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# Structural and Resistive Property of Cobalt/Silicon Thin Film as a Function of Thickness

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**Abstract:** ***The paper presents the structural and resistive property of Co/Si thin film as a function of thickness. The synthesis of Co/Si thin film has done by Resistive Heating. The structural property that deals here is of Three-Dimensional measurement of the sample. The technique used for the structural measurement is Atomic Force Microscopy (AFM). The resistive property is measured by Four-probe technique. Morphology of the thin film surface has been measured by AFM. The roughness shows drastic change with the increase of the thickness. The resistive behaviour shows parabolic carve against thickness.***

**Keywords:** AFM, resistivity, thin film, thickness, parabolic.

## 1. Introduction

During last few decades Co/Si thin films become area of research in the field of research and development due to its unique properties at nano-scale. With the advancement of technology, many unique devices comes into play like spintronic devices, magnetic read heads or sensors and GMR (giant magnetoresistance)-based storage devices etc [1]. The working principle behind these devices lays in the unique properties of the Co/Si thin films. In GMR devices, Co has a significant role because of its high spin polarization of carriers at Fermi level [2]. The unique properties come into play by the variation of grain size [3]. In the present paper morphology and resistive behavior of the Co/Si thin films has been study.

## 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 RINT All the characterization measurements were carried out at room temperature. Resistive Heating has been performed inside Vacuum Box Coater MODEL: BC-300. The atomic force microscopy (AFM) measurements have been done on Digital Instruments Nanoscope E model in contact mode. The resistivity measurement has been done using standard four-point probe technique.

## 3. Result and Discussion

### 3.1 XRD Measurement

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.

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

| 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 |

However, XRD pattern recorded on 400 Å, thick Co film shows increase in the intensity of peak and small shifts towards higher $2\theta$ 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.

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

| 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 |

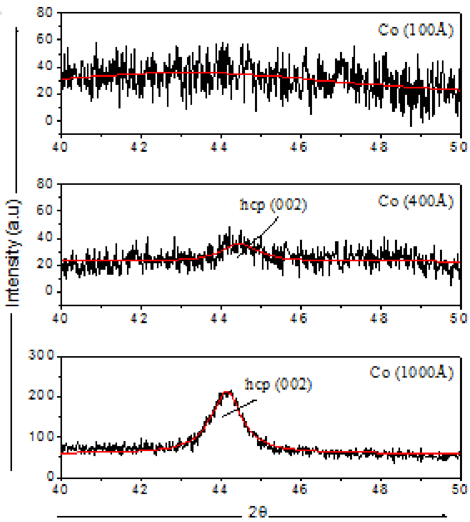


**Figure 1:** XRD pattern of Co thin films as a function of thickness

However, for 1000 Å thin film sample one can clearly see an intense peak at $2\theta = 44.22^{\circ}$ corresponding to (002) hcp Co as shown in table 3. The obtained $2\theta$ 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.

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

| 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 | 2.5317 | - | 2.1926 |
| 2 | 44.22 | 0.1417 | 1.5019 | 002 | - | 4.0915 | 2.0458 |

The average grain sizes calculated using Scherrer formulism [4] 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.

### 3.2 AFM Measurement

The paper presents nanoscale-sized structural features. Hence the surface morphology of the thin films has been studied using atomic force microscopy technique. Figure 2 illustrate the AFM images of Co/Si thin films of different thicknesses. The images of the film have been taken from different portion of the film surface, which is of an area of 2 μm × 2 $\mu$m. The AFM image of Co/Si (100 Å) thin film is showing a discontinuous nature of film that have been deposited and we have obtained an island type growth. However, the AFM image of 400 Å thin film sample shows increase in grain size of deposited Co/Si atoms. Roughness of the interface is increases from 100 Å to 400 Å. But there is a sharp decrease in the interface roughness from 400 Å to 1000 Å.

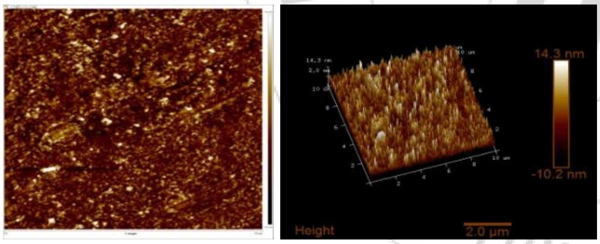


**Figure 2(a):** 2-D and 3-D AFM images of Co/Si 10n as-deposited

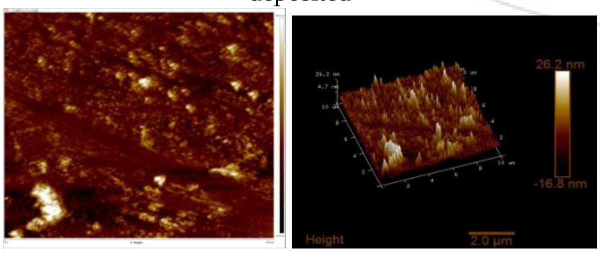


**Figure 2(b):** 2-D and 3-D AFM images of Co/Si 40n as deposited

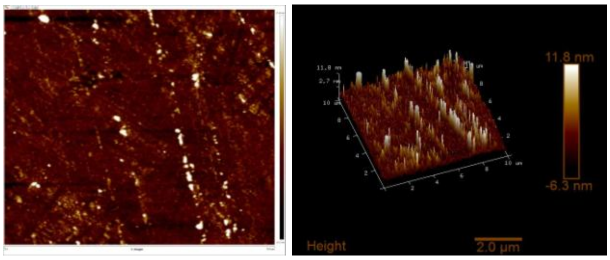


**Figure 2(c):**2-D and 3-D AFM images of Co/Si 100n as deposited

Finally, a continuous growth is obtained for 1000Å thin films with increase in grain size, as also revealed by our XRD measurements. This observed growth behaviour can be correlated with resistivity results, which show a decreasing pattern of resistivity in going from 100 Å to 1000 Å thin film samples as seen in Figure 3.

### 3.3 Resistivity Measurement

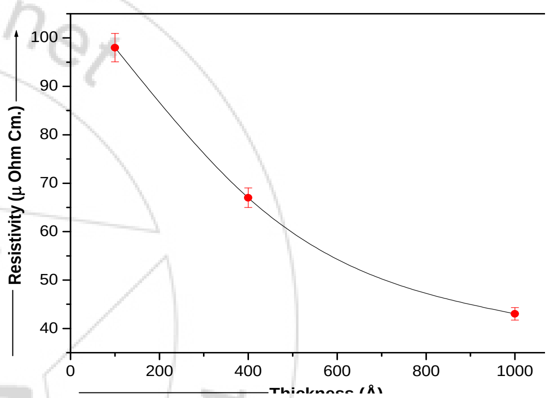


**Figure 14:** Resistivity Vs Thickness curve.

In order to gain more understanding about the growth mechanism of Co/Si thin films, we have done resistivity measurements using four-probe techniques. Figure 4 show the variation in resistivity of Co film as a function of Co/Si film thickness. It can be clearly seen in the figure that the 100 Å thin film shows higher value of resistivity (98.0 $\mu\Omega$ cm).This value is higher than the bulk resistivity for bulk Co/Si (6 $\mu\Omega$ cm). The higher value of resistivity obtained is due to an island type growth of the deposited film as also evident from the corresponding AFM image. The resistivity value drops for 400 Å thin film sample, which may be due to that average distance between the islands now is decreasing with increase in film thickness .The resistivity of 1000 Å sample is found to be 43.14 $\mu\Omega$ cm. The observed decrement in resistivity with thickness can be attributed to grain growth leading to formation of continuous Co film. Similar behaviour is also reflected from XRD and AFM measurements.

## 4. Conclusion

The deposition of different thickness of Co/Si film has been synthesized using resistive heating technique. Morphology of the Co/Si thin film has been studied. As the thickness increases, the grain size of the thin film increases. Initially, the growth pattern of the deposited film is observed to be island type (100 Å). From AFM measurements we have observed that the roughness increases upto 400 Å initially, then drastically decreases from 400 Å to 1000 Å. Also resistive behavior has been studied. It has been found that the resistivity is decreasing with the increase of thickness. Since the grain size of the deposited film increases, the conductivity increases.

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## 5. Acknowledgement

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