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Low Temperature Deposition of High Quality Silicon Oxide Films

Hideo IZAWA[+)++)], Yutaka NISHI[++)], Masaya OKAMOTO[+++)], Hiroshi MORIMOTO[++)], and Mitsuo ISHII[+)++)]

Giant Electronics Technology Co.[+)]
1-6-5 Higashinihonbashi,Chuou-ku,Tokyo 104, Japan
Liquid Crystal Laboratories[++)] and Liquid Crystal Display Group[+++)], Sharp Co.
2613-1 Ichinomoto-cho,Tenri-shi,Nara 632, Japan

The electrical properties of SiO_2 films deposited at low temperature below 600℃ with ECRCVD, Sputter and APCVD were compared with those of Th-SiO_2 film. The film of ECRCVD-SiO_2 deposited without substrate heating had a low density of interface state in MOS capacitor. Its density was 3.2×10^{10} ($cm^{-2}eV^{-1}$) near the Si mid-gap. It was convinced that the ECRCVD was one of the promising methods for high-quality SiO_2-film deposition at low temperature.

1.INTRODUCTION

It is said that a liquid crystal display is the most promising candidate of future display in 1990's. The fabrication of large-area TFT on inexpensive glass substrates is a key technology for liquid crystal display. Accordingly, the maximum temperature of TFT fabrication processes should be below a glass strain point of 600℃.

Recently, deposition processes of SiO_2 films at low temperature with ECR-plasma-CVD (ECRCVD) method[1)-5)],Sputter (SP) method[6)-7)] and Plasma-CVD method[8)] has been studied. In particular, the quality of SiO_2 films was improved below 200℃ by ECRCVD method and SP method. However, the low temperature deposition method has not been well established in fabricating gate insulator films with good electrical properties which are comparable to those of thermal SiO_2.

In this paper, the optical,chemical and electrical properties of ECRCVD-SiO_2 is discussed in comparison with those of SiO_2 films formed with SP, APCVD and Thermal oxidation(Th) methods.

2.EXPERIMENTAL PROCEDURE

Silicon oxide films were deposited with ECRCVD, SP, APCVD method, respectively. Typical conditions of each deposition method are shown in Table 1. The films were formed on P-type single crystal silicon wafers. Etching rate with buffered HF solution (HF content 5%, at 25 ℃) and refractive index were measured. The MOS capacitors were fabricated on P-type (100),10~15Ωcm silicon wafers with a 1000Å thick gate insulator, and a 0.005cm^2 aluminum gate electrode. Finally, those samples were postmetallization-annealed in N_2 at 400℃ for 40 min..

The current density-field strength (J-E) characteristics were measured using MOS capacitors by applying negative voltage to the aluminum gate electrode. The quasi-static C-V characteristics were also measured using MOS capacitors. The interface state density was calculated by using the quasi-static C-V curves[9]. The properties of films were evaluated by comparing with those of Th-SiO_2 fabricated by dry oxidation at 1000℃.

Table 1 Deposition Conditions

ECR-plasma-CVD method

Reactant gases	O_2 and SiH_4
Gas flow rate ratio	0.33 (SiH_4/O_2)
Gas pressure	1.5 mTorr
Microwave power	300 W
Substrate temperature	25 - 600℃

Sputter method (RF magnetron sputter)

Target	SiO_2 (6N)
Sputtering gas	Ar and O_2
Gas flow rate ratio	0.43 (O_2/Ar)
Gas pressure	5 mTorr
RF power	800 W
Substrate temperature	25 - 300 ℃

Atmospheric pressure CVD method

Reactant gases	SiH_4 and O_2
Substrate temperature	350 ℃

3.RESULTS AND DISCUSSIONS

The thickness unifirmity of films is less than ±6% on wafer (diameter: 100mm) in each deposition. Refractive index of SiO_2 films as a function of deposition temperature is shown in Fig. 1. Refractive indexes of both ECRCVD-SiO_2 and SP-SiO_2 were comparable to that of Th-SiO_2.

Chemical etching rates of SiO_2 films is shown in Fig. 2 as a function of deposition temperature. Etching rates of both ECRCVD-SiO_2 and SP-SiO_2 were farely lower than that of APCVD-SiO_2. The film of ECRCVD-SiO_2 had as low etching rate as that of Th-SiO_2 in high temperature region around 600℃. It was suggested that ECRCVD-SiO_2 and SP-SiO_2 deposited at low temperature were very dense films in comparison with APCVD SiO_2 films.

Breakdown field of SiO_2 films vs. deposition temperature is shown in Fig. 3. In low temperature region (R.T.~300℃), all

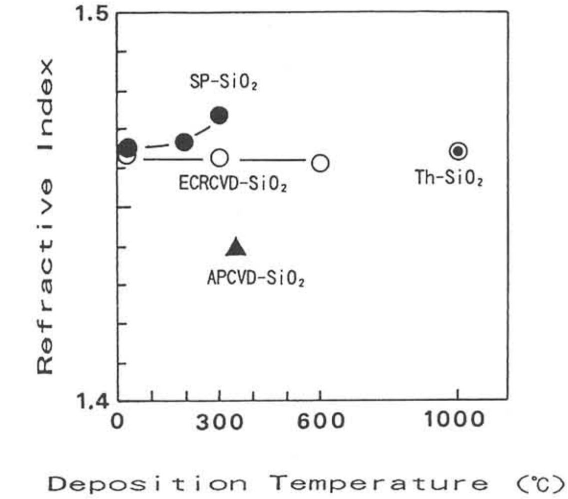

Fig.1 Refractive index of SiO_2 films as a function of deposition temperature.

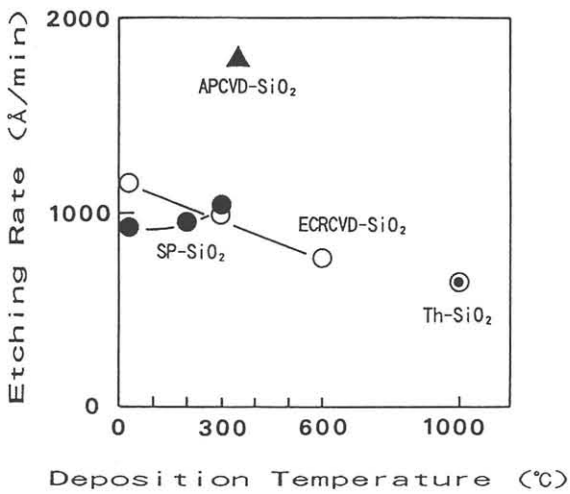

Fig.2 Etching rate of SiO_2 films as a function of deposition temperature.

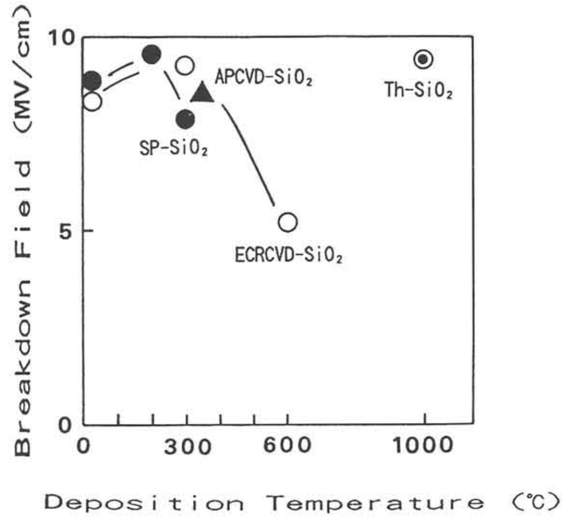

Fig.3 Breakdown field of MOS capacitors using SiO_2 films vs. deposition temperature.

of ECRCVD-SiO_2, SP-SiO_2 and APCVD-SiO_2 films had rather high breakdown field which was comparable to that of Th-SiO_2.

Figure 4 shows that the J-E characteristics of MOS capacitors using SiO_2 films formed under the following.

Th-SiO_2 :dry oxidation at 1000℃.

ECRCVD-SiO_2 :deposited with ECRCVD method without substrate heating.

SP-SiO_2 :deposited with SP method at 200℃ and then annealed in N_2 at 600℃ for 2 hours.

APCVD-SiO_2 :deposited with APCVD method at 350℃ and then annealed in N_2 at 600℃ for 2 hours.

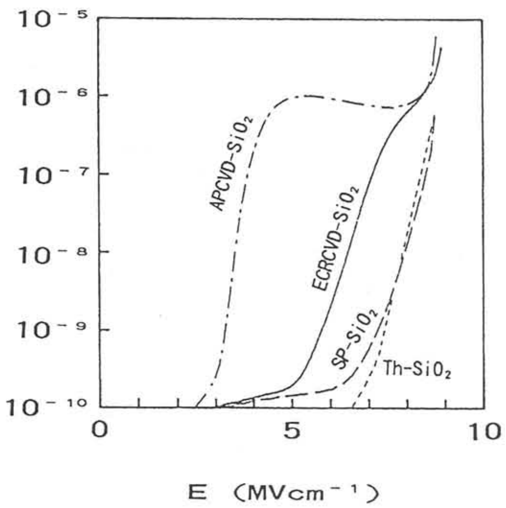

Fig.4 The J-E characteristics of MOS capacitors.

The J-E characteristics of ECRCVD-SiO_2 and SP-SiO_2 films were close to that of Th-SiO_2 in comparison with APCVD-SiO_2. However,the J-E curve of ECRCVD-SiO_2 had a small shoulder between 5 and 8 MV/cm.

The breakdown characteristics of ECRCVD-SiO_2 films were examined in detail as shown in Fig. 5. The breakdowns mainly occured at 9~10 MV/cm and a little of breakdowns at 2~7 MV/cm. These low field breakdowns and small shoulder in the J-E curve both indicated that ECRCVD-SiO_2 film had some weakspots caused by carrier traps.

The quasi-static C-V characteristics of the above-mentioned MOS capacitors are shown in Fig. 6. The characteristics of ECRCVD-SiO_2 films was very close to that of Th-SiO_2.

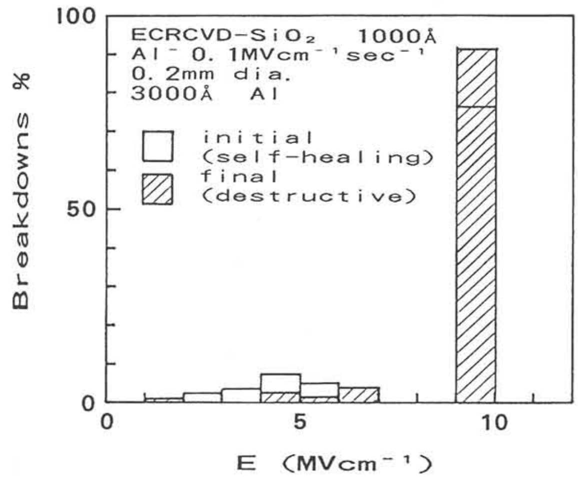

Fig.5 The breakdown distributions of MOS capacitors using ECRCVD-SiO_2 deposited without substrate heating.

Figure 7 shows the distributions of interface state density (Nss) calculated by using the quasi-static C-V characteristics. The interface state density between ECRCVD-SiO_2 films and c-Si was as low as that of Th-SiO_2 and $3.2\times10^{10}(cm^{-2}eV^{-1})$ near the silicon mid-gap. The film of ECRCVD-SiO_2 deposited without substrate heating had an exellent interface properties which were comparable to those of Th-SiO_2. It seems to be due to rather low energy bombardment of ions to the substrate compared with the SP method.

As a result, it was proved that ECRCVD was a very hopeful method for high quality SiO_2 films deposition at low temperature below 600℃.

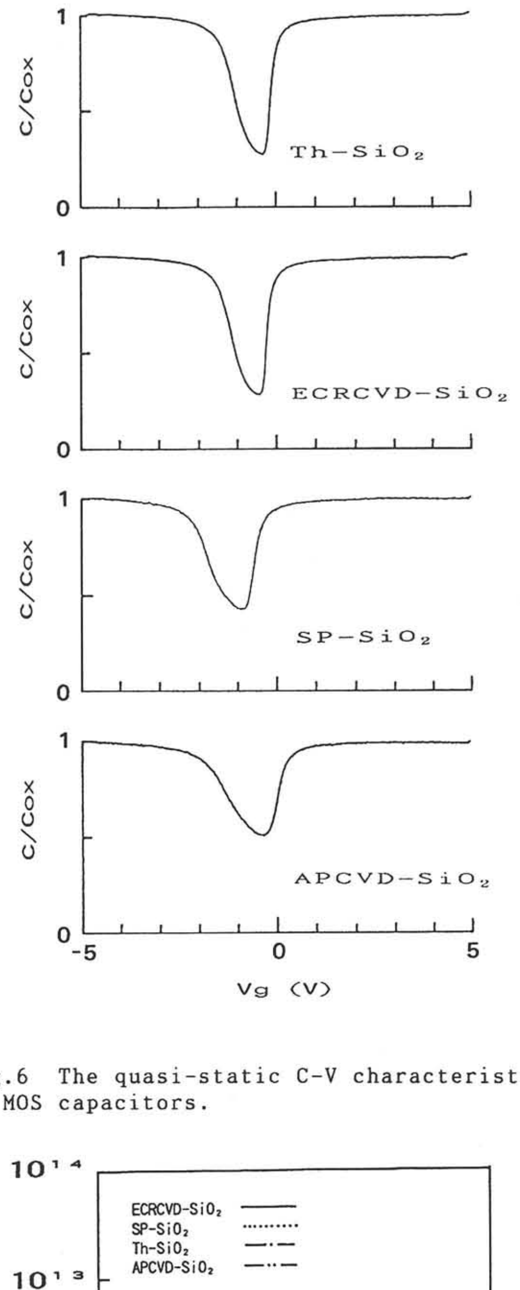

Fig.6 The quasi-static C-V characteristics of MOS capacitors.

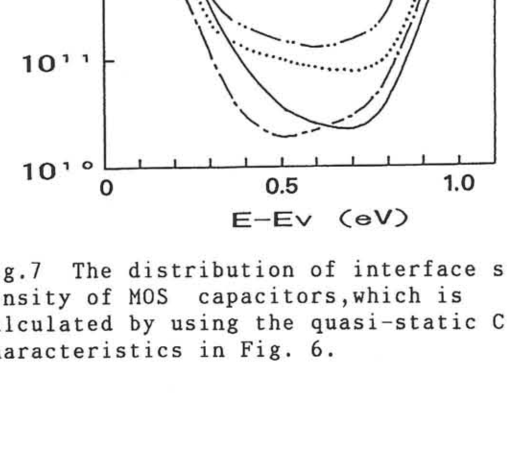

Fig.7 The distribution of interface state density of MOS capacitors, which is calculated by using the quasi-static C-V characteristics in Fig. 6.

4. SUMMARY

In order to develop the deposition method of high quality silicon oxide films at low temperature below 600℃, ECRCVD, SP, APCVD methods were studied. Refractive index , etching rate and breakdown field of ECRCVD-SiO_2 film and SP-SiO_2 film were comparable to those of Th-SiO_2 film. The C-V characteristics of ECRCVD-SiO_2 film without substrate heating were very close to that of Th-SiO_2 film. Interface state density of ECRCVD-SiO_2 film was 3.2×10^{10} ($cm^{-2}eV^{-1}$) near the silicon mid-gap. It was confirmed that ECR-CVD method was one of the most hopeful method for high quality SiO_2 film deposition at low temperature below 600℃.

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