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Deposition of Epitaxial Yittria-Stabilized Zirconia (YSZ) on Si(100) and Simultaneous Growth of Amorphous SiO_2 Interlayer

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1. Introduction

Single-crystal YSZ(200) on Si(100) provides an option for the fabrication of high-speed high-density and radiation-hard electronic devices using Si-on-insulator. We have already developed[1-2] that the heteroepitaxial growth on Si by the metallic mode of reactive sputtering using (Zr+Y) target. In order to improve electrical properties we propose new method to simultaneous growth of an amorphous SiO_2 during YSZ deposition between an epitaxial YSZ(200) and Si(100) interlayer. In this paper, we report a new processing method to grow thick (10-60nm) SiO_2 between single-crystal YSZ(200) and Si(100). This processing and the resulting multilayer structure provides a new option for fabricating innovative microelectronic devices.

2. Description of New Method

A conventional magnetron sputtering was used to deposit epitaxial YSZ(200) on Si(100) by the metallic mode of reactive sputtering. A target cover with 20 mm-diameter-aperture was used to protect target oxidation, so that the reaction of metal atoms with oxygen molecules occur on the substrate and deposit YSZ very rapidly. It was successful to deposit epitaxial YSZ(200) on Si(100). However, an epitaxial YSZ film deposited directly on Si is not always good electrical properties producing relatively large leakage current. To solve this problem we tried to deposit amorphous SiO_2 between YSZ(200) film and Si(100) wafer. As it is known that YSZ is a good O^{2-} ion conductor, a plasma anodization of Si substrate is tried to form at the YSZ-Si interface. The SiO_2 is formed by O^{2-} ions drift through YSZ to a positive voltage biased Si wafer during YSZ deposition.

3. Experimental

Figure 1 shows typical oxygen flow rate dependence of deposition rate. In the conventional reactive sputtering it is impossible to deposit oxide films in the metallic mode. However, in our technique it is possible to grow the heteroepitaxial YSZ on Si. An epitaxial growth condition is shown in Table 1. Fig.2 shows the cross-sectional transmission electron micrograph (XTEM) of the interfacial region between YSZ film and Si(100) substrate. As seen in the figure XTEM lattice image of the 1.5 [nm] interfacial region between YSZ and Si was not amorphous but lattices continued from a Si substrate to a YSZ film through SiOx region. A lattice mismatch is relaxed 30% by the void formation in this region. Fig.3(a) shows how to deposit an epitaxial YSZ on Si(100) by the reactive sputtering and

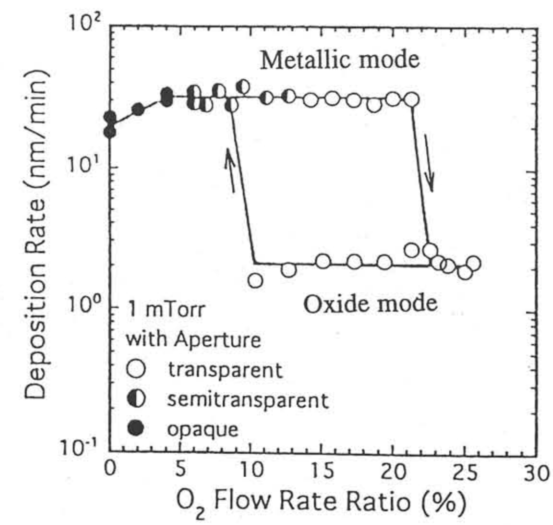

Fig.1 Deposition rate v.s. O_2 flow rate with 20 mm aperture for the reactive sputtering.

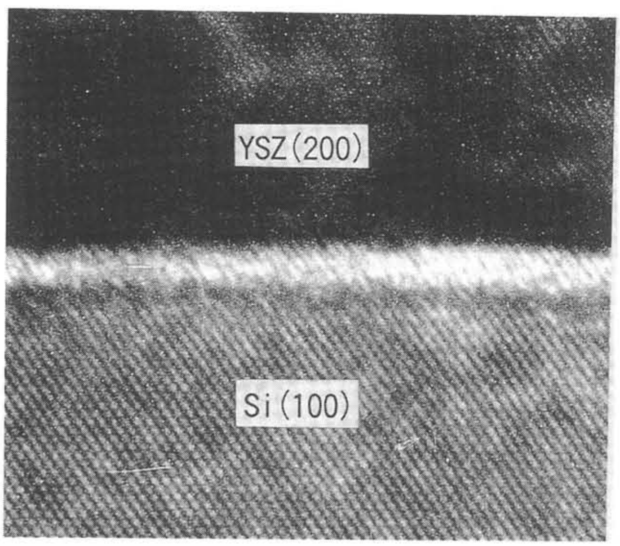

Fig.2 Cross-ectional TEM of reactive sputtered YSZ (200) / Si(100) showing heteroepitaxy and the existing 1.5 [nm] SiOx layer in the interface.

Table 1. Epitaxial growth conditions

Gas pressure	1 mTorr
O2/(Ar+O2)	5.8 %
dc input power	80 W
Target-Substrate	72 mm
Substrate Temp.	~800℃

simultaneous growth of an amorphous SiO_2 interlayer by the plasma anodization. Thickness of YSZ and SiO_2 are possible to control by changing the bias and the discharge voltages. Fig.4(a) is the XTEM photograph of whole sample and the interfaces between (b) YSZ and SiO_2 and (c)SiO_2 and Si, where the total intermediate layer thickness of SiO_2 is about 50 nm. The interface between YSZ and SiO_2 is not as sharp as that between SiO_2 and Si. However, YSZ layer shows very good crystallinity and structural properties. A full width at half-maximum height (FWHM) of the locking curve of the (200) peak was about 1.0° of about 80nm YSZ films and there is no difference of YSZ (200) films in FWHM between YSZ / Si and YSZ /SiO_2/Si structures. Fig.5. Shows the deposition rate of YSZ and the formation speed of SiO_2 for different deposition time. As this figure shows the deposition rate of YSZ is proportional to deposition time. But, formation speed of SiO_2 reduces as YSZ and SiO_2 thickness increases.

4. Conclusions

A multilayer structure of single-crystal YSZ(200) on amorphous SiO_2 on Si (100) was successfully realized by bias sputtering. The introduction of a fairly thick SiO_2 layer between single-crystal YSZ and Si maintained the cube-on-cube epitaxial nature of YSZ on Si. This SiO_2 layer reduced the leakage current greatly to 10^{-10} [A/cm^2] at 10^6 [V/cm]. Though it was not shown here, we were succeeded in heteroepitaxial growth of Si film on YSZ/Si substrate by ion beam sputtering. Similar YSZ/SiO2/Si and YSZ/Si structure has been tried by laser ablation technique[3-4]. But ours are the most simple and elegant technique and have good electrical property.

References

1) T.Hata,H.Okada,S.Nakano,K.sasaki: Proc.Int. Symp.Sputter.& Plasma (1997), EI1-1

2)T.Hata,H.Matsuda,R.Ando,S.Horita:Jpn.J.Appl. Phys.Vol.33(1994)L455

3)J.C.Delgado,F.Sanches,R.GuiarY.Maniette,C. Ferrater,M.Varela:Appl.Phys.Lett.68(1996)1048

4)Q.X.Jia,X.D.Wu,D.S.Zhou,S.R.Foltyn,P.TiWari,D. E.Peterson,T.E.Mitchell:Phil.Mag.Lett.72(1995)385

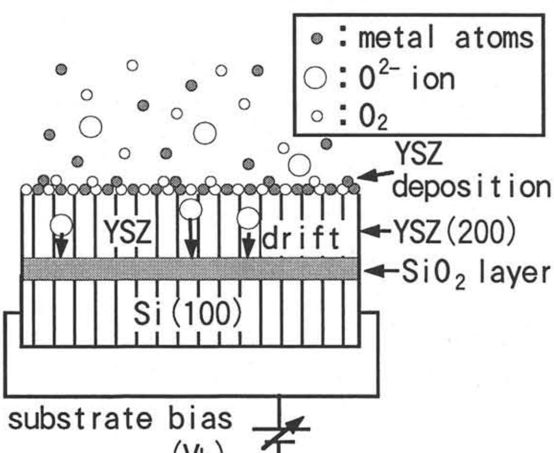

Fig.3 How to deposit SiO_2 layer by plasma anodization between Si (100) and YSZ (200).

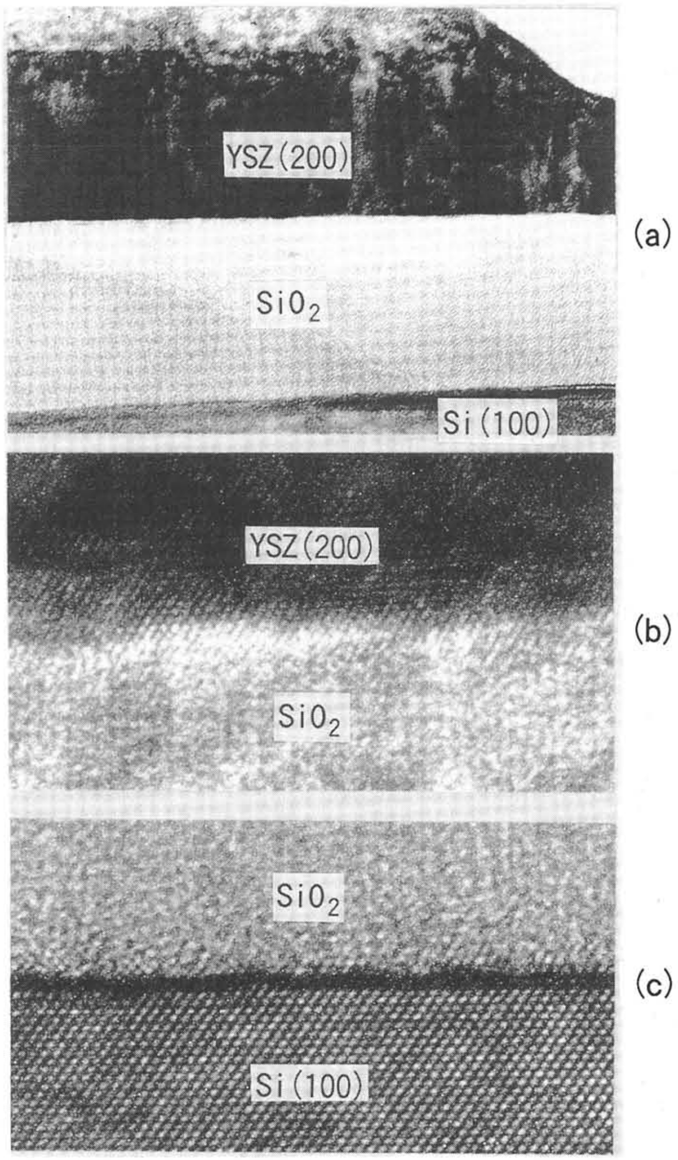

Fig.4 Cross-ectional TEM photograph of (a) SiO_2 between Si (100) and YSZ (200). (b) YSZ and SiO_2 and (c) SiO_2 and Si.

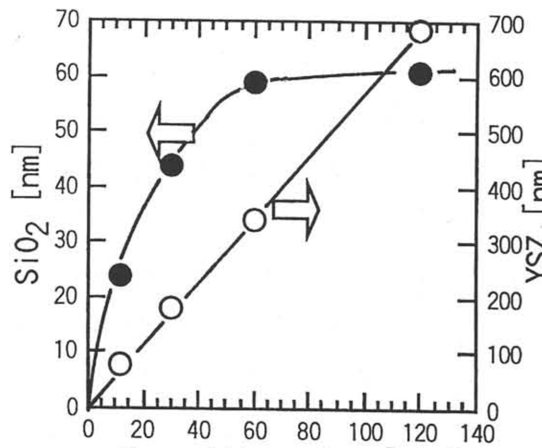

Fig.5 Deposition time dependences of SiO2 and YSZ thickness.