Low-Temperature Oxidation for Gate Dielectrics of Poly-Si TFTs using High-Density Surface Wave Plasma

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Gate dielectric formation at low temperatures is one of the key technologies for Low Temperature Poly Silicon (LTPS) TFTs. Oxidation processes can form an excellent interface rather than using deposition. We described a combined process of oxidation followed by plasma enhanced chemical vapor deposition (PECVD), which provides both an excellent interface and practical thickness [1]. Microwave plasma, especially surface wave plasma (SWP) [2][3], is one of the most promising candidates for low temperature oxidation. It is reported that Kr-mixed gas improves both oxidation rate and electric properties at 400°C - 500°C [4][5].

In this work, we studied the properties of Si-oxidation films formed at temperatures lower than 400°C using high-density surface wave plasma.

The oxidation was carried out as follows. P-type single crystal silicon (100) was used and treated with DHF before oxidation. SWP using a Kr/O_2 gas mixture was generated by a microwave of 2.45 GHz. Microwave power was 1200 W, and pressure was kept at 80 Pa. The Kr/O_2 ratio was fixed to 97/3 for the film analysis. A pure O_2 plasma condition was also used for the comparison.

Figure 1 shows the oxidation temperature dependence on the leak current density of films prepared using O_2 plasma and Kr-mixed plasma. With Kr-mixed plasma, the current density scarcely changed from 200°C to 350°C, while the films using pure O_2 plasma increased the current density as the temperature decreased. To analyze this result, the composition of the film was measured using X-ray Photoelectron Spectroscopy (XPS) as shown in Fig. 2 (about 4 nm in thickness). With the Kr-mixed plasma, the O/Si ratio was 1.98 at 200°C and 300°C. For the other, the O/Si ratio was smaller when pure O_2 plasma was used, even though the temperature rose to 350°C. This result roughly corresponds to Fig. 1; i.e., the leak current decreased in a high O/Si ratio region. Then, oxide film thickness as a function of oxidation time was measured. The parabolic rate constant (B value) was obtained from this data. The activation energy of the B value was 0.08 eV for both the Kr-mixed and the pure O_2 plasma (Fig. 3). This indicates that the oxidants are the same for both cases. The large difference between them is due to its electron density as shown in Fig. 4. The electron density increased abruptly in a region of more than 90 % concentration of Kr. The number of excited Kr and Kr ions were generated proportionally to the electron density. The energy of the excited species and ions was measured. It was less than 10 eV in both cases and would not have caused damage on the surface. Thus, the oxidation kinetics may be properly enhanced using the above species during oxidation with the Kr-mixed plasma.

In conclusion, silicon dioxide with a high O/Si ratio can be obtained at 200°C with a low leak current density using Kr-mixed surface-wave plasma oxidation. It may be adopted for a low-temperature plastic-substrate process.

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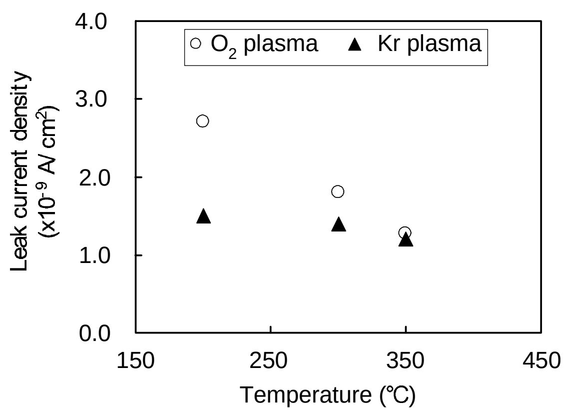

Fig. 1 Oxidation temperature dependence on leak current density at E = 2 MV/cm.

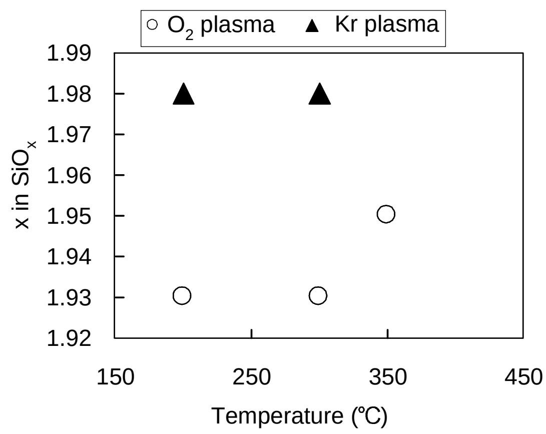

Fig. 2 O/Si ratio of SiO_x films determined using XPS as a function of oxidation temperature.

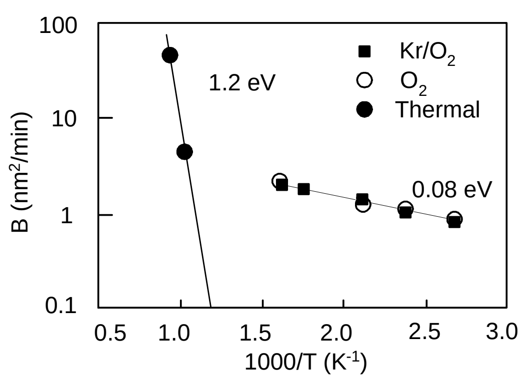

Fig. 3 Activation energy of B value for Kr/O_2 (97/3) and O_2 plasma

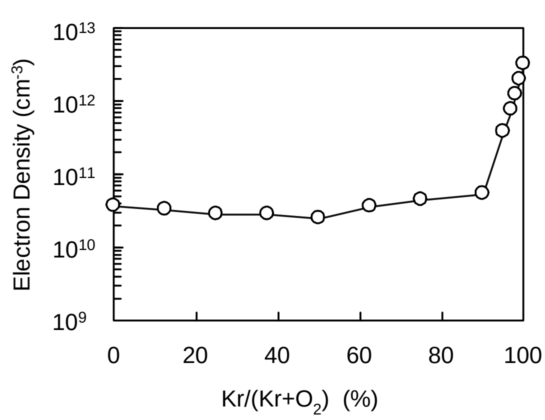

Fig. 4 Electron density of Kr/O_2 plasma as a function of Kr/(Kr+O_2) ratio.