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STRUCTURAL PROPERTIES OF COBALT/SILICON THIN FILM AS A FUNCTION OF DEPOSITED THICKNESS AND ANNEALED TEMPERATURE

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ABSTRACT

The paper presents structural property measurement of Cobalt/silicon thin film as a function of thickness as well as of annealed at different temperatures. The synthesis of Co/Si thin film is done by Resistive heating. The structure of the Co/Si interface gets change with increase of thickness of interface, from amorphous to nano-crystalline. The X-ray diffraction measurement gives oriented growth of as-deposited Co/Si film in hcp (0 0 2) direction. But the sample annealed around 400˚C shows the formation of CoSi at the interface. The change in the structural behaviour is because of certain causes mainly: (i) relaxation of stress, (ii) growing nature of grain which is indicated by X-ray diffraction (XRD) measurement.

Keywords: XRD, thin film, nano-crystalline, interface, amorphous.

1. Introduction

Interest in the magnetic thin films and their interfaces with semiconductor surfaces has obtained significant attention in the recent years because of their technological applications like non-volatile memories and in the developing field of spintronics [1–3]. In addition to this, the combination of magnetism of the ferromagnetic layer along with the electronic properties of the underlying substrate gives the opportunities for designing innovative magneto transport devices in near future. However, the main problem that comes in these devices is the significant intermixing of semiconductor elements into the overlayer, which results in a drastic decrease of the magnetization and increase the resistivity of the whole system [4,5]. But on application of heat treatment the structural properties gets changed because of the significant intermixing of the underlying substrate element into the over layer [4,6,7]. Hence it is very important to study the

effect of heat treatment on structural properties of Co/Si thin film. The present study is, therefore aimed at investigation of the structural properties of Co/Si thin films as function of thickness and annealing temperature.

2. Experimental Details

The different thickness of Co/Si thin films was deposited on Silicon substrate using resistive heating. The deposition was carried out at a base pressure. The deposition rate was kept constant for each deposition. The structural measurement was done using high angle X-ray diffraction technique on X-ray diffractometer (Rigaku RINT 2000) using Cu Kα radiation. All the characterization measurements were carried out at room temperature. To study the structural changes upon thermal annealing, the as-deposited films were subjected to thermal annealing in a furnace of the temperature range 100-400˚C in steps of 100˚C for 2 hours. Resistive Heating has been performed inside Vacuum Box Coater MODEL: BC-300.

3. Results and Discussion

a. Function of Thickness

Figure 1 shows the XRD pattern of Co/Si thin film as a function of thickness. The XRD of Co (100Å) thin film sample shows a broad hump around 2θ value of 44.57˚, as shown in Table 1, which is the reflection of Co (002) plane. Hence this indicates that the thin film is of an amorphous in nature. This amorphous nature of the thin film is because of the deposition of lower grain size atom.

PEAK	2θ	$Sin^2\theta$	$4/3(h^2+hk+k^2) + l^2/(c/a)^2$	hkl	a	c	d
1	44.57	0.1438	1.5245	002	-	4.061032	2.0305

Table 1: Work Table for the Cobalt of 100 Å(10nm).

However, XRD pattern recorded on 400 Å, thick Co film shows increase in the intensity of peak and small shifts towards higher 2θ value. The increase in sharpness of the peak indicates the increase in grain size of Co thin film and the shift in peak position is due to release of stresses

with increase in the film thickness. It is well known that ultra thin film structures contain various point defects and stresses and they are released as the film becomes more continuous.

PEAK	2θ	$Sin^2\theta$	$4/3(h^2+hk+k^2) + l^2/(c/a)^2$	hkl	a	c	d
1	41.82	0.12738	1.3504	100	2.490	-	2.1575
2	44.68	0.14509	1.5382	002	-	4.042	2.0215

Table 2: Work Table for the Cobalt of 400 Å(40nm).

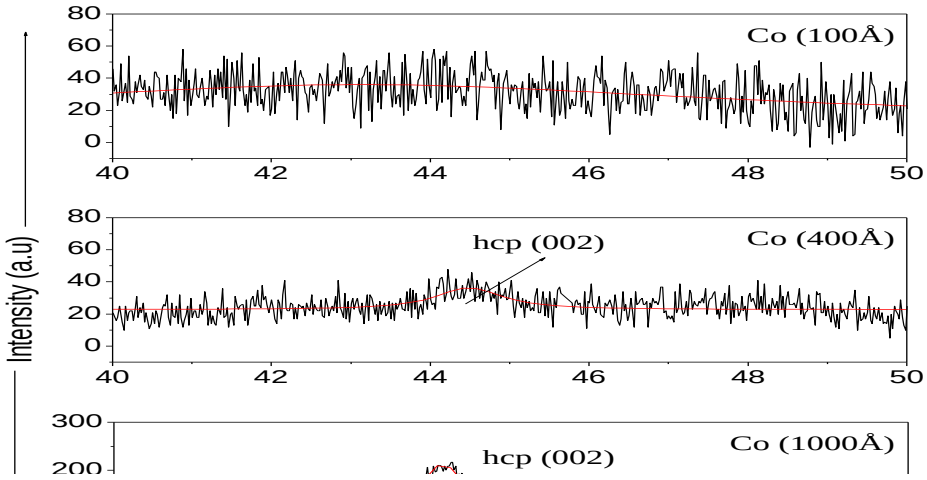

Figure 1: XRD pattern of Co thin films as a function of thickness

However, for 1000 Å thin film sample one can clearly see an intense peak at 2θ = 44.22˚ corresponding to (002) hcp Co as shown in table 3. The obtained 2θ position is consistent with the value reported for hcp Co. The intense (002) peak shows an amorphous to nano-crystalline transformation is occurred in Co thin film by surface energy minimization.

PEAK	2θ	$Sin^2\theta$	$4/3(h^2+hk+k^2) + l^2/(c/a)^2$	hkl	a	c	d
1	41.12	0.1233	1.3075	100	2.53175	-	2.1926
2	44.22	0.1417	1.5019	002	-	4.0915	2.0458

Table 3: Work Table for the Cobalt of 1000 Å(100nm).

The average grain sizes calculated using Scherrer formulism [7] as a function of film thickness. The grain size increases with the film thickness and found to be 7.6 nm for 400Å and 21.04 nm for 1000Å thick Co/Si film sample.

b. Function of annealing temperature

Fig. 2 shows the XRD patterns of as-deposited as well as annealed Co/Si thin film at different temperatures. The pattern corresponding to as-deposited film shows the occurrence of sharp peak at 2θ= 44.68, where the reflection from Co (0 0 2) plane resides.

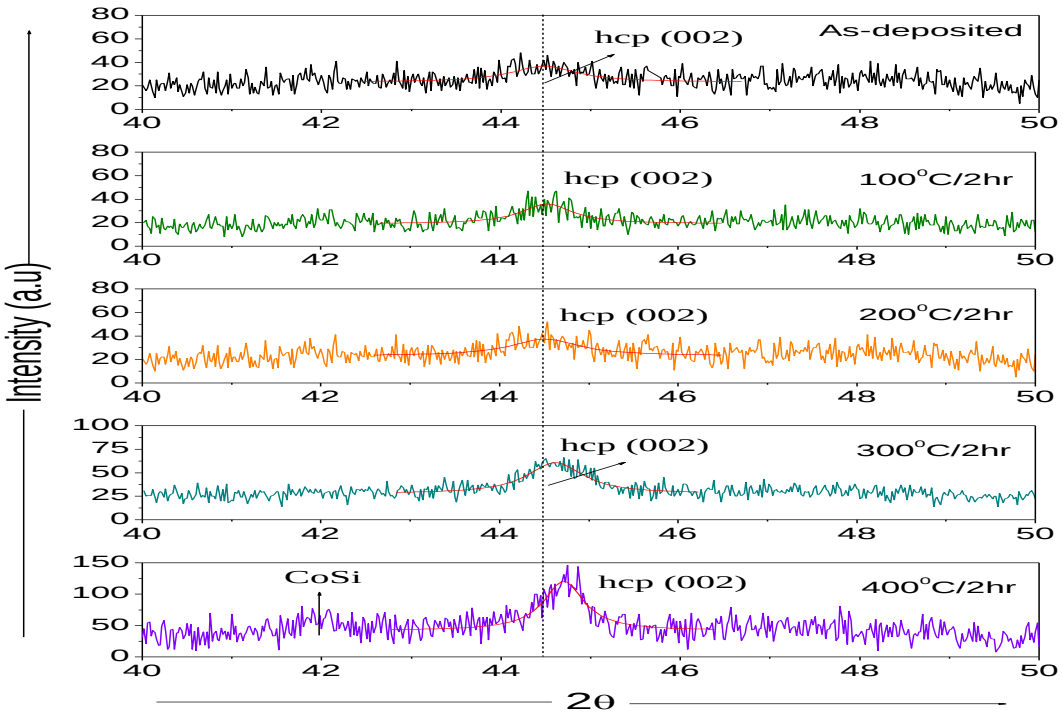

Figure 2: XRD pattern of as-deposited and annealed Co/Si film.

The presence of slight peak around 44.68 indicates the as-deposited sample is mostly microcrystalline in nature. The obtained 2θ position is consistent with the value reported for hcp Co [9]. The formation of the pure elemental Co has been seen, hence concluded that solid-state reaction has not taken place at room temperature while depositing overlayer onto the substrate. The XRD pattern recorded after 100 ˚C annealing shows a slight shift in the peak towards higher 2θ value along with an increase in peak intensity. Similarly, at 200 ˚C annealing temperature, the sample follows the same pattern and peak gets intensified along with shifting towards higher value of 2θ. However XRD pattern recorded at 300 ˚C clearly shows sharp peak and substantial transformation from microcrystalline to crystalline hcp (002) phase. On increasing temperature to 400 ˚C peak is shifted towards higher value of 2θ which clearly visible now. The peak is around 2θ=44.82, which shows the reflection of (002) hcp plane. Along with hcp (002) peak formation, a compound CoSi is formed at 2θ=42.01, which is a reflection of (100) plane. The formation of CoSi takes place at the interface of the sample.

4. Conclusion

The deposition of different thickness of Co/Si film has been synthesized using resistive heating technique. Investigation of structural property as a function of thickness has been done. The grain size increases with the increase in film thickness is been observed by XRD measurement. Along with thickness, the present work shows the influence of annealing on structural property of Co/Si thin film. XRD measurements of annealed samples confirm the formation and growth of CoSi compound at the interface upon annealing at higher temperatures, indicating solid-state reaction-taking place between the substrate and the overlayer.

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