Double Patterning of Contact Array with Carbon Polymer

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ABSTRACT

The spacer patterning technique (SPT) is well known as one of the methods expanding the resolution limit and mainly useful for patterning line & space of memory device. Although contact array could be achieved by both spacer patterning technique and double exposure & etch technique (DEET) [1], the former would be preferable to the latter by the issues of overlay burden and resolution limit of isolated contact. The process procedure for contact array is similar to that for line & space which involves the 1st mask exposure, etch, carbon polymer deposition, the 2nd mask exposure and etch step sequentially. With SPT, it would be possible to realize contact array of 30nm half pitch including 30nm isolated contact as well as line & space of 30nm half pitch.

Keywords: Double Patterning, Amorphous Carbon Spacer, Si BARC

1. INTRODUCTION

Based on this study, SPT will be the most effective method to realize line & space pattern under 40nm. SPT can be divided into negative type in which spacer remains as space and positive type in which spacer is finally patterned as line. On deciding which type of SPT is more suitable for contact array, the number of process step and CD uniformity can be major factors. Even though both of negative SPT and positive SPT are available for array contact, we considered negative SPT more preferable to positive SPT to define smaller isolated contact as well as contact array without increasing NA of scanner or additional process steps.

2. PROCESS STEP REDUCTION

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Line & space pattern obtained with negative SPT consists of 1st line, 2nd line, and space. 1st line is originated from the line on Mask A, 2nd line is from Si BARC which fills the gap between spacers deposited on 1st lines and space pattern is formed from spacer deposition on 1st line. In the previous paper [2, 3], we had adopted poly Si as 1st line material (Figure 1), but deposition of poly Si induced some limitation on choosing hard mask material due to thermal budget of poly Si. Eventually this limitation made process scheme of negative SPT more complex than we expected. By suggesting Si BARC as 1st line material (Figure 2), we can avoid thermal budget and reduce 14 process steps into 6 process steps. 6 process steps consist of Mask A, Si BARC etch, carbon polymer deposition, Mask B, Si BARC etch back and carbon polymer & spin on carbon (SOC) etch (Figure 3). Mask A step includes SOC coating, Si BARC coating, BARC coating and photo resist coating. Mask B step also needs Si BARC coating and photo resist coating in the case of realizing contact array. By choosing some materials more properly, we can expect that the negative SPT would be applied for mass production more easily.

3. CD UNIFORMITY

Since process flow of negative SPT for contact array is very similar to one of negative SPT for line & space, it would be meaningful to check CD uniformity of negative SPT for line & space prior to evaluate negative SPT for contact array. We measured inter-field CD uniformity and LWR at the final step, and added mask A step and Si BARC etch step to analyze which steps have a negative effect on CD uniformity and LWR. Figure 4 shows the results of CD uniformity at each step. In mask A step, we obtained good CD uniformity of 1.8nm on resist line patterns, but CD uniformity of the line pattern after Si BARC etch increased to 5.2nm. After final SOC etch, inter-field CD uniformity data of 1st line, 2nd line and space were 5.2nm, 3.4nm and 4.1nm respectively; the result that CD uniformity of 2nd line is better than one of 1st line is different from that we expected. Figure 4(f) indicates that the abnormal result is from the property of carbon polymer deposition equipment; deposition thickness of carbon sidewall spacer was thick at the region where CD of 1st line is low, while one of carbon sidewall spacer was thin at the region where CD of 1st line is high. Therefore, we need to modify recipes for Si BARC etch and carbon polymer deposition to obtain good CD uniformity for mass production. Although Figure 5 suggests acceptable results that LWR data of 1st line and 2nd line were 2.9nm, nm and 2.0nm respectively, additional improvement of LWR of 1st line is needed for mass production. From the result that LWR of 1st line became worse through Si BARC etch, we may conclude that LWR of 1st line can be improved by optimization of BARC etch recipe.

4. EXPERIMENT

Figure 6 and Figure 7 show process flow for contact array and isolated contact, respectively. We coated in regular process sequence SOC of 2200Å, Si BARC of 500Å and BARC of 330Å at mask A step. Half pitch of 60nm line & space pattern was exposed on photo resist of 1000 Å under the illumination condition of ArF wet 0.93NA with dipole.

After Si BARC etch, we deposited fluorocarbon polymer (which has been made by Lam Research Co., Ltd) of 200Å along the side wall. At mask B step, we coated Si BARC of 500Å in order to fill the gap between each 1st line. ArF Dry 0.93NA is used for exposing Mask B. After development, photo resist on the region where contact patterns should be placed was removed, and Si BARC etch back was done to expose carbon polymer. With removing fluorocarbon polymer and SOC by O2 plasma sequentially, contact array patterning was finally achieved.

5. RESULTS

Figure 8 and Figure 9 provide top view images at each step for contact array and isolated contact respectively. Also, Table 1 shows that CD uniformity data of contact array and isolated contact match are similar to simulation data that we obtained with the following equation: CD uniformity of 2nd line=√{(CD uniformity of 1st line)^2+(2*CD uniformity of spacer)^2}. Although we failed to keep CD balance of contact array, we succeeded in patterning isolated contact with negative SPT as well as contact array. In addition, we confirmed that isolated contact can be easily formed via negative SPT without using high NA illumination; normal pattern transfer for isolated contact needs high NA illumination. Figure 10 implies that mask A has enough DOF margin in patterning 60nm half pitch with ArF wet 0.93NA with dipole. With these results, we can predict the resolution limit of contact array with negative SPT as in Figure 11.

7. SUMMARY

Negative SPT has been chosen to realize isolated contact as well as contact array. Before adopting negative SPT, we found that remarkable process step reduction could be achieved by substituting Poly Si with Si BARC as a material of 1st line and 2nd line. Even though inter-field CD uniformity result could not satisfy the condition for mass production, it was found that this problem can be resolved by optimizing process conditions such as Si BARC etch recipe. With the result that enough DOF margin was obtained under the illumination condition of ArF /0.93NA for 60nm half pitch, we can expect 21nm half pitch contact array might be obtained with the combination of 1.35NA ArF scanner and negative SPT.

8. REFERENCES

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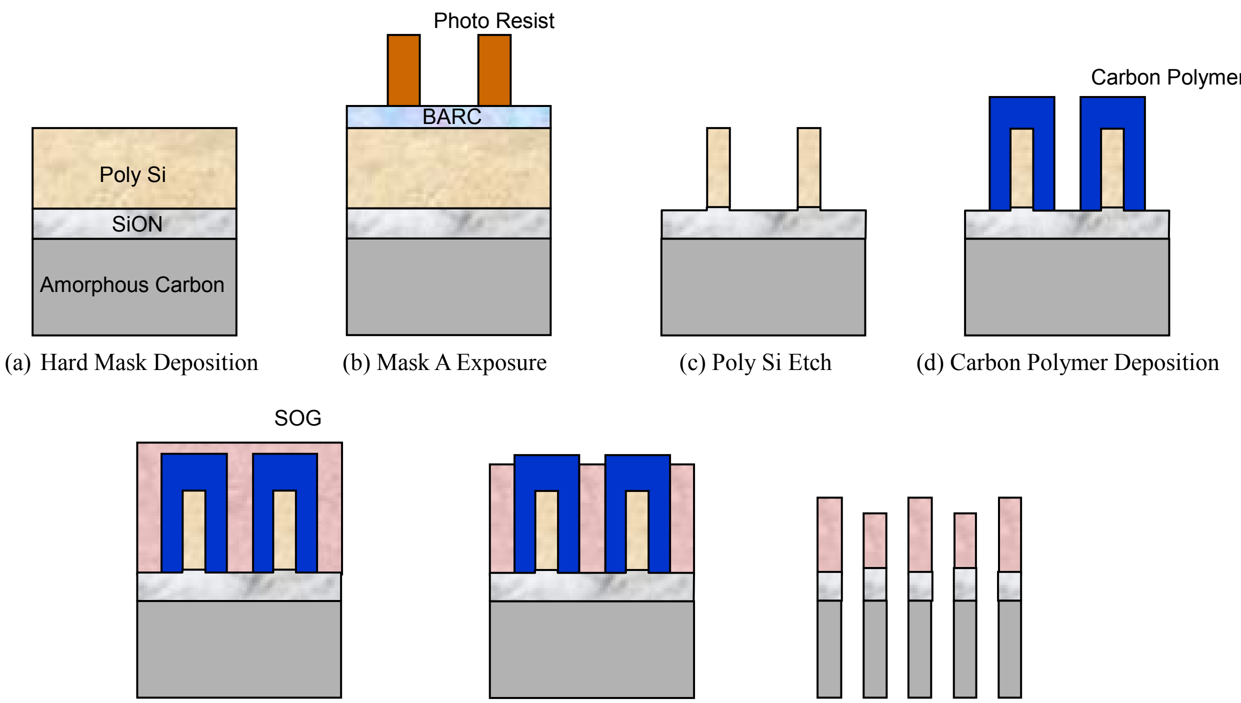
[2] Woo-Yung Jung, "Patterning with Spacer for Expanding the Resolution Limit of Current Lithography" Proceedings of SPIE, Optical Microlithography SPIE, 6156(2006)

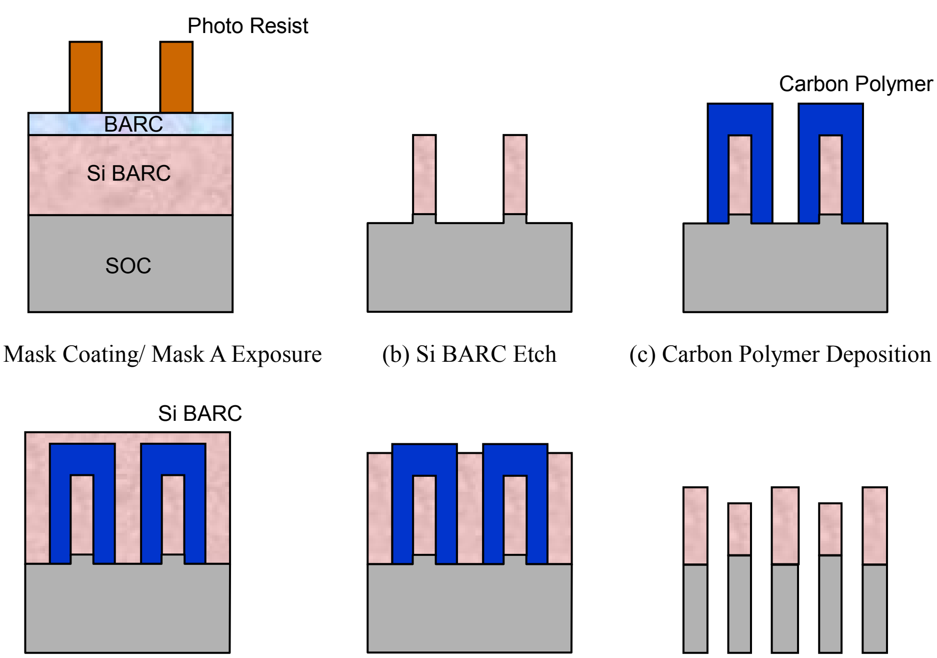
[3] Woo-Yung Jung, "Patterning with Amorphous Carbon Spacer for Expanding the Resolution Limit of Current Lithography Tool" Proceedings of SPIE, Optical Microlithography SPIE, 6520(2007)



(a) Hard Mask Deposition (b) Mask A Exposure (c) Poly Si Etch (d) Carbon Polymer Deposition

e) SOG Coating f) SOG Etch-back g) Polymer Strip/ Carbon Etch

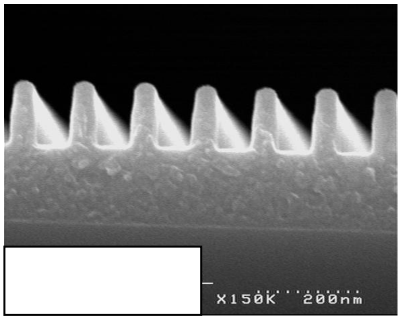
Figure 1. Process flow for negative SPT on poly Si.



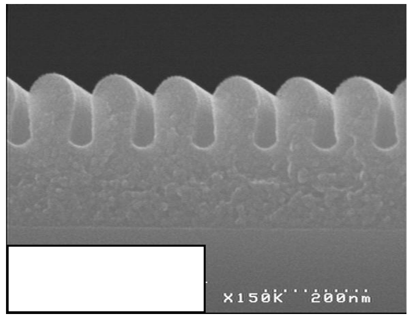
(a) Hard Mask Coating/ Mask A Exposure (b) Si BARC Etch (c) Carbon Polymer Deposition

d) Si BARC Coating e) Si BARC Etch-back f) Polymer Strip/ SOC Etch

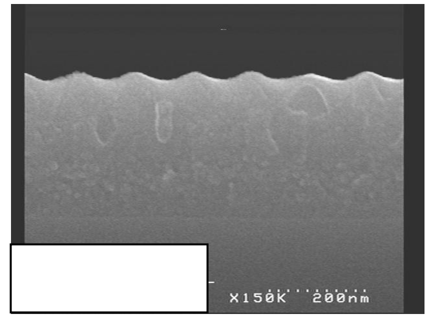
Figure 2. Process flow for negative SPT on Si BARC.



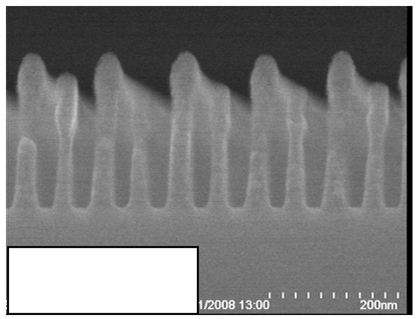
(a) Si BARC Etch



(b) Carbon Polymer Deposition

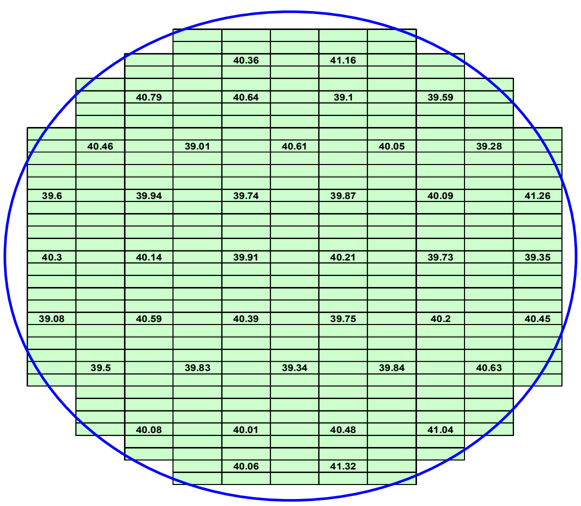


(c) Si BARC Coating

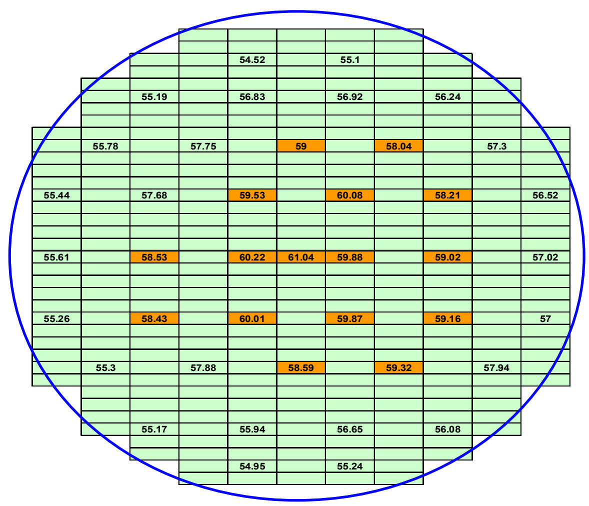


(d) Polymer Strip/ SOC Etch

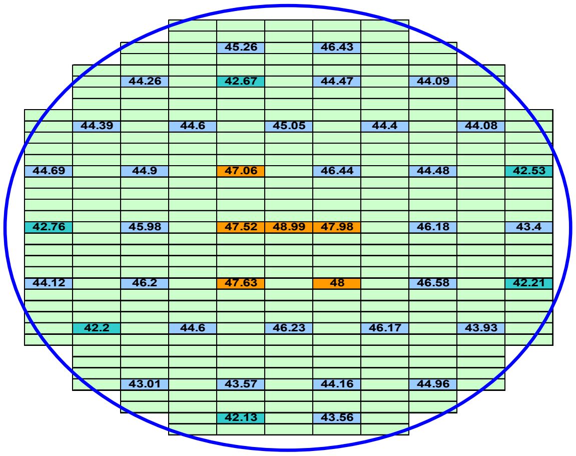
Figure 3. SEM cross section of negative SPT on Si BARC.



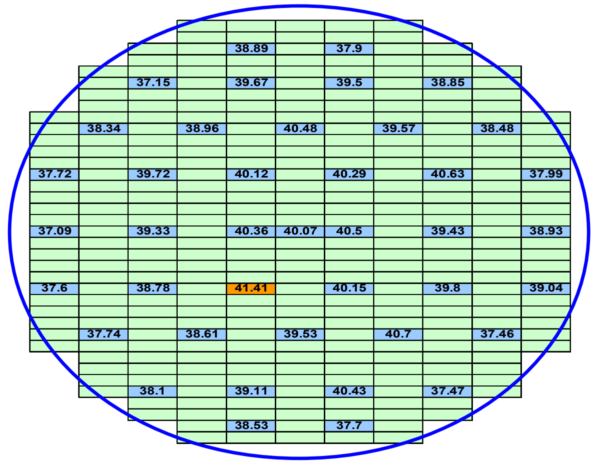
(a) Line CD after Mask A Exposure (3σ=1.8nm)



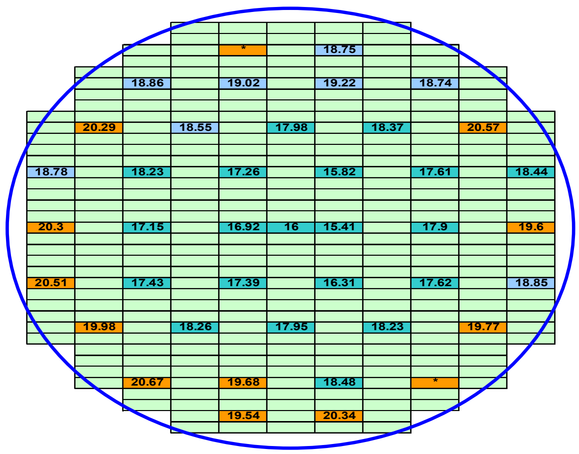
(b) Line CD after Si BARC Etch(3σ=5.4nm)



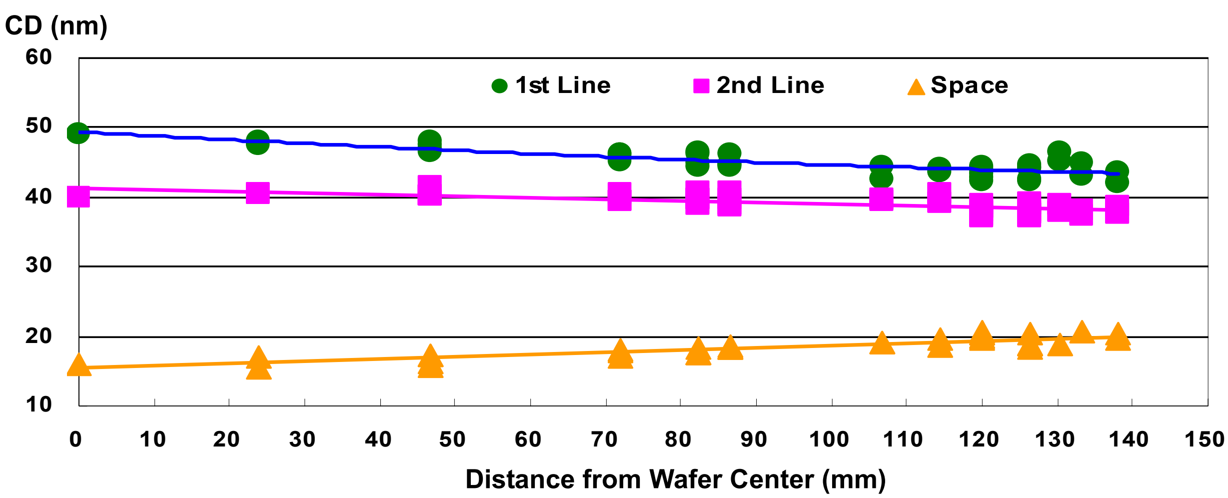
(c) 1st Line CD after Polymer Strip & SOC Etch(3σ=5.2nm)



(d) 2nd Line CD after Polymer Strip & SOC Etch (3σ=3.4nm)

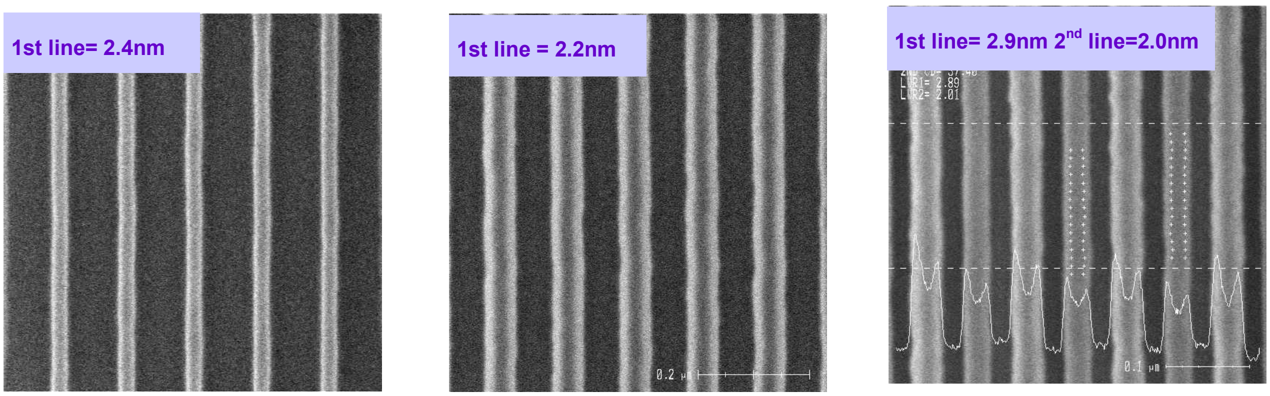


(e) Space CD after Polymer Strip & SOC Etch (3σ=4.1nm)



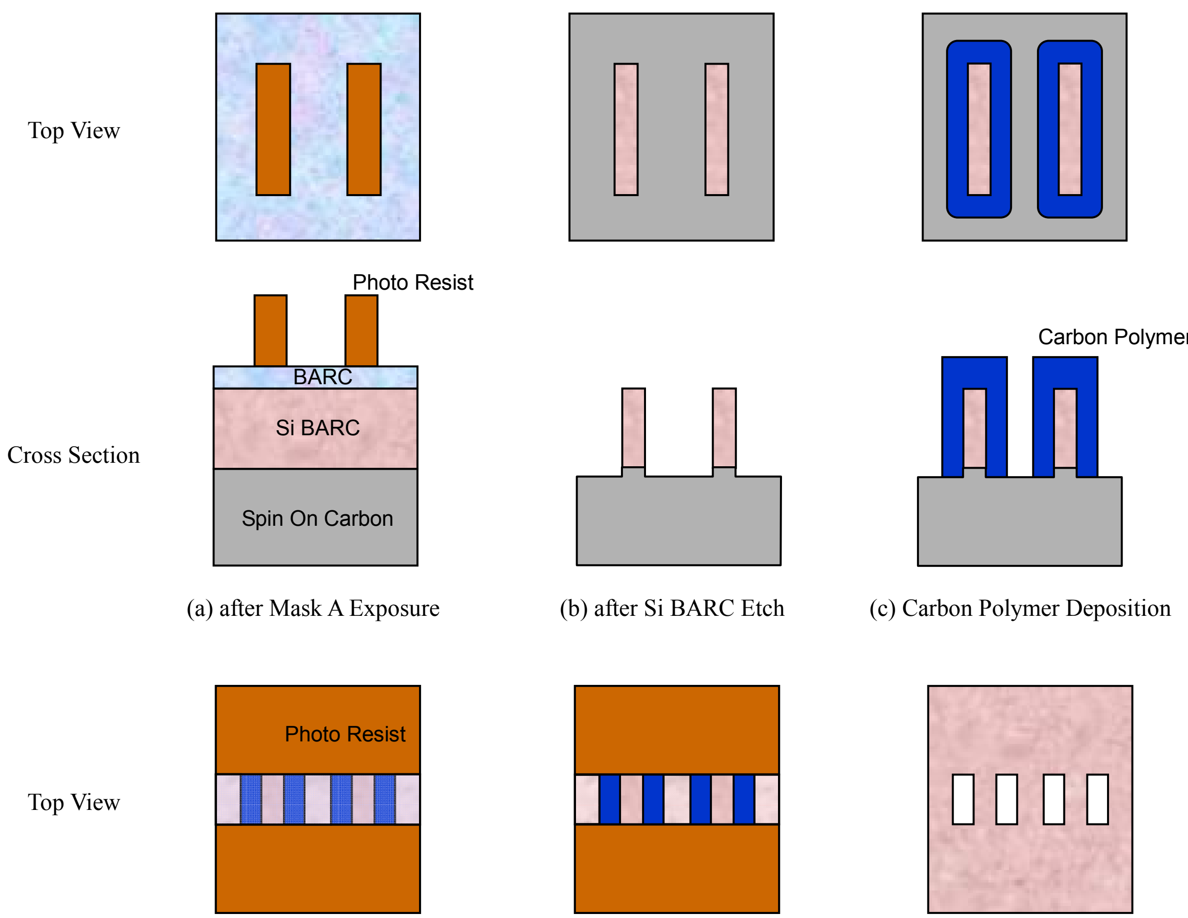
(f) CD Dependence on Wafer Position

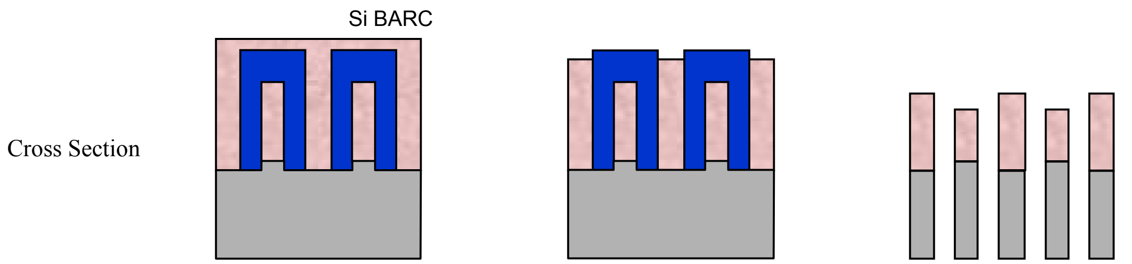
Figure 4. Inter-field CD uniformity of negative SPT on Si BARC.



(a) after Mask A Exposure (b) after Si BARC Etch (c) after Polymer Strip and SOC Etch

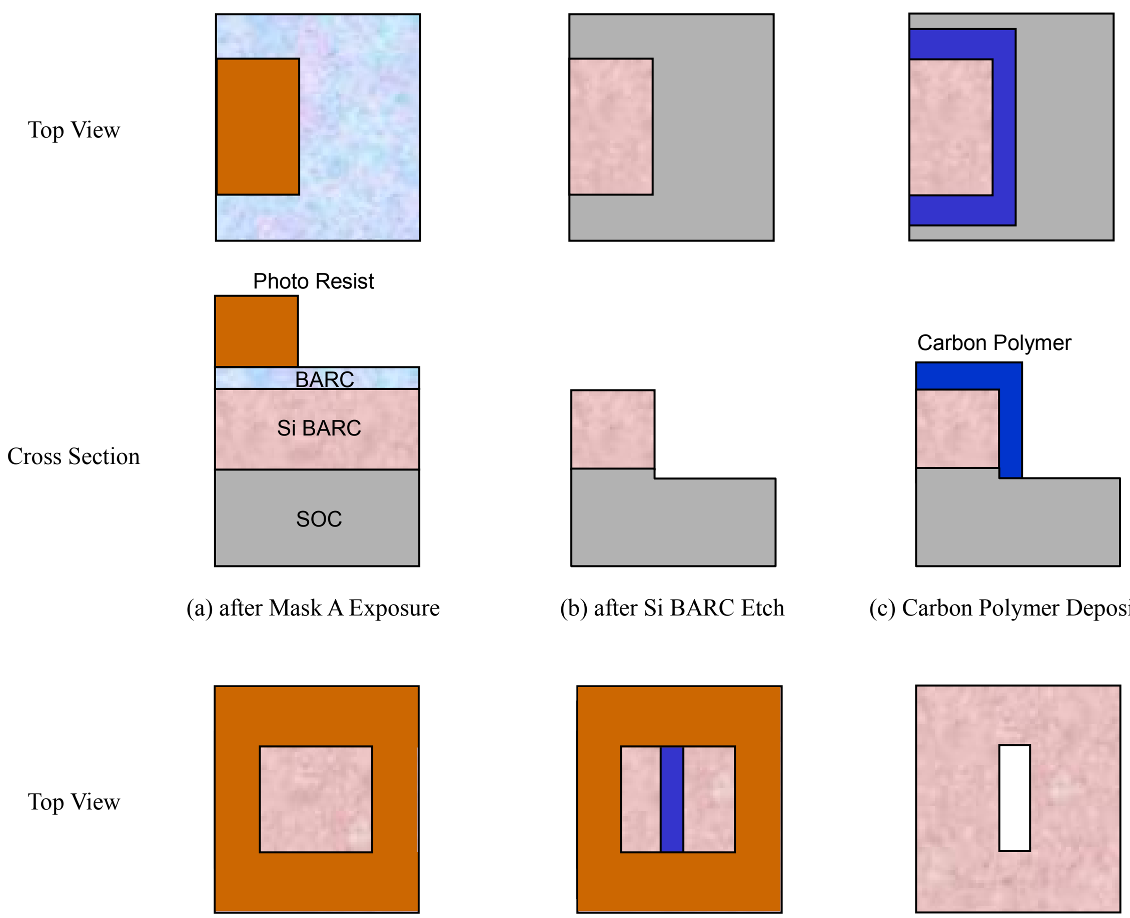
Figure 5. LWR of of negative SPT on Si BARC.



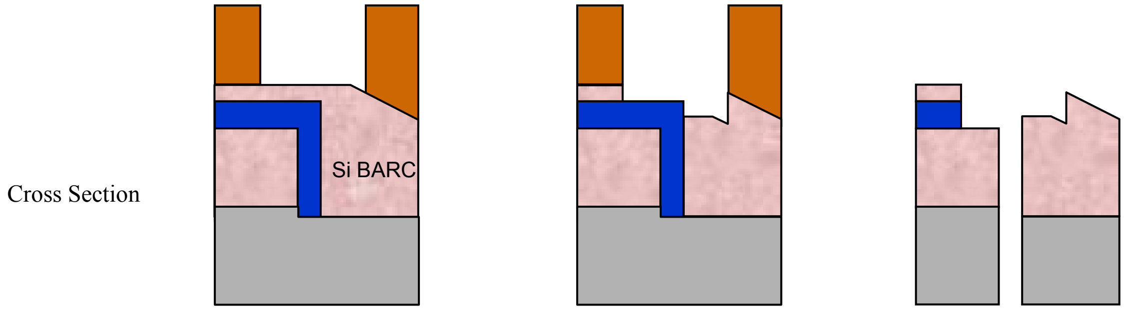


d) Si BARC Coating/ Mask B Exposure e) Si BARC Etch-back f) Polymer Strip/ SOC Etch

Figure 6. Process flow for contact array with negative SPT.

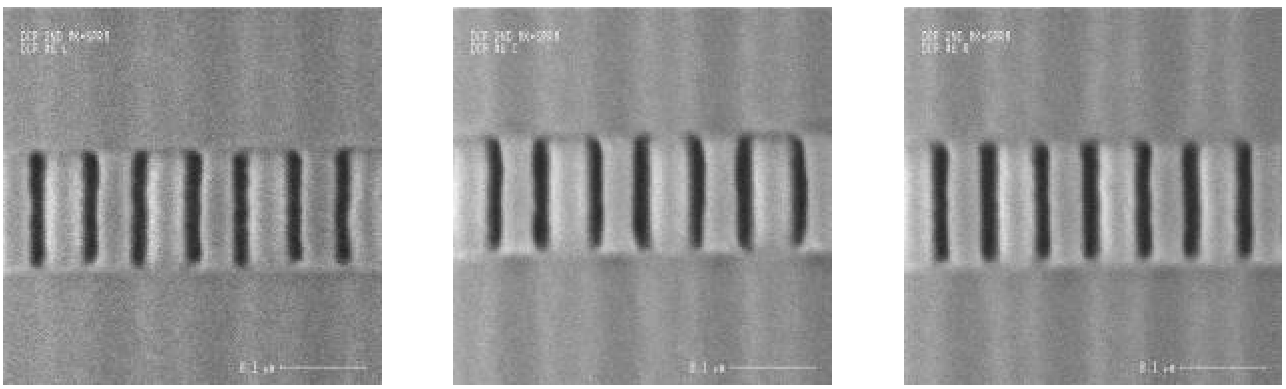


(a) after Mask A Exposure (b) after Si BARC Etch (c) Carbon Polymer Deposition



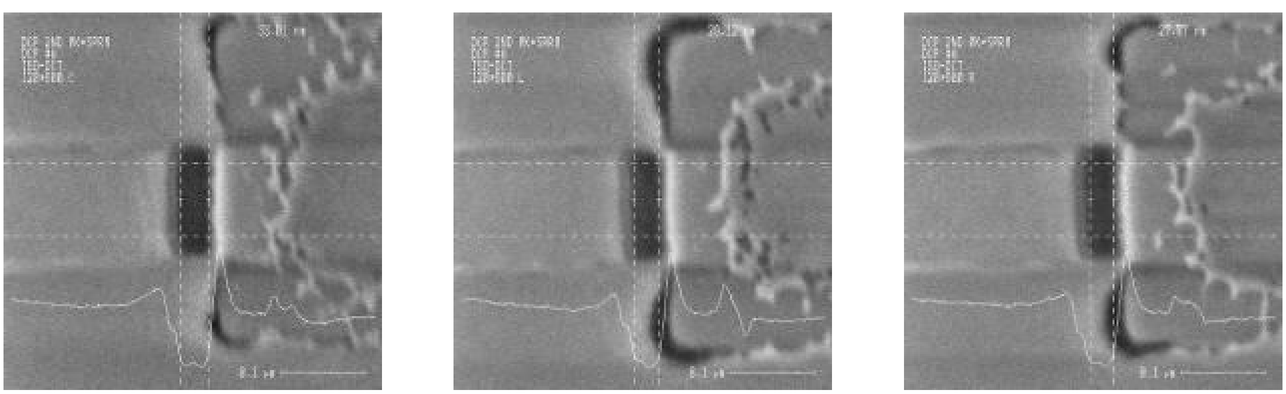
d) Si BARC Coating/ Mask B Exposure e) Si BARC Etch-back f) Polymer Strip/ SOC Etch

Figure 7. Process flow for isolated contact with negative SPT.



(a) Left (b) Center (c) Right

Figure 8. Top view of contact array with negative spacer patterning technique.



(a) Left (b) Center (c) Right

Figure 9. Top view of isolated contact with negative SPT.

Pattern	1st Bar(3sig.)	2nd Bar(3sig.)	Space(3sig.)
Contact Array	4.4nmnm	5.1nmnm	1.7nmnm
Isolated Contact	-	-	4.7nmnm

Table 1. Inter-field CD uniformity of contact array and isolated contact.

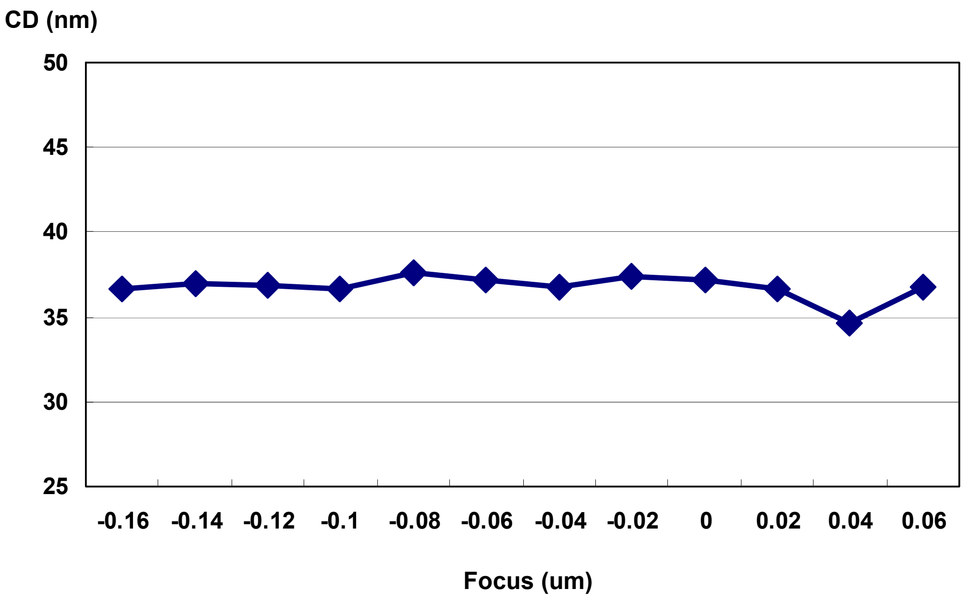


Figure 10. DOF margin of mask A.

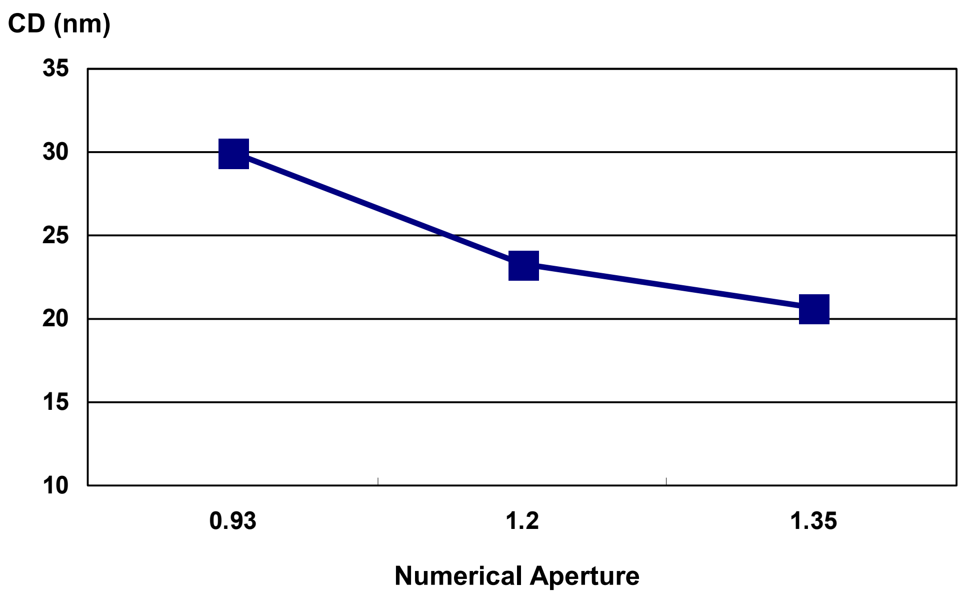


Figure 11. Resolution limit of contact array with negative SPT.