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A method to form the gate oxide and recrystallize the polycrystalline silicon (poly-Si) active layer simultaneously is proposed. During the irradiation of excimer laser, the poly-Si film is recrystallized while the oxygen ion impurities injected into the amorphous silicon (*a*-Si) film are activated by laser energy and react with silicon atoms to form SiO_2. Our experimental results show that a high quality oxide and a poly-Si film with fine grain have been fabricated successfully by the proposed method. High quality interface between oxide and poly-Si films has also been obtained. © *1997 American Institute of Physics.* [S0003-6951(97)03703-0]

The polycrystalline silicon thin film transistors (poly-Si TFTs) are widely used for active matrix liquid crystal displays (AMLCDs). The characteristics of poly-Si TFTs are determined by not only the quality of gate insulator but also polycrystalline silicon (poly-Si) active layer.[1,2] Recrystallization of amorphous silicon (*a*-Si), which is usually deposited by either plasma-enhanced chemical-vapor deposition (PECVD) or low-pressure chemical-vapor deposition (LPCVD), is a critical factor to enhance the performance of poly-Si, TFTs.[3] The excimer laser-induced recrystallization is a promising tool for fabricating poly-Si TFTs on low-cost glass substrates.[4] It is well known that the surface roughness of poly-Si layer recrystallized by excimer laser increases with the energy density of excimer laser. The CVD, such as PECVD or atmospheric pressure chemical vapor deposition (APCVD), oxides are usually employed to fabricate gate insulators in low temperature processed poly-Si TFTs. The oxides for poly-Si TFTs are required to exhibit low leakage current, high dielectric strength, and good interface with the poly-Si active layers.

It is reported that the field effect mobility of TFTs is affected by the roughness of the gate insulator.[5] In most low temperature processed poly-Si TFTs, the gate oxide is deposited after recrystallization of poly-Si active layer so that interface between gate insulator and active layer may be easily contaminated and the performance of poly-Si TFTs is degraded. The poly-Si active layer which has smooth surface roughness and good electrical characteristics is required. Besides the quality of poly-Si active layer, a high quality SiO_2 which has good interface with the poly-Si active layer is needed to improve the performance of poly-Si TFTs.[6]

We propose a new method to form the gate oxide and to recrystallize the poly-Si active layer simultaneously by irradiation of the XeCl excimer laser on an oxygen implanted amorphous silicon(*a*-Si) thin film. By the thermal energy of the excimer laser, the poly-Si film is recrystallized, while the oxygen ion impurities injected into the *a*-Si film react with the silicon atoms to form SiO_2.

Our experimental results show that a high quality oxide, a poly-Si film with fine grain, and a smooth and clear inter--face between oxide and poly-Si film have been successfully obtained by the proposed fabrication method.

The process sequences of the proposed method are as follows. The *a*-Si film of 3000 Å thickness was deposited on the substrate by LPCVD at 550 °C. A dose of 5×10^{17} cm^{-2} oxygen ions at 10 KeV were implanted into *a*-Si layer. The excimer laser irradiation was carried out at an energy density from 254 to 371 mJ/cm^2. The energy of the laser is absorbed in the oxygen-rich *a*-Si film, and the absorbed thermal energy becomes a heat source for the oxygen impurities to react with the silicon atoms. As a result of excimer laser irradiation, structure of oxide-on-polycrystalline silicon film was formed at the same time. We entitle the oxide fabricated by proposed method as laser induced implanted oxide (LI^2Ox). It should be noted that, although we employed relatively high temperature process for our convenience such as LPCVD 550 °C, the deposition of *a*-Si layer may be altered to PECVD which can be processed below 350 °C with dehydrogenation process in order to get a similar material property to LPCVD *a*-Si layer in hydrogen content.

The Auger electron spectroscope (AES) analyzed atomic concentration of the oxygen implanted *a*-Si film before and after the laser irradiation is shown in Fig. 1. In the sample, which is not irradiated by excimer laser, the oxygen concentration peak is observed at depth about 250 Å with a Gaussian distribution. The constant concentration up to about 500 Å, which implies that stoichiometry of SiO_2 is well matched, is observed in excimer laser annealed sample. Those data show that oxygen ions have reacted with the silicon atoms to form SiO_2 by the laser energy and a sharp oxide/poly-Si interface is obtained.

The cross-sectional TEM image of the oxide (LI^2Ox)/poly-Si structures fabricated by a proposed method is shown in Fig. 2. The samples in Fig. 2 were irradiated by three shots with the energy density of 371 mJ/cm^2. As shown in Fig. 2, the grains of poly-Si have not any internal defects such as micro twins. The fully recrystallized poly-Si from the bottom poly-Si/substrate interface to top interface with oxide (LI^2Ox) layer is formed by proposed method. The sharp and clear interface between poly-Si layer and oxide (LI^2Ox) is obtained as shown in Fig. 2.

The roughness of the interface between poly-Si and oxide measured by atomic force microscope (AFM) are shown

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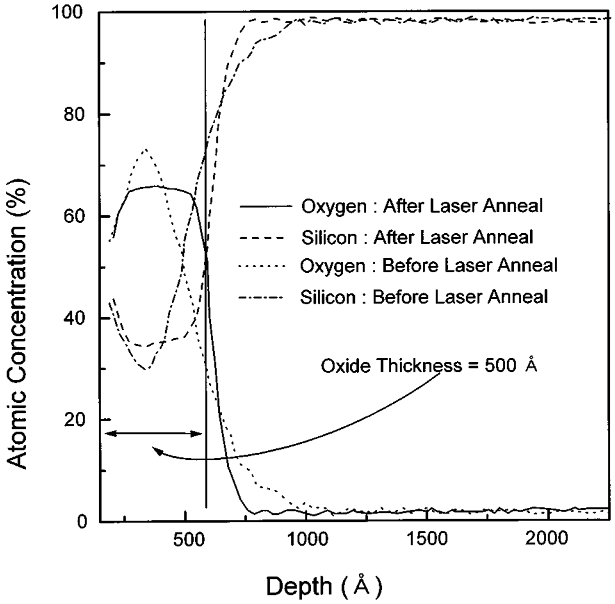

FIG. 1. The oxygen and silicon atomic concentration analyzed by AES before and after excimer laser irradiation.

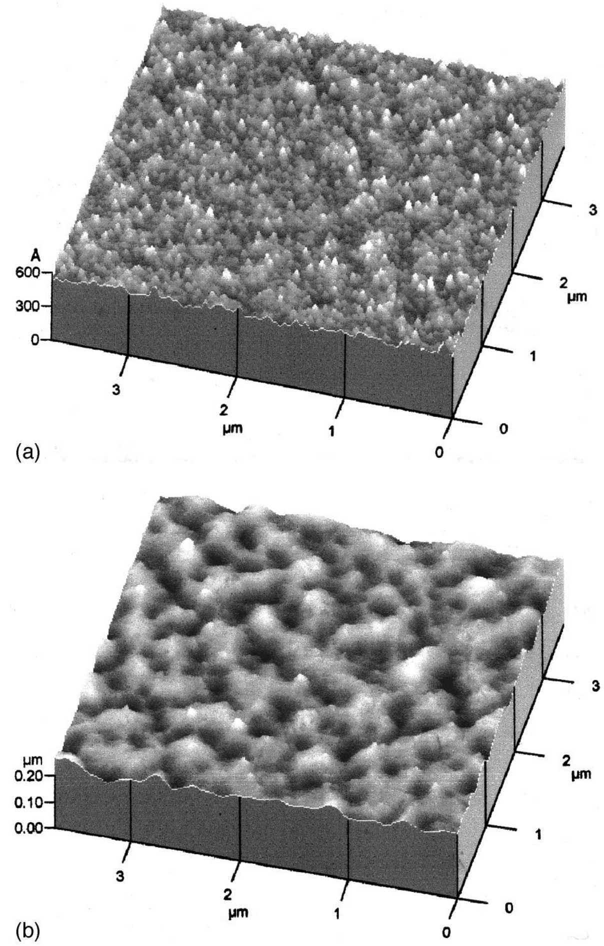

FIG. 3. The AFM image of interface between poly-Si and LI^{2}Ox fabricated by new method. (a) Laser energy density is 283 mJ/cm^2. The rms surface roughness of the interface is 23 Å. (b) The AFM image of surface morphology of poly-Si recrystallized from *a*-Si by conventional method. Laser energy density is 283 mJ/cm^2. The rms surface roughness of poly-Si is 111 Å.

in Fig. 3. For the AFM measurement of the surface roughness, the oxide layer was removed by the wet etching using buffered HF acid. It is pointed out that the morphology of the interface may be preserved by such a treatment, because the poly-Si is not attacked by the HF-based solutions. Figure 3(a) is the interface of poly-Si and oxide (LI^{2}Ox) fabricated by new method and Fig. 3(b) is the surface morphology of poly-Si recrystallized conventionally with the excimer laser energy density of 283 mJ/cm^2. The rms surface roughness of the interface is 23 Å, while that of the conventionally recrystallized poly-Si film is 111 Å. It is easily seen that the surface roughness is dramatically improved by the proposed method.

The time zero dielectric breakdown (TZDB) characteristics are measured to investigate the quality of fabricated oxide (LI^{2}Ox) by ramp-up voltage stress method.[7] The area of capacitor dot used for the measurement is 2500 μm^2. The Fowler–Nordheim tunneling region of new proposed oxide (LI^{2}Ox) starts at high electric field level compared with vari-

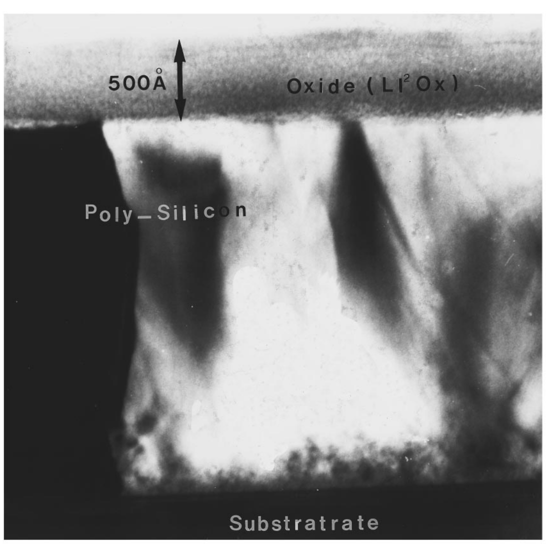

FIG. 2. TEM image of fabricated LI^{2}Ox and poly-Si. The scale of the image is 1:250000. The sample was irradiated with laser energy density of 371 mJ/cm^2. The LI^{2}Ox, fully recrystallized poly-Si, and clean interface of LI^{2}Ox and poly-Si is observed.

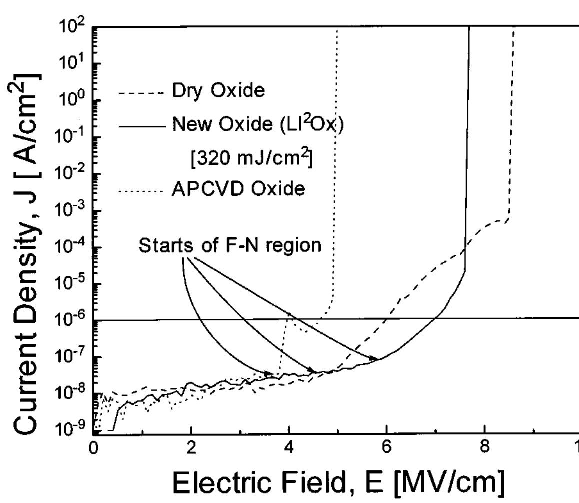

FIG. 4. The oxide breakdown electric field in LI^{2}Ox, APCVD oxide, and thermal dry oxide grown from poly-Si.

ous oxides such as thermal oxide grown from poly-Si and APCVD oxide as shown in Fig. 4. We have measured 25 capacitor dots uniformly distributed on 4 in. silicon wafer and most of them exhibit similar Fowler–Nordheim and breakdown characteristics to Fig. 4. This result implies that the local electric field at the oxide/poly-Si interface is reduced because the interface roughness by the proposed method is smoother than the conventional one. The oxide breakdown electric field corresponds to 10^{-6} A/cm^2 of leakage current density level has been compared with each sample. The improvement of breakdown field in the new oxide (LI^{2}Ox) compared with APCVD oxide is observed. We examined the oxide (LI^{2}Ox) breakdown electric field as a function of irradiated laser energy density. The maximum oxide (LI^{2}Ox) breakdown electric field occurs at the excimer laser energy density of 320 mJ/cm^2 and exceeds 7 MV/cm.

We have succeeded in *in situ* fabrication of oxide (LI^{2}Ox) and poly-Si film by excimer laser irradiation. Our experimental results show that a high quality oxide (LI^{2}Ox) and a poly-Si film with fine grain are fabricated simultaneously. In addition, a sharp and clear interface between oxide (LI^{2}Ox) and poly-Si film has been obtained by the proposed fabrication method. The maximum oxide (LI^{2}Ox) breakdown electric field exceeding 7 MV/cm is obtained at the excimer laser energy density of 320 mJ/cm^2.

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