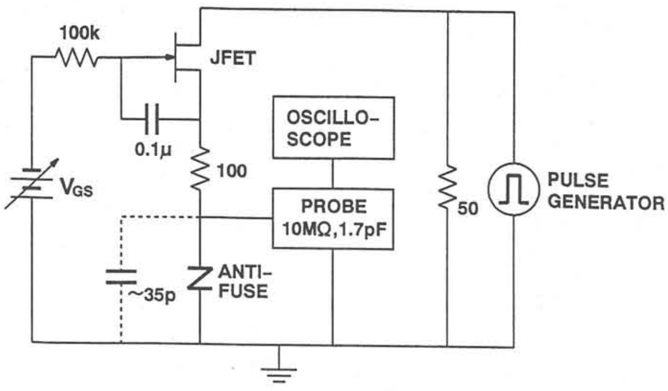

Figure 5. Circuit configuration used to program by short pulse.

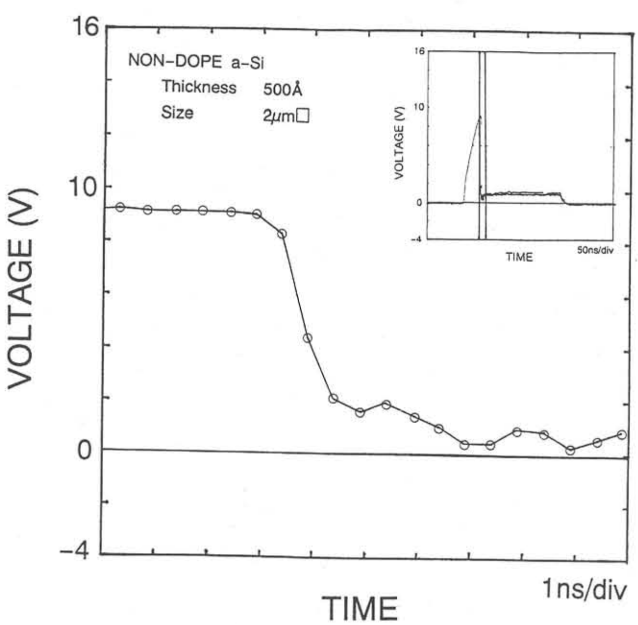

Figure 6. Resistance change on the moment the antifuse is programmed by short pulse.

Figure 6 shows the change of resistance when the pulse was applied to the antifuse at the first time. The pulse duration is 250nsec. The constant current source of 7mA was used as the external programming circuits shown in Fig. 5 for this experiment. By the parasitic capacitance of 35pF, the voltage applied to the antifuse is gradually increased as shown in the insert in Fig. 6. The voltage get large enough to program the antifuse, then the programming are completed in the short time of 2nsec. It indicates that the formation of silicide region proceeds rapidly more than 500cm/sec.

The average discharge current of the parasitic capacitance can be estimated as 150mA, where V_{BD}, V_F and t_d are 10.5V,1.75V, and 2nsec respectively.

The programmed antifuse shows the resistance of 150Ω. It is supposed that the on-state resistance of the anti-fuse programmed in this experiment for the direct probe measurement is lower than that in the circuits for the actual use, because discharge current are quite large compared to the current supplied from the current source.

The reaction to form an programmed state is so fast that pulse duration can be shortened to less than several nsec by reduction of parasitic capacitance. The antifuse is programmed by only one pulse, and stable even after applying of 100 pulses.

4. CONCLUSION

In conclusion, a low-resistivity antifuse has been developed by using CDS technology in a metal-amorphous silicon-metal structure. The R_{on} decreases as the programming current to power of about 1.6. This technology is promising for low-power, high-speed field-programmable devices.

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