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TEM Investigation of Er_2O_3 Thin Films Grown on Si (100) by Laser MBE

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Er_2O_3 is a rare earth metal oxide showing reduced interfacial reactivity with silicon substrate even at temperatures as high as 900^o C [1]. It also has a high dielectric constant (10-14) and large band gap. Therefore it is currently being studied as a gate dielectric to replace SiO_2 for complementary metal-oxide-semiconductor devices. In the past few years, various techniques have been applied to the growth of Er_2O_3 thin films on Si substrates, such as metal organic chemical vapor deposition [2], electron beam gun evaporation [3], and molecular beam epitaxy (MBE) [4] etc. Depending on different deposition methods and deposition parameters, Er_2O_3 thin films with preferred orientations of either (110) or (111) on Si(100) were obtained. In this paper, laser MBE was used to prepare Er_2O_3 thin films on Si(100) and the microstructures, especially the interface layer, of as-received thin films were investigated by means of transmission electron microscopy (TEM) and associated techniques.

Er_2O_3 thin films with a thickness of 30 nm were prepared on Si(100) substrates by Laser MBE. The substrate temperature was kept at 620^o C. The oxygen pressure was 3×10^{-4} Pa. The output of a Lambda Physik LEXTRA200 excimer laser (308 nm, 20 ns, 2 Hz) was used as the laser source with an energy density of about 1 J/cm^2. TEM specimens were prepared for cross sectional observation. A Tecnai F30 transmission electron microscope at 300 kV, equipped with Gatan imaging-filter (GIF), was used to carry out lattice imaging and elemental mapping analysis
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Fig. 1(a) shows a low magnification high resolution TEM image of Er_2O_3/Si layer prepared by laser MBE. The interface between the film and Si is distinct. Two layers can be distinguished above the crystalline Si substrate: an interface layer with around 2nm thick, and a crystalline Layer of Er_2O_3. The interfacial layer can be better seen in an enlarged image of Fig. 1(b). It should be pointed out that the present interface layer thickness is well below the value of 3.5nm reported for electron beam evaporated films with the whole thickness of 6.5nm [3]. Because the interface layer usually plays an important role in electrical properties of oxide thin films, it is worthwhile to further understand the chemical composition of this layer. Energy filtered TEM images were obtained to get composition information for different elements. Fig. 2 shows an elastic-filtered image of Er_2O_3/Si layered structure, with the erbium, silicon and oxygen mapping distribution. Si map (Fig. 2b) demonstrates the interface layer contains slight Si. Similarly, the erbium map (Fig. 2c) reveals continuous coverage within erbium oxide layer. The erbium distribution can also be detectable in the interfacial layer, indicating the interface layer also contains Er. In combination with O-map (Fig. 2d), it can be judged that the interface layer is an intermixed Er-containing silicates layer. However, it is worth noting that the content of Si in this layer is relatively low compare with that in Er_2O_3 films prepared by other methods [2]. In summary, HRTEM observations show that a 2nm thick interface layer exists in Er_2O_3 thin films grown on Si(100) substrates by laser MBE. The interface layer contains much Er, slight Si and O by elemental mapping analysis. The financial support from China was much acknowledged [5].

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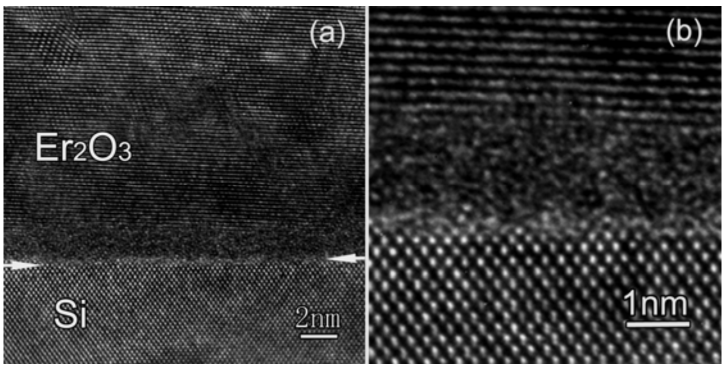

FIG. 1. (a) A typical HRTEM image of Er_2O_3 thin films grown on Si (100) substrate by laser MBE and (b) an enlarged part of interfacial area of (a) showing the existence of interfacial oxide layer with the thickness of around 2 nm.

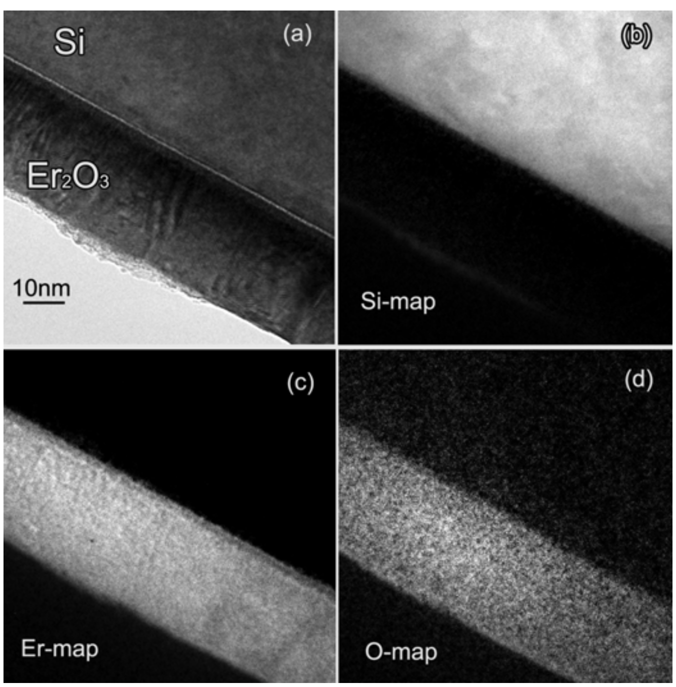

FIG. 2. (a) Zero-loss filtered image of Er_2O_3/Si layer structure with corresponding elemental mapping images of (b) Si; (c) Er and (d) O, respectively.