Production technique for Au-Pt Buffer Layer for the High Piezoelectric PZT

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Abstract

The piezoelectric material such as PZT is one of the candidates for microactuators in MEMS. However, decreasing of piezoelectricity affected by reduction volume of thinned PZT becomes non-sufficient power for driving it as the microactuators. Here, it is shown by the multiscale method based on homogenization method that the piezoelectricity shows the maximum when PZT(111) and PZT(110) are alternately located on the crystal plane. Furthermore, it is also reported that Au(111) crystal plane is effective to preferentially grow PZT(111) up, and Pt(111) crystal plane is effective to preferentially grow PZT(110) up, because of low lattice mismatch rate between thin film and buffer layer.

Therefore, the alternately arranged Au(111) and Pt(111) particles in nano or sub-micro scale as buffer layer are deposited by the Au-Pt composite target (which is a Pt thin foil with pinholes located on Au target, and the target area of Au and Pt is set to 1:3, considering the sputtering rate of Au and Pt) and the ECR(Electron Cyclotron Resonance) sputtering deposition method. However, not only Au(111) and Pt(111) but also another crystal orientations are appeared on the surface. Because, Si substrates have natural oxide film on the surface, therefore, the crystal structure for deposited film cannot be controlled.

In this study, the Au(111) and Pt(111) buffer layer deposited on Si(111) by using the Au-Pt composite target, which oxidised layer on the Si(111) substrate was removed by using HF solution and annealed in vacuum chamber, is used to grow alternately arranged PZT(111) and PZT(110) in nano or sub-micro scale. As a result, the alternately arranged substrate of Au(111) and Pt(111) is effective to show high piezoelectricity for PZT.

1 Introduction

The piezoelectric material such as PZT is one of the candidates for microactuators in MEMS. However, decreasing of piezoelectricity affected by reduction volume of thinned PZT becomes non-sufficient power for driving it as the microactuators. Here, it is shown by the multiscale method based on homogenization method that the piezoelectricity shows the maximum when PZT(111) and PZT(110) are alternately located on the crystal plane [1]. Furthermore, it is also reported that Au(111) crystal plane is effective to preferentially grow PZT(111) up, and Pt(111) crystal plane is effective to preferentially grow PZT(110) up [2], because of low lattice mismatch rate between thin film and buffer layer.

In this study, the alternately arranged Au(111) and Pt(111) particles in nano or sub-micro scale as buffer layer are deposited by the Au-Pt composite target (which is a Pt thin foil with pinholes located on Au target, and the target area of Au and Pt is set to 1:3, considering the sputtering rate of Au and Pt) and the ECR(Electron Cyclotron Resonance) sputtering deposition method. However, not only Au(111) and Pt(111) but also another crystal orientations are appeared on the surface. Because, Si substrates have natural oxide film on the surface, therefore, the crystal structure for deposited film cannot be controlled.

In this study, the Au(111) and Pt(111) buffer layer deposited on Si(111) by using the Au-Pt composite target, which oxidised layer on the Si(111) substrate was removed by using HF solution and annealed in vacuum chamber, is used to grow alternately arranged PZT(111) and PZT(110) in nano or sub-micro scale. In order to recognize the sputtering conditions to show same intensities for both of Au(111) and Pt(111) deposited on Si(111) substrate without the oxidized layer, the XRD intensities are compared with deposition sample on Si(111) with natural oxidised layer.

2 PZT crystal orientation with high piezoelectricity[1]

A multiscale finite element method based on homogenization method is applied to optimize the microstructure of polycrystalline piezoelectric ceramics such as PZT and $BaTiO_3$ so that it can maximize the homogenized macro-structural piezoelectric response [1]. Piezoelectric ceramics are polycrystalline materials consisting of randomly orientated crystals. The piezoelectric strain constant (d_{333}) of the layered structure is 35 % higher than that for a randomly oriented polycrystalline material,

and that (d_{311}) for the alternating structure is 284 % higher. The optimized microstructures achieve a stronger piezoelectric response than single-crystal due to the mechanical effect caused by the heterogeneity of crystal orientations [1]. The optimized microstructure maximizes the mechanical effect such as piezoelectricity, which is the most effective for enhancing piezoelectric ceramics exhibiting a large off-axis electric field and strong anisotropy in the vertical plane. Those microstructures are available for piezoelectric ceramics such as PZT.

It is well known that the buffer layer is effective in order to control to grow an appropriate crystal structure up. Here, lattice parameter of PZT is a=b=0.4036 [nm], and c=0.4146 [nm]. And, lattice parameter of Au and Pt are a=0.408 [nm], a=0.3921 [nm], respectively. Moreover, it is clear that the thin film can grow up on the buffer layer, when the lattice mismatch rate is less than 1%, generally. Especially, the lattice mismatch rate between PZT(111) and Au(111) in the direction of PZT[101] and [110] is very small at 0.28 %. In addition, the lattice mismatch rate between Pt(111) and PZT(110) is 0.74 %. Furthermore, it is also reported that Au(111) and Pt(111) crystal planes are effective to preferentially grow PZT(111) and PZT(110) up [2], respectively. Therefore, we propose to use the Au(111) and Pt(111) buffer layer, which are alternately arranged in nano or sub-micro scale, in order to grow PZT piezoelectric material to show high piezoelectricity.

3 Production technique of Au-Pt buffer layer and crustal orientation for Au-Pt buffer

As a production of the Au-Pt buffer layer, ECR sputtering method is used. In addition, the Pt foil with a pinhole (Pt surface has innumerable small holes.) located on Au target are used to produce the alternately arranged Au(111) and Pt(111) buffer layer [4]. Au particles are bombarded through the pinholes on the Pt surface, and Pt particles are sputtered on the Pt foil. The sputtering rate of Au and Pt were considered so that the Au and Pt area of the target was set to 1:3.

Fig.1 shows the results of XRD analysis for Au(111) and Pt(111) buffer layer deposited by using the Au-Pt composite target on Si(111). Generally, the Si(111) substrate has the oxidised layer on the surface. Therefore, it was removed by using HF solution and annealed in vacuum chamber to avoid changing of crystal orientation due to the penetration of hydrogen particles by HF solution into the Silicon substrate.

The intensity rate between Au(111) and Pt(111) is almost same (less than 1% error). Fig.2 shows the results of XRD analysis for PZT(111) and PZT(110) deposited on Au(111) and Pt(111) buffer layer scattered in nano or sub-micro scale. As a result, the XRD intensity for both PZT(111) and PZT(110) by using Si(111) substrate without the oxidized layer, is 20% improved when compared with Si(111) having oxidised layer.

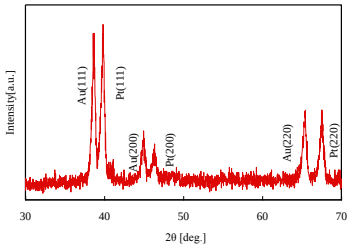

Figure 1: XRD analysis result of Au-Pt buffer layer.

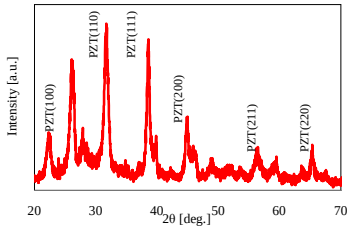

Figure 2: XRD analysis result PZT thin film on the Au-Pt buffer layer with HF etching.

4 Conclusions

The substrate of Au(111) and Pt(111) scattered in nano or sub-micro scale deposited by using the Au-Pt composite target on Si(111) without oxidised layer is effective to show high piezoelectric property for PZT.

References:

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