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The Disk Shape Stacked Capacitor Cell for 256Mb DRAM

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A new cell structure with the disk shape stacked capacitor is proposed for 256 Mb DRAM. The disk shape storage node is formed on the outer side wall of cylindrical storage node in self-aligned manner. The disk shape stacked capacitor needs no extra lithography process except that of cylinder one. It is estimated that the capacitance of 30fF/cell can be obtained in the 0.5 μm storage node height in a 0.72 μm^2 cell area. The electrical characteristics of the proposed capacitor with ON dielectric film (teq=5nm) is also studied.

1.INTRODUCTION

The reduction in memory cell area is necessary for realizing high density DRAM, therefore various three dimensional memory cell structures have been proposed. In the case of 256 Mb DRAM, as the cell area is 0.72 μm^2, a simple stacked capacitor (STC) can't obtain a sufficient capacitance. For this reasons, the major memory cells have the STC of cylinder [1] and fin [2] structure.

In the cylindrical STC, as the cell area is reduced, it is necessary that the storage node height is increased for sufficient capacitance. Another way, HSG-Si [3] is reported. In the fin structure, the sufficient capacitance is provided by increasing the number of fin storage nodes, but the layout area of storage node is limited by lithography process.

In this paper, we propose the disk shape stacked capacitor cell for 256Mb DRAM [4]. This structure is formed on the side wall of cylindrical storage node by using self-aligned manner, therefore the increasing with the layout area of storage node is more than 30% for using lithography process. The lithography process of disk shape storage node is the same as that of the cylinder shape. The storage node height is estimated 0.5 μm for capacitance of 30fF/cell. The disk shape stacked capacitor, to which ON dielectric film is applied, is investigated in regard with the electrical characteristics.

2.CELL CONCEPT AND STRUCTURE

Figure 1 shows the schematic cross section of this structure. The new structure has the disk shape storage node. The storage node is formed on the top of the word and the bit lines. The distance between storage nodes of 0.1 μm can be realized. Figure 2 shows the SEM photograph of disk shape storage node with the height of 0.5 μm. The fine structure of five disks is obtained. The vertical distance between disks is 50nm and the distance between storage nodes is less than 0.1 μm.

3.FABRICATION PROCEDURE

Figure 3 shows the fabrication procedure of disk shape stacked capacitor cell.

(a) After the isolation regions and the active transistor with self-aligned side wall spacer are defined, thick silicon dioxide film is deposited and the hole is defined on doping area. Then poly-Si is filled in this hole, and silicon nitride and silicon dioxide is deposited alternately by LPCVD. The contact hole is defined on poly-Si plug, silicon dioxide film is etched selectively by HF wet etching (side etching). The side etching process controls the space between storage nodes by using self-align manner. In the space of 0.1 μm between storage nodes, 0.55 μm^2 layout area of storage node can be realized.

(b) When P doped poly-Si is deposited by CVD, it is deposited for the space between silicon nitrides,

and disk structure is formed on sidewall of cylinder by using self-align manner. Then hole is filled with resist, and the poly-Si on the top surface is removed by RIE.

(c) Then silicon nitride and silicon dioxide is removed by wet etching of HF and H_3PO_4, and disk shape storage node is formed, as shown in Fig.2. The following dielectric film formation, which is multilayer of silicon nitride and silicon dioxide, and upper cell plate formation are the same as the conventional fabrication procedure.

4.RESULTS AND DISCUSSION

Figure 4 shows that the estimation with storage capacitance of various storage node height in 0.72 μm^2 cell area. In this case, the layout areas of storage node are 0.55 μm^2 (disk) and 0.4 μm^2 (cylinder), the thickness of the storage node poly-Si is 50nm and that of the dielectric film is 5nm of SiO_2 equivalent thickness (teq). It is clear that the storage capacitance of more than 30fF/cell can be obtained in 0.72 μm^2 cell area with 0.5 μ m storage node height.

Figure 5 shows the measured and calculated storage capacitance as a function with the layout area of storage node. This sample is 33,000 disk shape stacked capacitor arrays and the dielectric film is SiO_2/Si_3N_4 double layer (teq=4 or 5nm). The diameter of disk is 1.26 μ m, the length of disk is 0.15 μ m, and the thickness of storage node is 50nm. The calculation and measurement are in good agreement. In the case of 256Mb DRAM, we investigate that five disks are necessary for 30fF/cell at the area of storage node is 0.4 ~0.5 μm^2.

Figure 6 shows the leakage current density with the disk shape capacitor array. The dielectric film is SiO_2/Si_3N_4 double layer (teq=5nm). The low leakage currents, less than 2nA/cm^2 at cell-plate voltage $\pm$1.5V, could be achieved. At the bias of 1.0V, the leakage current is satisfactorily low for applying to DRAM.

Figure 7 shows the dependence of time to failure on the effective field in TDDB with the disk shape stacked capacitor array. The thickness of the dielectric film is 5nm of SiO_2 equivalent thickness. From this results, the time to failure is estimated over 10 years at positive and negative electric field of 2.0MV/cm (half Vcc=1.0V). The disk shape stacked capacitor with SiO_2/Si_3N_4 double layer dielectric films applied have sufficient lifetime for 256Mb DRAM.

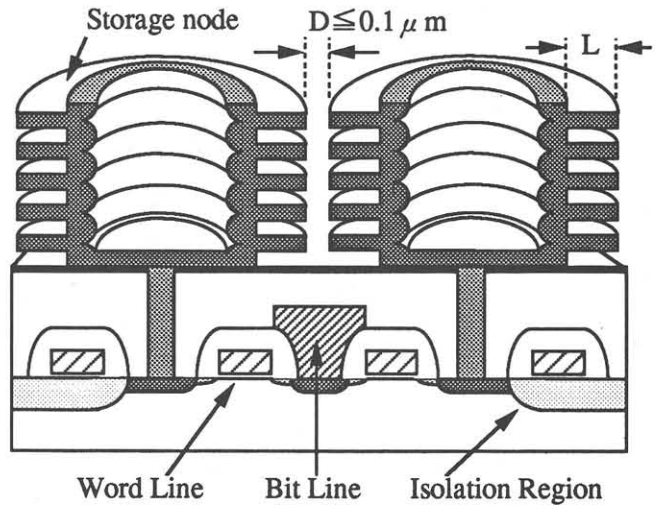

Fig.1 Schematic cross section of memory cell using the disk shape stacked capacitor

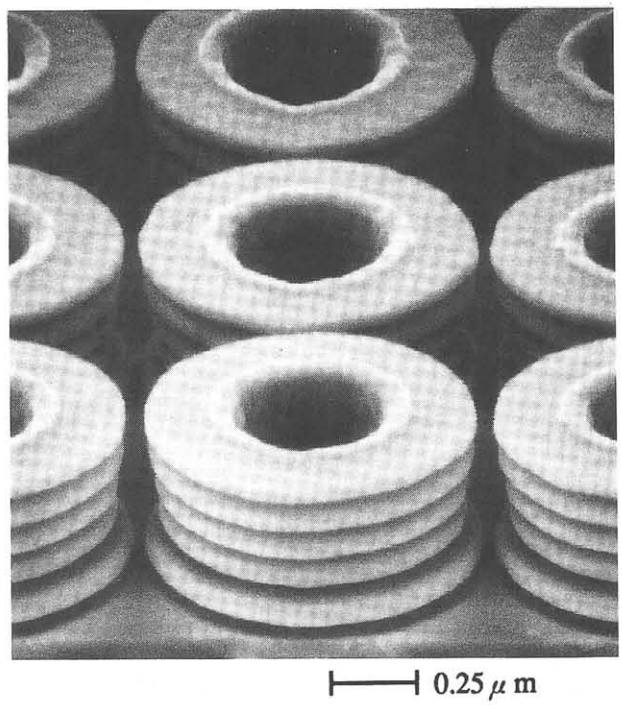

Fig.2 SEM of disk shape storage node

5.CONCLUSION

The disk shape stacked capacitor structure has been developed. This evaluation shows that the disk shape stacked capacitor has high potential to realize 256Mb DRAM.

ACKNOWLEDGEMENTS

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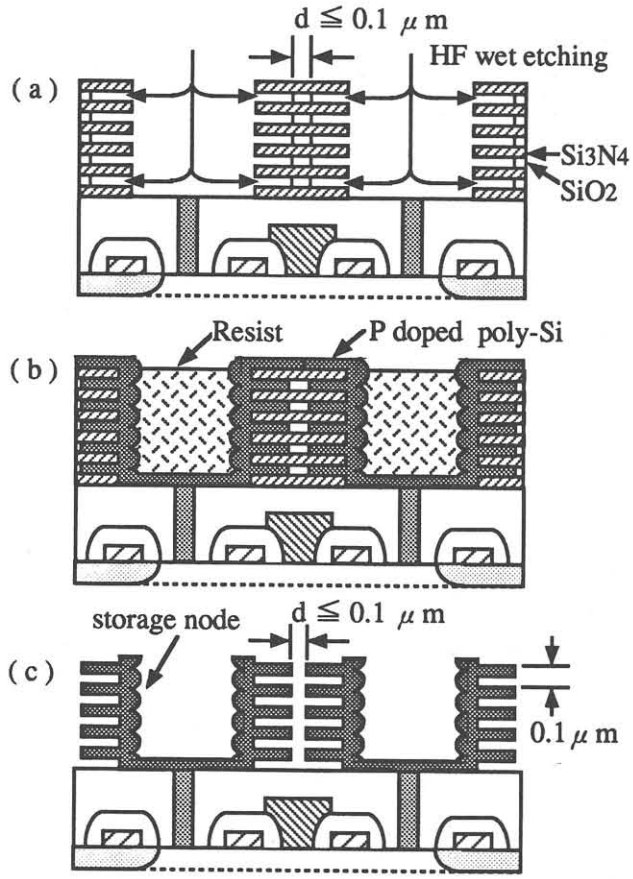

Fig.3 Fabrication Procedure

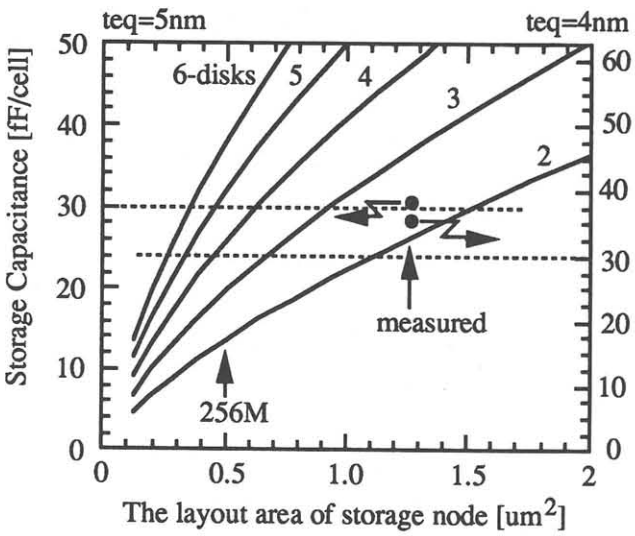

Fig.5 Calculated and measured storage capacitance

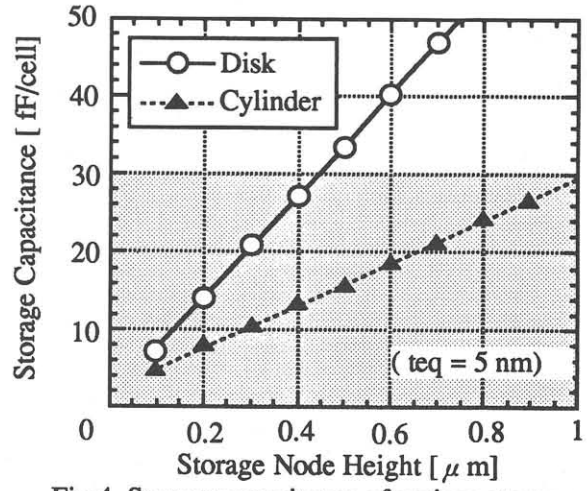

Fig.4 Storage capacitance of various storage node height (cell area=0.72 μm^2)
SN area=0.4 μm^2(cylinder)
0.55 μm^2(disk)

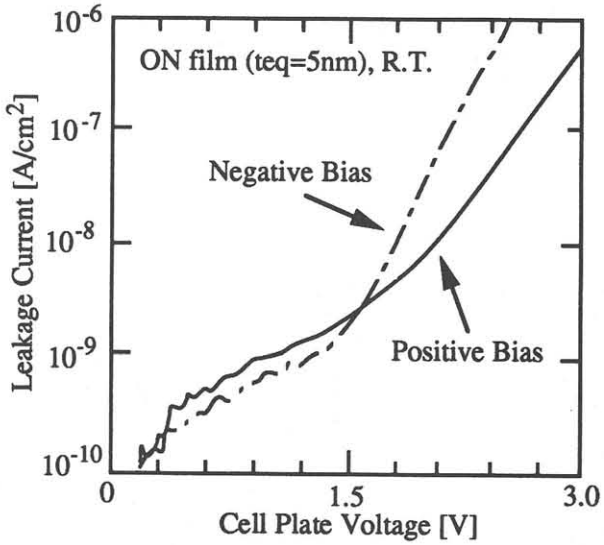

Fig.6 Leakage current with dielectric film of disk shape stacked capacitor

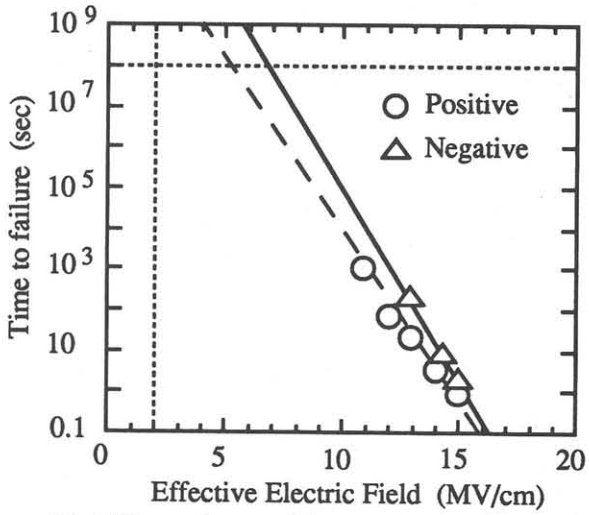

Fig.7 Dependence of time to failure on the effective field in TDDB with the disk shape stacked capacitor

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