Extended Abstracts of the 2016 International Conference on Solid State Devices and Materials, Tsukuba, 2016, pp729-730

PS-4-04

Elliptical Pillar Duplication by Self-Aligned Double Patterning Technology

Augustin J. Hong[1], Jeongseop Shim[1], Mina Lee[1], Kiseok Lee[1], Kiwook Jung[1], Jiseok Hong[1], Hyejin Seong[1], Kwangmin Kim[1], Sungho Jeon[1], Yeram Kim[1], Jemin Park[1], Hyeongsun Hong[1], Kyupil Lee[1] and ES Jung[1]

[1] Samsung Semiconductor Research & Development Center
San #16 Banwol-Dong, Hwasung-City, Gyounggi-Do, 445-701, Korea
Phone: +82-31-8037-0615 E-mail: hj.augustin@samsung.com

Abstract

The self-aligned double patterning (SADP) technology has gained great attention to overcome the resolution limit of ArF immersion (ArFi) lithography. Here, we suggest and demonstrate a novel elliptical pillar SADP scheme which can extend manufacturability of the SADP technology to the elliptical pillar duplication. Critical dimension (CD) is addressed in 2 directions (X, Y) to understand 2 dimensional (2D) CD controllability of the proposed scheme. The self-generated pillar CDs in 2 orthogonal directions are measured to be matched within 2% and 1% margin from the CD target for X and Y respectively. Furthermore, unique CD uniformity (CDU) behavior between the core pillar and the self-generated pillar is discovered.

1. Introduction

As the technology node decreases to the extreme, conventional lithography technique by ArF immersion (ArFi) cannot be used due to its resolution limit. Although extreme ultraviolet (EUV) lithography has been developed to overcome ArFi resolution limit, several challenges such as higher source power for better throughput, numerical aperture improvement for higher resolution, resist and mask improvement to give sufficient pattern quality are known to make EUV lithography inappropriate for mass production yet [1]. Self-aligned double patterning (SADP) technology is another promising way to achieve resolution beyond ArFi, which uses spacer material to double the pattern defined by lithography [2]. Ultimately, line array formed by this SADP technology has been successfully applied in mass production for sub-30 nm NAND flash memory [3]. In case of forming 2D patterns such as hole or pillar for sub-20 nm node memory technologies, litho-etch/litho-etch technology (LELE) is considered to be the easier choice than SADP technology because initial core mask can represent the final pattern directly. However, overlay control is critical for tight pitch patterns [4]. Multiplying circular hole array in a symmetric cell pitch using the SADP technology has been recently reported, which was adopted to form honeycomb structure capacitor array for 20 nm node DRAM development [5]. In this letter, we suggest and demonstrate a novel scheme to duplicate elliptical core pillar array in an asymmetric rectangular cell pitch using SADP technology. By this scheme, we can not only overcome overlay control challenge of the widely used LELE process but also save process cost significantly for the elliptical pillar formation in sub-20 nm node memory development by minimizing photolithography steps. Furthermore, we demonstrate CD controllability and CD uniformity (CDU) of the elliptical pillar array resulted from the proposed scheme.

2. Results

Fig.1 shows the process flow of the elliptical pillar SADP scheme. First, lithography is done using ArFi and then after development inspection (ADI) is done to measure CD and CDU. Etch process follows to form core pillar (C-pillar) array (Fig.1a). To quantify the elliptical pillar CD and CDU, 2D parameters are denoted as X_1, Y_1 for the C-pillar and X_2, Y_2 for the self-generated pillar (S-pillar). An atomic layer deposition (ALD) oxide is used as the sidewall spacer (Fig.1b). After coating carbon filler and etch back process, carbon etch mask for S-pillar pattern is formed (Fig.1c). Oxide spacer between C-pillar and S-pillar mask is selectively removed by an oxide etch process to separate C-pillar and S-pillar array (Fig.1d). Finally, pillar array duplication is completed by elliptical patterns transferred to the target pattern layer with improved circularity and both X, Y CD targeted (Fig.1e). Fig. 2 shows experimental results of the proposed pillar SADP technology. Fig.2a and 2b shows the step by step X, Y CD values normalized to the CD target. It is critical to note that the S-pillar can be matched within 2% and 1% margin from the X and Y CD target. This result proves that 2D CD control of the self-generated pillar is possible in the level of manufacturing requirement using the proposed scheme. Fig 2c shows top, vertical scanning electron microscope (SEM) images of the elliptical C-pillar and S-pillar array corresponding to the pillar SADP process steps. Overall pillar density is doubled after the oxide etch step and S-pillar circularity is improved through the final etch process. Fig.3 shows that final X CDU of the S-pillar X_2 (4.22 nm at the final etch) is superior to the final X CDU of the core pillar X_1 (5.09 nm at the final etch). However, final Y CDU of the S-pillar Y_2 is degraded than C-pillar Y CDU Y_1. This unique CDU behavior of the proposed scheme implies that X CDU of the C-pillar affects Y CDU of the S- pillar more dominantly while Y CDU of the C-pillar heavily affects X CDU of the S-pillar when elliptical pillars to be duplicated by the SADP technology. Experimental results in Fig.3 also suggest that S-pillar CDU can be further improved if the CDU at photolithography (ADI) can be improved.

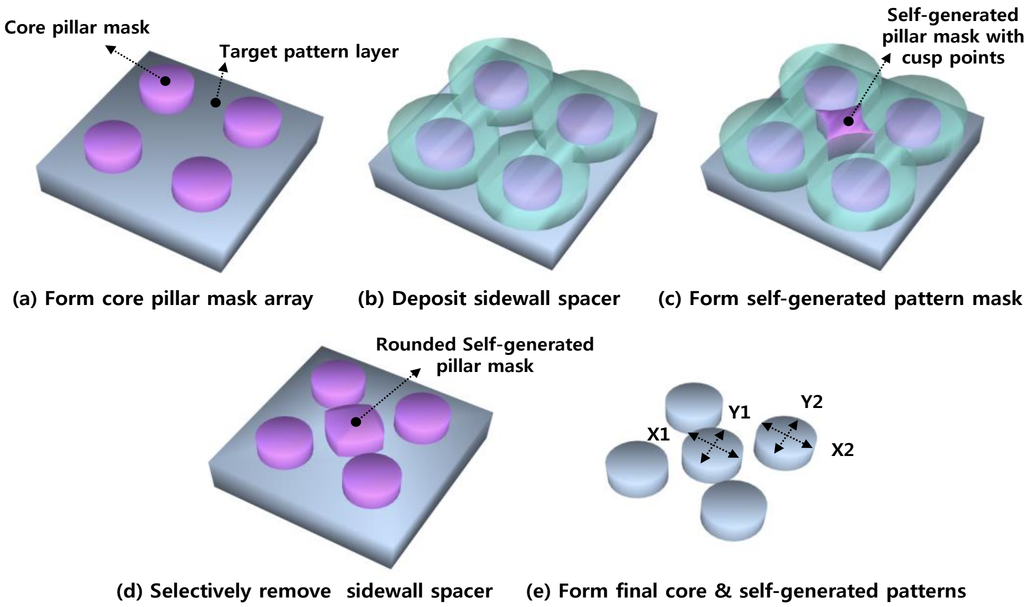

Fig.1 Schematic process flow of the elliptical pillar duplication by self-aligned double patterning technology

Therefore, improving lithographical inputs such as resist or resist develop method must be accompanied for more robust elliptical pillar SADP scheme development

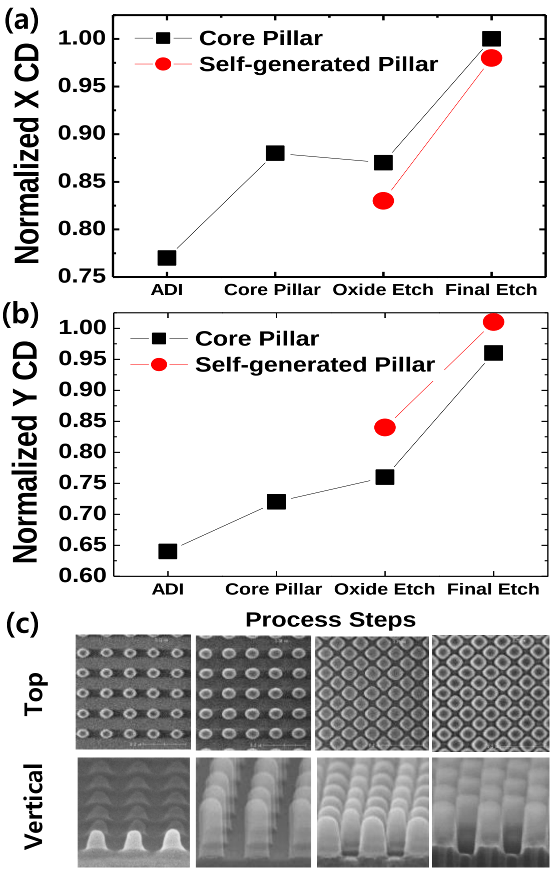

Fig. 2 Step by step (a) X and (b) Y CD controllability and (C) Top, vertical SEM images

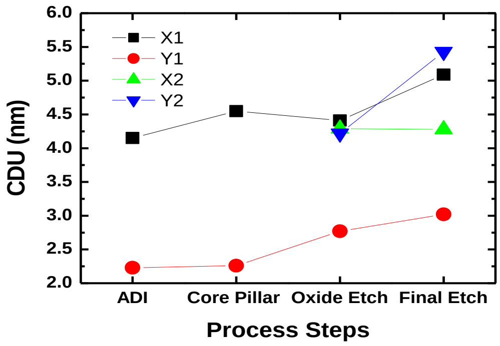

Fig.3 Step by step CDU values of the core pillar (X_1, Y_1) and the self-generated pillar (X_2, Y_2).

3. Conclusions

A novel scheme to duplicate the lithographically defined core elliptical pillar array is suggested based on SADP technology. We experimentally demonstrate that 2D CD of the self-generated pillar pattern formed by SADP technology can be matched with the CD target. Also, unique CDU behavior of the self-generated pillar pattern is discovered and analyzed. Hence, proposed elliptical pillar SADP scheme is feasible and can be a promising candidate as a cost effective and misalign free pillar formation scheme to enable next generation memory device in production.

References

[1] ITRS 2013 Edition: Lithography Summary, <http://www.itrs.net/Reports.html>
[2] Y. K. Choi, T. J King and C. Hu *IEEE Trans. Electron Devices*, 49(3), 436. (2002)
[3] B. Hwang et al., *Solid State Device Research Conference*, 2009. p. 269-271. (2009)
[4] W. L. Kuo, *Proceedings of SPIE* Vol. 8682, 86821G-1 (2013)
[5] J. Park, et al., *International Electron Device Meeting*, 677 (2015).