Efficient TSV repair method for 3D memories

Ilwoong Kim, Keewon Cho, and Sungho Kang

Dept. of Electrical & Electronic Engineering
Yonsei University
Seoul, Korea
{woong, ckw150}@soc.yonsei.ac.kr and shkang@yonsei.ac.kr

Abstract

Through-silicon-via (TSV) based 3D stacked memory is recognized as the next generation memory architecture but its low TSV yield is one of the manufacturing cost factors. In this paper, an efficient TSV repair method is proposed for 3D memories. The proposed method uses a new 2-dimensional 1-4 switching technique to enable efficient repair of clustered TSV faults using repair circuitry with reasonable area overhead. Therefore, the proposed TSV repair method can contribute the improvement of TSV yield for 3D memories.

Keywords- 3D memory, TSV repair, clustered TSV faults

I. Introduction

Through-silicon-via (TSV) based 3D stacked memory is recognized as the next generation memory architecture due to its high density, high band-width, low power interface and small form-factor. However, its low TSV yield is one of the factor which increases manufacturing cost. TSV repair is performed by replacing faulty TSVs with fault-free redundant TSVs like the memory cell repair. According to the recent study [1], the TSV yield without repair process for 4-layer stacked chip has been calculated as 15%. The TSV yield for 2-layer stacked chip can be estimated as 53.1%. Therefore, TSV repair is crucial to get a reasonable yield of TSV based 3D memories.

Typically, the TSV array of 3D memories has a wide rectangular shape and has fine-pitch to allocate large area to memory cell blocks as possible. Therefore, the TSV yield can be dropped by clustered TSV faults [1-2]. Furthermore, the area portion for peripheral circuitry is limited due to increase the net-die count. Therefore, the area overhead for TSV repair circuitry should be minimized as much as possible.

The TSV repair methods are classified into three kinds: signal shifting, signal switching, and signal routing. Signal shifting [3] has low area overhead but it is weak for clustered faults. Signal switching [1] has reasonable area overhead and better repair efficiency than the signal shifting, but not enough for clustered faults. Signal routing [4] has good repair efficiency but it needs too much area overhead to apply for 3D memories.

In this paper, an efficient TSV repair method is proposed for 3D memories. The proposed method uses a new 2-dimensional 1-4 switching technique to enable efficient repair of clustered TSV faults using reasonable area overhead for repair circuitry.

II. Proposed TSV Repair Method

A. Hardware Architecture

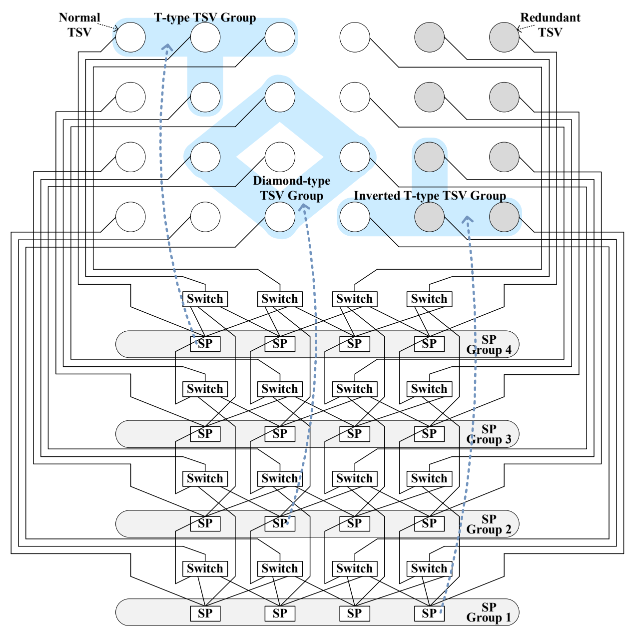


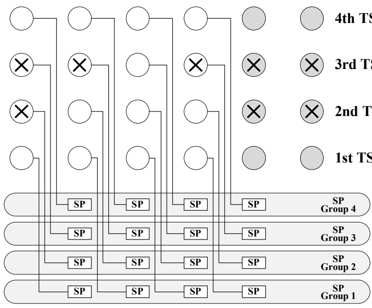
Fig. 1 Hardware architecture for the proposed TSV repair method

The proposed TSV repair method uses 2-dimensional TSV array and 1-4 switches enabling 4-directional path selection from a signal port to TSVs. Fig. 1 shows an example of 4x6 TSV array whose each row has 2 redundant TSVs and the paths from signal ports (SP) to TSVs through 1-4 switches. A TSV Group is defined as a set of TSVs connected with a signal port and it is classified into 3 types; diamond-type, inverted T-type, and T-type as shown in Fig. 1. In Fig. 1, the signal ports in SP Group 2, 3 are connected with diamond-type TSV Groups, and the signal ports in SP Group 1, 2 are connected with inverted T-type, T-type TSV Groups respectively.

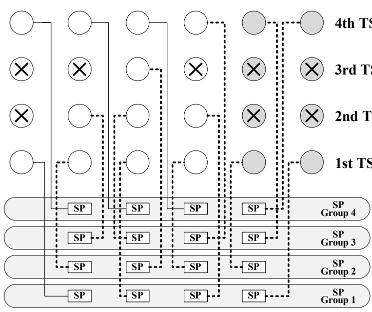
The TSV repair efficiency is dependent on the number of available redundant TSVs. Although the total number of redundant TSVs in a given TSV array is fixed, the number of locally available redundant TSVs for clustered TSV faults is variable according to the type of TSV Groups.

The proposed 2-dimensional TSV Groups enable TSV sharing between neighbored TSV rows. Therefore, in the given example of a TSV array, the maximum 8 redundant TSVs can be used for clustered TSV faults.

B. Repair Method



(a) Before TSV repair



(b) After TSV repair

Fig. 2 Example of the proposed repair method for clustered TSV faults

Fig. 2 shows an example of the proposed TSV repair for clustered TSV faults and the X-marked TSVs denote faulty TSVs.

Fig. 2-(a) shows the status before TSV repair of the TSV array with 8 faulty TSVs and the solid lines connecting signal ports and TSVs denote default connections. SP Group 1's signal ports are connected with their default TSVs in 1st TSV Row and other SP Group's signal ports are also connected with their corresponding default TSVs. 1st and 4th TSV Row doesn't have any faulty TSV and has 2 extra TSVs respectively. 2nd TSV Row has 3 faulty TSVs and lacks 1 TSV. 3rd TSV Row has 5 faulty TSVs and lacks 3 TSVs.

Fig.2-(b) shows the status after TSV repair and the dotted lines denote the changed connection between signal ports and TSVs. SP Group 1' signal ports are connected with 3 TSVs in 1st TSV Row and 1 TSV in 2nd TSV Row. SP Group 2's signal ports are connected with 3 TSVs in 1st TSV Row and 1 TSV in 3rd TSV Row. SP Group 3's signal ports are connected with 2 TSVs in 2nd TSV Row and 2 TSVs in 1st TSV Row. SP Group 4's signal ports are connected with 4 TSVs in 1st TSV Row. Such connections between signal ports and TSVs enables TSV sharing between neighbored TSV rows and fully utilizing the given 8 redundant TSVs for clustered TSV faults.

III. Experimental Results

For the simulation of repair rate, only 1,271,625 fault cases are used for 4x6 array since greater than 8 faults cannot be repaired with 8 redundant TSVs. Fig. 3 shows the repair rate comparision of the proposed one with the previous works. The un-repairable cases are clustered TSV faults and the repair rate depends on the number of locally available redundant TSVs. The number of locally available redundant TSVs for [3], [1],

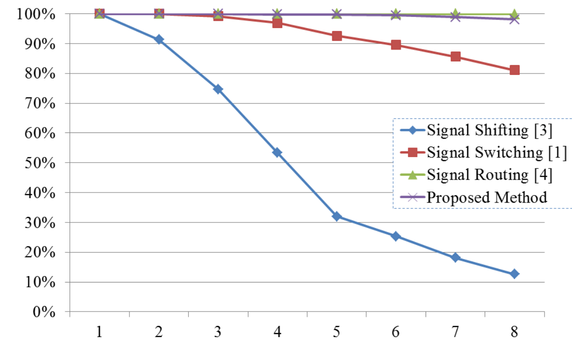


Fig. 3 Repair rates for the number of TSV faults

[4], and the proposed method is 1, 2, 2~8, and 8, respectively. If all TSVs in the any TSV Group are faulty, the proposed repair method can't repair such clustered TSV faults.

In general, the switch circuit is either MUX or DEMUX and its control signals are usually connected with fuses to keep the paths between signal ports and TSVs. TABLE 1 shows the repair circuitry comparision of the proposed one with the previous works (the parentheses denote the switch type).

The repair rate of the proposed method is 98.57% using the repair circuitry similar to the signal switching method [1].

TABLE I
H/W OVERHEAD FOR THE REPAIR CIRCUITARY

	[3]	[1]	[4]	Proposed
Switch Count	16 (1-2)	16 (1-3)	48 (1-3)	16 (1-4)
Fuse Count	16	32	80	32

IV. Conclusion

The proposed TSV repair method using a new 2-dimensional 1-4 switching technique enables efficient repair of clustered TSV faults using reasonable area overhead for repair circuitry. Therefore, the proposed TSV repair method can contribute the improvement of TSV yield for 3D memories.

Acknowledgment

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MEST) (No. 2010-0024707).

References

[1] U. Kang, H. Chung, S. Heo, D. Park, H. Lee, et al., "8 Gb 3-D DDR3 DRAM Using Through-Silicon Via Technology," *IEEE Journal of Solid-State Circuits*, 45(1):111-119, 2010.
[2] J. Kim, C. Oh, H. Lee, D. Lee, H. Hwang, et al., "A 1.2 V 12.8 GB/s 2 Gb Mobile Wide-I/O DRAM With 4×128 I/Os Using TSV Based Stacking," *IEEE Journal of Solid-State Circuits*, 47(1):107–116, Jan. 2012.
[3] I. Loi, S. Mitra, T. Lee, S. Fujita, L. Benini, "A low-overhead fault tolerance scheme for TSV-based 3-D network on chip links," *Proc. ICCAD 2008*, pp.598-602.
[4] L. Jiang , Q. Xu, B. Eklow "On effective TSV repair for 3D-stacked ICs", *Proc. Des. Autom. Test Eur. Conf. Exhibit.*, pp.6-11, 2012.