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One-time-programmable Electrical Fuse Memory Enabling Security of Biomedical Devices

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Abstract

With the rapid progress of medical engineering, many medical wearable devices have been invented. In response to the development of portable biomedical devices, the security requirement for data storage has increased. To prevent storing space from hacking, as well as reducing high-voltage exposure, a high-security, high-reliability memory unit for storing sensitive biomedical data is significant.

Introduction

To achieve the goals mentioned above, an electrically programmable fuse (efuse) is a non-volatile memory that features intentional physical deformation of a circuit to store a “1” or a “0” in a memory bitcell, thereby reducing the read instability caused by environmental factors. An efuse circuit exploits electromigration to physically break down a poly-gate, metal-gate, or metal wire in a bitcell.

The resistance of an efuse bitcell after programming presents several orders of magnitude higher than the resistance before programming. In addition, the physical deformation of an efuse bitcell can maintain its stability against PVT variations, because the breaking poly-gate, metal-gate or metal wire significantly reduces the possibility of re-growing back to its virgin status to nearly zero. So, the efuse technology is one of the promising technologies to ensure data security and reliability.

Discussion

Different materials and lengths of an efuse cause different programming results, in which the lowest programming current or programming voltage is desired while maintaining a good programming yield.

(a) Fuse length:

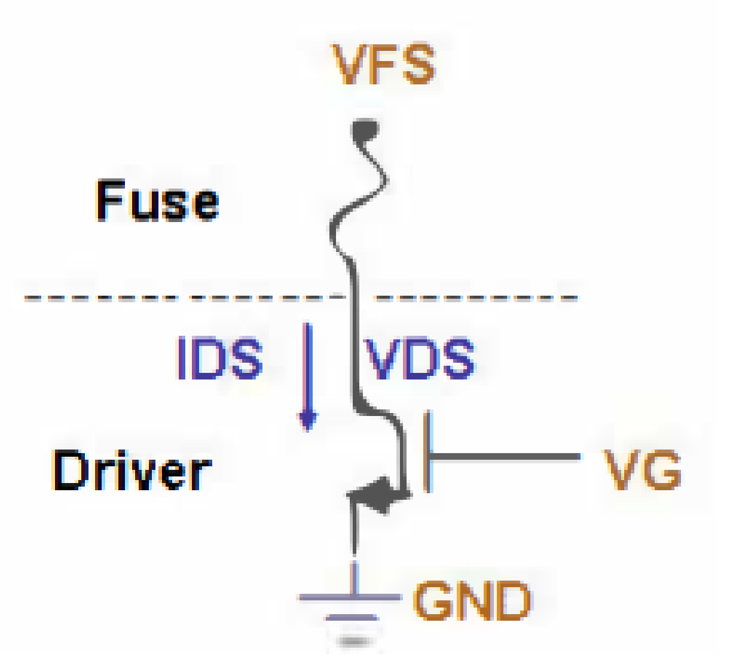


Fig.1 Schematic of e-fuse bit cell

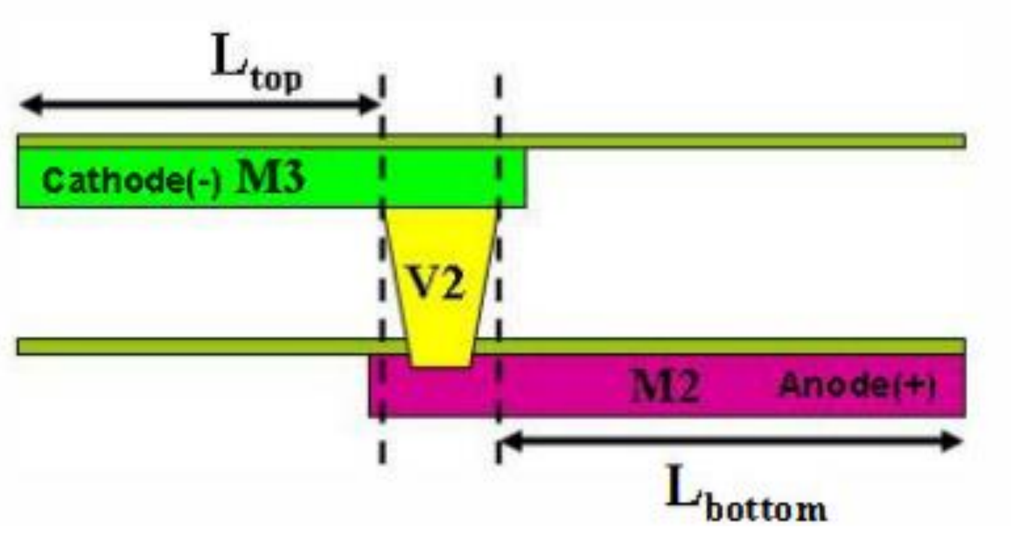
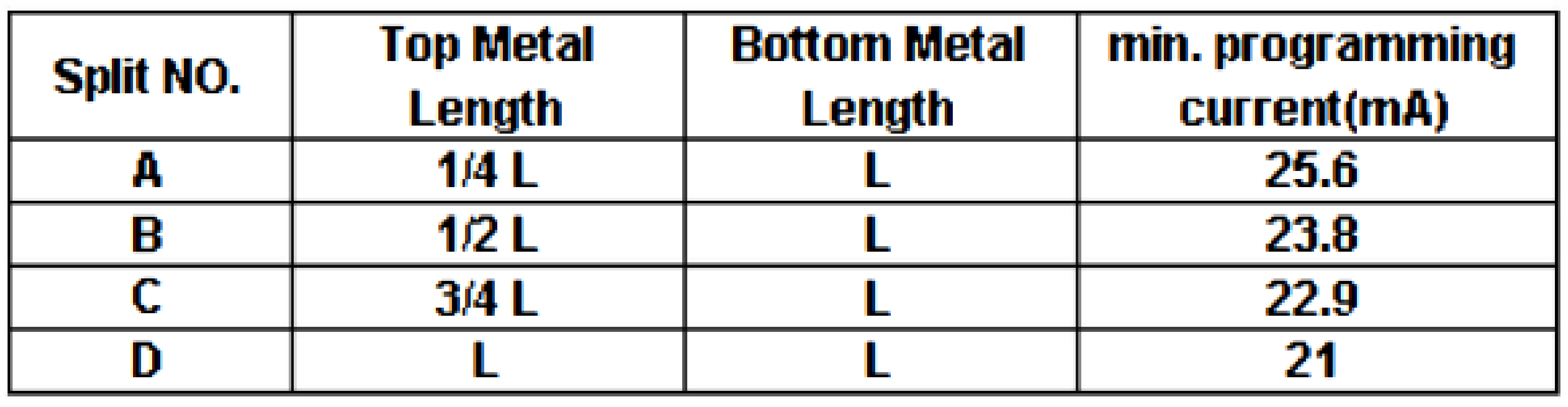


Fig.2 2 X-section of Cu metal fuse



Split NO.	Top Metal Length	Bottom Metal Length	min. programming current(mA)
A	1/4 L	L	25.6
B	1/2 L	L	23.8
C	3/4 L	L	22.9
D	L	L	21

Fig.3 Characterization summary table of top metal splits

Fig. 1 ~ Fig. 3 are captured from [1]. Fig. 1 shows the basic schematic circuit of efuse bitcell, which contains a NMOS transistor and a metal-fuse resistor. Fig. 2 shows the cross-section of Cu metal fuse. Fig. 3 shows the summary of length splits of top metal line and results. When top metal line is shrunk from L to 1/4L, the minimum blowing current is enlarged from 21mA to 25.6mA. From the above results, less program current is needed with a longer top metal line of fuse is used for efuse bitcell. It's a good way to reduce the overall power consumption, but the fuse length can't be extended infinitely. We need to take both bitcell area and the effect caused by different type of efuse bitcell into consideration.

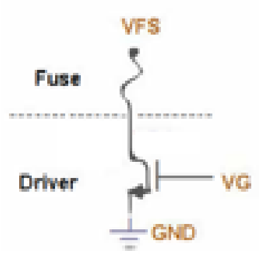
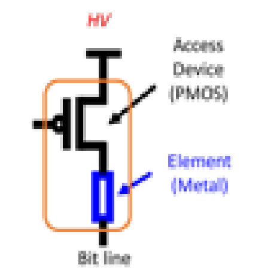
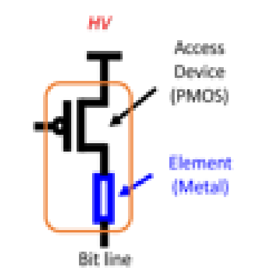
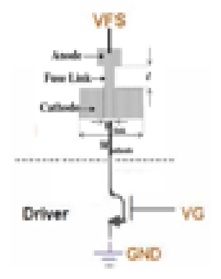
	Conference'11 [1]	JSSC’17 [2]	JSSC’10 [8]	Letters'02[4]
Technology	28nm CMOS	14nm high-k metal gate	32nm high-k metal gate	0.12um CMOS
Bitcell topology	1T1R	1T1R	1T1R	1T1R
Bitcell size	N.A.	0.9um^2	1.37um^2	N.A.
Fuse type	Metal	Metal	Metal	N+ and P+ semiconductor
Bitcell schematic				
Program method	Voltage mode	Voltage mode	Voltage mode	Voltage mode
Supply Voltage/ Blowing time	1.8V/1.8V/1us	2.4V/1.2V/20us	2V/1.05V/1us	3.3V/1.5V/200us
Program Current	21mA~29.8mA	N.A.	N.A.	10mA
Fuse resistance before programmed / after programmed	1.6k ohm / 5M ohm	N.A.	N.A.	120 ohm / >7M ohm
Yield	N.A.	97.5% - 99.99%	99% - 99.99%	N.A.

Table.1 Comparison Table

Conclusion

There are many ways to improve the programming yield. One of them is mentioned in this poster : “fuse type”. Different types, lengths, and even geometry have different result of efuse programming. We are trying to figure out what combination would be the best one to reach a nearly 100% programming yield using the lowest programming voltage.

References

[1] K.-S. Wu, et al. “Investigation of Electrical Programmable Metal Fuse in 28nm and beyond CMOS Technology”, IEEE International Interconnect Technology Conference, April 2011

[2] Z. Chen, et al. “A 0.9-µm2 1T1R Bit Cell in 14-nm High-Density Metal Fuse Technology for High-Volume Manufacturing and In-Field Programming”, IEEE Journal of Solid-State Circuits, Vol. 52, No. 4, April 2017.

[3] S. H. Kulkarni, et al. “A 4 kb Metal-Fuse OTP-ROM Macro Featuring a 2 V Programmable 1.37 um^2 1T1R Bit Cell in 32 nm High-k Metal-Gate CMOS”, IEEE Journal of Solid-State Circuits, Vol. 45, No. 4, April 2010.

[4] C. Kothandaraman, at al. “Electrically programmable fuse (eFUSE) using electromigration in silicides”, IEEE Electron Device Letters, Vol. 23, Issue 9, September 2002.