Abs. 959, 206th Meeting, © 2004 The Electrochemical Society, Inc.

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

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System on glass (SOG) is an innovative technology for realizing a human-friendly display. Low-temperature poly-silicon thin film transistors (LTPS-TFTs) can be used to integrate the numerous circuits required to enable SOG technology. Gate dielectric formation at low temperatures is a key technology for LTPS-TFTs. Several low-temperature oxidation methods have been reported [1, 2]. Among these methods, microwave plasma, in particular surface wave plasma (SWP) is promising that meets the requirements of both high electron density and low ion energy [3] for improving the SiO_2/Si interface characteristics. We have developed a low-temperature SWP oxidation and plasma-enhanced chemical vapor deposition (PECVD) combination process for LTPS-TFTs that yields good interface and practical thickness[1].

We have investigated the plasma oxidation behavior under rare gas dilution and the relationship between the plasma condition and the oxide characteristics.

Figure 1 shows the electron density and the oxygen atom density as a function of the Kr dilution ratio [4]. The electron density increased abruptly at the dilution ratio of above 90%. The plasma, which was highly diluted with Kr generated high-density electrons and Kr metastables, which efficiently generated oxygen atoms from a small amount of O_2 gas. The structure and interface properties of the plasma-oxides were also examined using X-ray photoelectron spectroscopy. Oxide films of approximately 1-nm-thickness were prepared at 300ºC on Si(100) substrates with and without Kr dilution (97%). Table 1 shows the result of the intermediate oxidation states (Si^{n+}, n=1-3) analyzed based on the Si 2p spectra [5]. The total amounts of Si^{n+} were approximately the same, and approached 1 ML, which indicates that an abrupt compositional transition took place in these oxides. Figure 2 shows the O 1s photoelectron energy loss spectra observed for the above three oxides. An energy loss at the threshold energy of 3.5 eV was observed for all oxides. The amounts of oxides were as follows: Kr/O_2 plasma oxide < Thermal oxide < O_2 plasma oxide. The value of 3.5 eV corresponds to the minimum energy required for direct interband transition at the Γ point in the energy band structure of Si [6]. The number of O 1s photoelectrons escaping into the vacuum without inelastic scattering in oxide decreased as the uniformity of the SiO_2 film increased [7]. Therefore, the Kr/O_2 plasma oxide was more uniform than the O_2 plasma oxide. This uniformity may correspond to the high concentration of Kr metastables shown in Fig. 1. In addition, we have also investigated the surface-wave-excited PECVD method as a stacked CVD layer. Figure 3 shows the fixed charge density properties of the SiO_2 films prepared at 300ºC. The fixed charge density could be reduced up to 8×10^{10} cm^{-2} by decreasing the electron temperature.

This research was supported by NEDO and METI.

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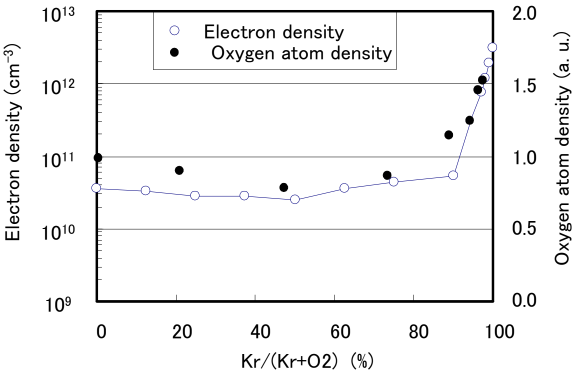

Fig. 1 Kr dilution dependence of the electron density (after [4].)

Table 1 Amount of Si^{n+} and total amount of suboxides for three low-temperature oxide films. [5]

	Amount of suboxide (ML)			
	Si^{1+}	Si^{2+}	Si^{3+}	total
Kr/O_2 plasma oxide	0.33	0.26	0.36	0.95
O_2 plasma oxide	0.27	0.27	0.42	0.96
Thermal oxide	0.26	0.26	0.27	0.79

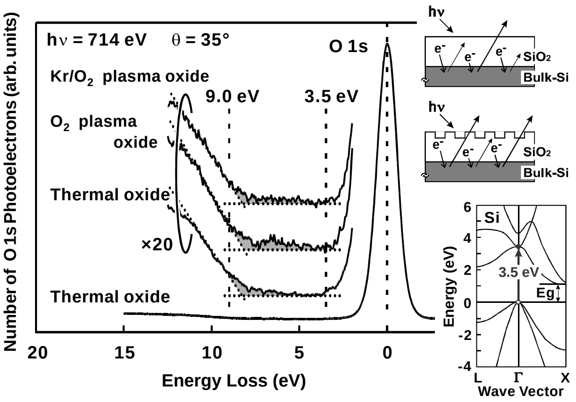

Fig. 2 O 1s photoelectron energy loss spectra measured for three oxides. (after [7].)

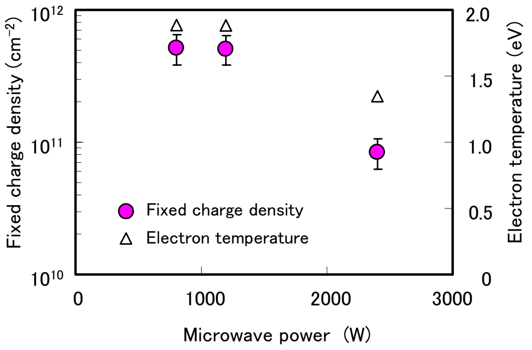

Fig. 3 Fixed charge density and electron temperature as a function of microwave power.
The film thickness was fixed to 30 nm.