S10-3

Challenges and Prospects of Advanced Plasma Process Technology 2
先端プラズマプロセス技術の課題と展望２

Toshihisa Nozawa
野沢俊久

Tokyo Electron LTD, TEL Sendai Technology Center Sendai
1 Techno Hills, Taiwa-cho, Kurokawa-gun, Miyagi 981-3629, Japan
東京エレクトロン株式会社　TELテクノロジーセンター仙台
〒981-3629宮城県黒川郡大和町テクノヒルズ1番

The plasma process has evolved as a key technology for semiconductor manufacturing. Extensive research and development efforts on the plasma process technology especially on the etching process have been done, and great progress have been achieved in practice.　Low temperature plasma process for beyond 10 nm nodes such as advanced thin film deposition technology using plasma CVD and ALD are facing more stringent requirements. The challenges and prospects of these techniques are described herein.

1. Background

The state-of-the-art miniaturization of semiconductor devices has come to beyond 10nm nodes. As technology trend evolves, the introduction of 3D gate, new materials such as Ⅲ-Ⅴ［1］, and practical use of the STT-MRAM [2] has become necessary and highly demanded. Traditionally, lithography technology has leaded miniaturization of semiconductor processing; however, in the era of sub-10nm, commercialization of EUV lithography system has been seriously delayed due to lack of productivity. Alternately, the double patterning technique by incorporating plasma etching into current lithography technology has been applied for process and device miniaturization [3]. Herein, the challenges and prospects of plasma process technology for beyond 10nm nodes are briefly described.

2. Plasma etching

Plasma etching of conventional films (e.g. Si, SiO_2, SiN) have been well studied and understood, and is being applied to mass production. The etching equipment technology such as more rigid control over uniformity, stability, and reproducibility are critical for beyond 10nm nodes device processing in the future. As new materials are being introduced into devices, plasma etching has been facing more challenges to etch those unconventional materials, for example, the material used in MRAM is difficult to be etched and to obtain vertical profile. The breakthrough in etching technology is unquestionably needed for these challenges.

In addition, materials degradation often occurs during plasma etching process due to plasma induced damage (sputtering, VUV, etc.) Damage-less or even damage-free etching will be definitely required for beyond 10nm nodes process, especially for new materials such as Ⅲ-Ⅴmaterials. Countermeasures for plasma induced damage have to be developed.

3. Plasma CVD

As Ⅲ-Ⅴ materials and transition metals are preferred to be processed at less than 400℃, low temperature film deposition using plasma technology with resulting film properties comparable to that of thermal CVD film is required.

4. Plasma ALD

3D device structure has been utilized and films in devices are getting thinner. ALD technology has been inevitably applied in device processing to achieve extremely thin and conformal deposition. ALD processing is also preferred to be carried out at low temperature, which promoted plasma assist ALD process for high quality conformal film deposition at low temperature.

5. Prospects for plasma process

Plasma process is a method of using ions and radicals to add and/or remove materials. Higher density of radicals and ions contributes to obtain higher quality film property in the low temperature process. It is necessary to use high frequency and high power for achieving high density plasma process. Currently, frequency of 400kHz ~ 2.45GHz [4] is used in the semiconductor process. Research on high frequency microwave and VHF plasma has not been sufficient. Further exploration in this area is expected.

In recent years, in order to reduce the plasma induced damage, neutral beam [5] and pulsed plasma [6] have been developed for etching and CVD process [7]. A neutral beam system is physically isolated from the plasma chamber by the utilization of apertures. Therefore, processing is done under less irradiation by ions, electrons and UV photons, which avoids or lessens the plasma induced damage.

Since there is no re-dissociation of reaction products by plasma, new process phenomena that will be different from the conventional plasma process would be expected in a neutral beam process.

6. Summary

To manufacture devices with further higher speed and higher integration, the development of plasma etching technology for new materials and plasma ALD and CVD technology for high quality films is required.

References

[1] S. Takagi et al: VLSI Technology (2010)147
[2] K. Ando et al: J. Appl. Phys. 115, 172607 (2014)
[3] G. E. Bailey et al. :SPIE 6521, (2007)
[4] V. Donnelly: J. Vac. Sci. Technol. A**31** (2013)
[5] D. Nakayama: J. Phys. D: Appl. Phys. **46(**2013)
[6] T. Mukai et al: Jpn. J. Appl. Phys. **45(2006)**
[7] Y. Kikuchi et al: J. Phys. D: Appl. Phys.(2013)

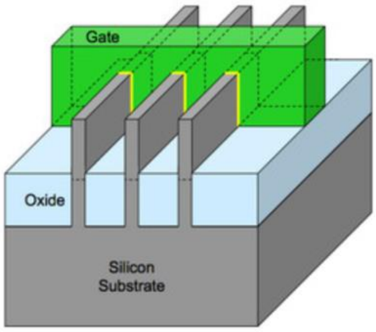

Fig.1. 3D gate structure

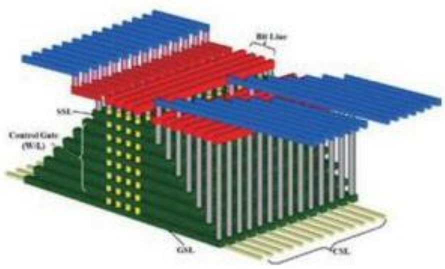

Fig.2. 3D NAND structure

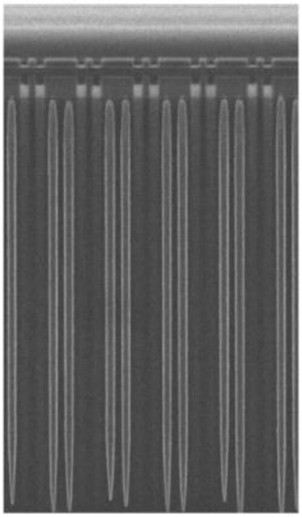

Fig3. DRAM capacitor

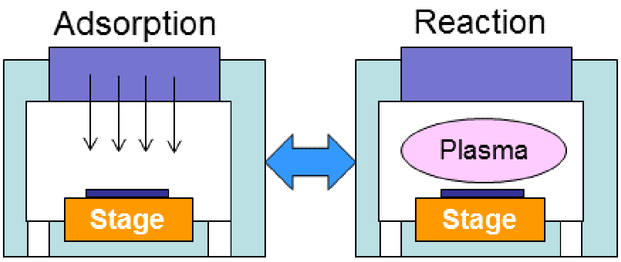

Fig.4. ALD method

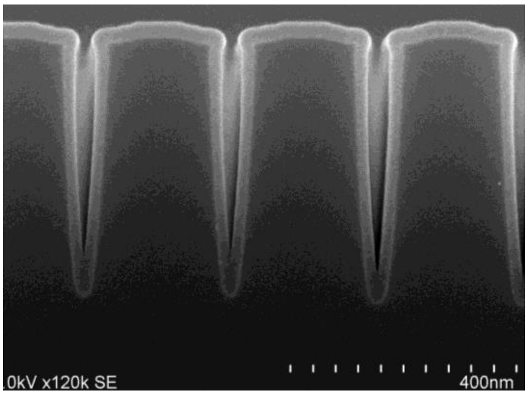

Fig.5. Conformal SiN film by plasma ALD

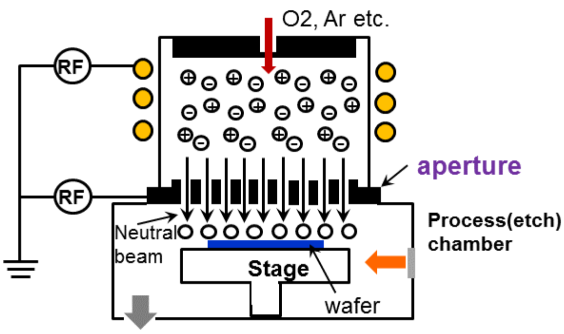

Fig.6. Schematic diagram of neutral beam system