Ultrathin Aluminum Oxide Gate Dielectric Prepared by Anodization Followed by Rapid Thermal Anneal

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In this work, we present a novel method to oxidize the aluminum film. Room temperature anodic oxidation in deionized water (DI) water was used to oxidize aluminum for the first time.

Three-inch p-type Si wafers were used. After standard RCA cleaning with final HF dip, 1% Si-Al with different thicknesses of 1.9 nm ~ 4.3 nm were evaporated on the Si wafer.

In the following anodic oxidation procedure, wafer with Al film acts as an anode. Constant electrolyzing voltage of 30V was applied from 5 ~ 30 minutes separately at room temperature using DI water as electrolyte. After anodization procedure, post-anodic-oxidation rapid thermal annealing (RTA) at 900℃ for 20sec in N_2 ambient was treated to evolve the hydrogen from the films. After the dielectrics were prepared, standard lithography and etching were utilized to fabricate a MOS capacitor structure.

Figure 1(a) and 1(b) show the Al 2p XPS spectra of original Al and anodic-oxidized Al_2O_3, respectively. It is observed that native oxide was existed on the Al surface, but after 10-min anodic oxidation, Al was totally converted into Al_2O_3. In addition, we can observe that the binding energy level of anodized Al_2O_3 is higher than origin one. This is probably due to the interfacial layer grown during anodization is not pure SiO_2 but Al-silicate layer with dielectric constant of 5.5 ~ 6.0 that is higher than conventional SiO_2. The dielectric constant is estimated to be about ~9.7.

Figure 2(a) and 2(b) shows the effect of N_2 RTA annealing to the anodic-oxidized Al_2O_3. It is observed that N_2 RTA can evolve the hydrogen from the anodic-oxidized Al_2O_3 films; therefore, electron trap density can be significantly reduced.

Figure 3 shows the J-V plot of anodic-oxidized Al_2O_3 (EOT = 2.5 nm) compared with SiO_2 while device was biased at accumulation region. It is clearly observed that the anodic-oxidized Al_2O_3 has two order of magnitude lower than SiO_2 for the same EOT.

Figure 4 shows the reliability characteristics of the anodic-oxidized Al_2O_3 film. The conduction characteristics have very weak temperature dependency and the leakage remains low at T=100℃, indicating a low bulk trap density in the bulk of the film.

Ultrathin Al_2O_3 film prepared by anodization in DI water was demonstrated to have gate quality characteristics, including low leakage current, low interface and bulk trap densities, and high thermal stability in this work. Beyond thermal oxide method, room temperature anodization may be a promising alternative method to prepare Al_2O_3 for gate dielectric.

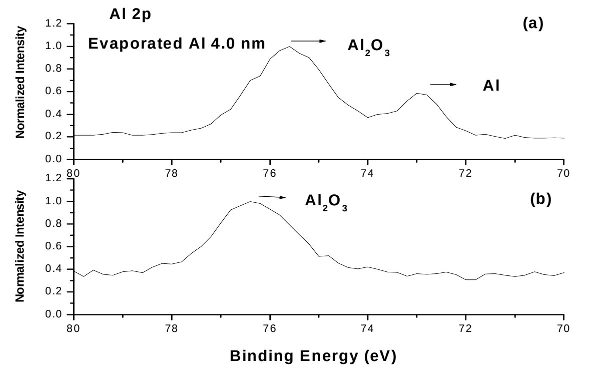

Fig. 1. XPS Al 2p spectra for Al film of (a) original Al film and (b) after 10min anodization.

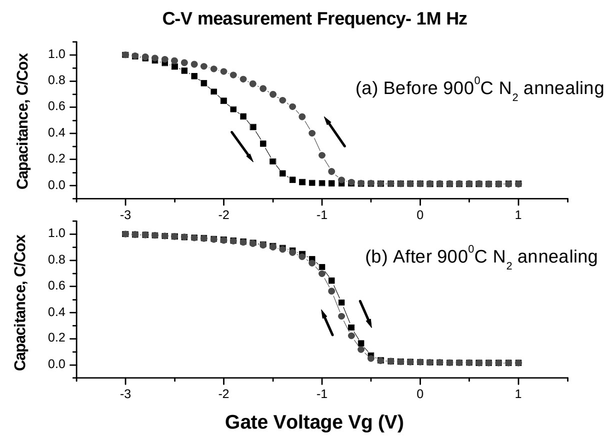

Fig. 2 C-V hysteresis for anodic Al_2O_3 (a) before N_2 RTA and (b) after N_2 RTA.

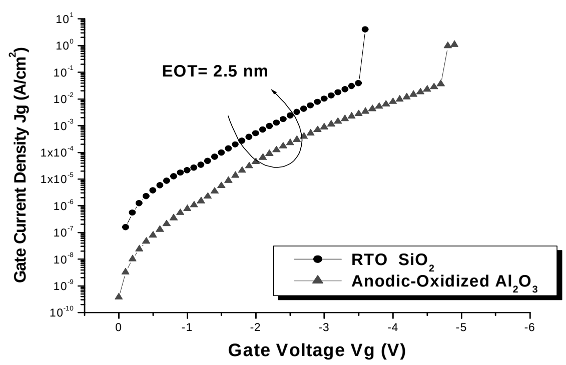

Fig. 3. J-V plot of anodic-oxidized Al_2O_3 and SiO_2 (EOT=2.5nm)

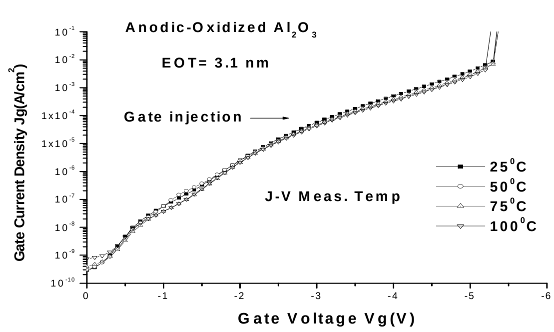

Fig. 4. J-V measurements of anodic-oxidized Al_2O_3 for temperatures varied from 25℃ to100℃.