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A-4-5 Formation of an epitaxial Si/insulator/Si structure by vacuum deposition of CaF_2 and Si

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Epitaxial silicon films on composite insulator/silicon substrates are of great interest in such applications as the fabrication of three dimensional LSI's and the isolation of bipolar LSI's. Recently, it has been shown that single crystalline Si islands or polycrystalline Si films with well-oriented Si grains can be formed on amorphous SiO_2 substrates or SiO_2/Si structures by the laser annealing technique, but the dimension of each crystallite is limited within a few tens of μm at present.[1] Another method to realize the Si/insulator/Si structure with the larger area is considered to be the double-hetero epitaxy of the insulator and Si films onto the Si substrates. In fact, formation of the Si/MgO·Al_2O_3/Si structure by the CVD technique is preliminarily reported.[2] In the present work, we show that the epitaxial Si/insulator/Si structure can be realized by vacuum deposition of CaF_2 and Si onto Si(111) substrates, owing to the small mismatch(0.6%) of lattice parameters between CaF_2 and Si. Crystalline quality of the films is characterized by the backscattering and channeling measurements with MeV ions.

Both (111) and (100) oriented p-type Si wafers with resistivities of about 10Ω-cm were chemically cleaned and loaded in a vacuum chamber equipped with ion pumps. A base pressure of the chamber was less than 10^{-6}Pa. CaF_2 grains were evaporated by resistive or e-gun heating onto Si substrates at temperatures from room temperature to 400°C. Pressures during the evaporation were less than 2×10^{-5}Pa. The samples were then annealed in the same vacuum at 800°C for 30min. Fig.1a) shows the typical backscattering spectra for a CaF_2/Si(111) structure. We can see from the random spectrum that the composition ratio of Ca to F in the deposited and annealed film is about 1 to 2. The channeling minimum yield χ_{min}, which is defined as the ratio of the aligned to random yields near the surface in the Ca spectrum, is about 0.05. Fig.1b) shows typical backscattering spectra for a CaF_2/Si(100) structure which was formed by the same condition as the sample shown in Fig.1a). In contrast to the CaF_2 film on Si(111) substrate, no channeling effect was observed in the film on Si(100), although the composition ratio Ca/F was 1/2. From these figures we can say that almost perfect crystalline CaF_2 films can be grown only on Si(111) substrates.

In order to form a Si/CaF_2/Si structure, Si films 200nm thick were evaporat-

ed by an e-gun onto the CaF_2/Si(111) structure. During the Si deposition the substrates were kept at temperatures from 500°C to 700°C. The deposition rate of the Si film was about 0.1nm/sec, and the pressure during the deposition was about 8×10^{-6}Pa. It was confirmed from the backscattering analysis that no interdiffusion between the top Si and CaF_2 films or the CaF_2 film and the Si substrate occurred during Si deposition at temperatures up to 700°C. Fig.2 shows backscattering spectra for a sample deposited at 500°C onto the CaF_2/Si(111) structure shown in Fig.1a). We can see from this figure that the deposited Si film grows epitaxially on the CaF_2/Si(111) structure, although the channeling minimum yield is still high at present. Degradation of the crystalline quality and diffusion at the interface were not observed for the post annealing up to 800°C.

In summary, an epitaxial Si/insulator/Si structure was formed by the sequential vacuum deposition of CaF_2 and Si. Improvement of the crystalline quality and measurement of the electrical properties in this structure are being investigated. The authors are gratefully acknowledge useful discussions of Prof. S. Furukawa and Dr. H. Matsumura.

[References] 1) J. F. Gibbons et al: Appl. Phys. Lett. 34(1979)831 2) T. Ihara et al: Abstracts of the 28th Meeting of Japan Soc. Appl. Phys.,29p-B-18(1981)

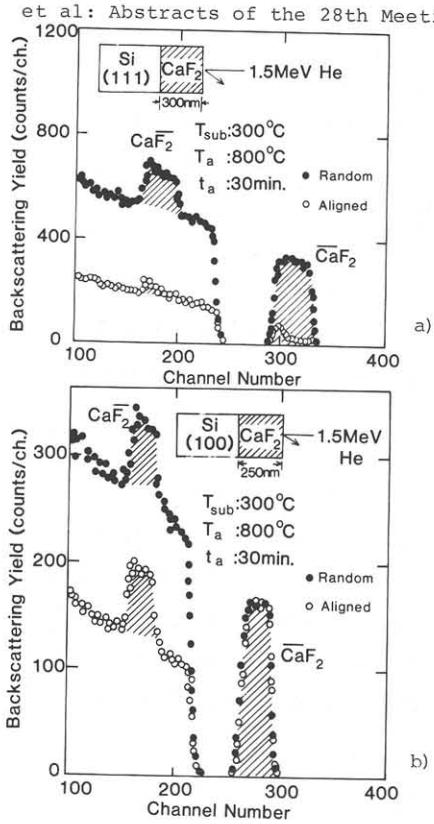

Fig.1 Backscattering spectra for CaF_2 films on a)Si(111) and b)Si(100) substrates

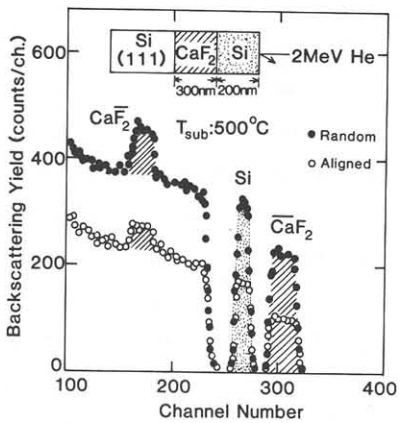

Fig.2 Backscattering spectra for Si/CaF_2/Si(111) structure