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Electrical Resistivity in Copper Thin Films

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Abstract

Copper is one of the most employed metals in the manufacturing industries for a variety of applications due to its high electrical and thermal conductivities. This metal has also attracted much interest as a thin and ultrathin film material, which was driven by the increasing demand for nano ranged downscaled electrical, electronic, and magnetic devices Cu thin films with different thicknesses from 50–220 nm have been deposited on glass substrate by DC magnetron sputtering technique at room temperature in pure Ar gas. The thickness effect on the structural, morphological and electrical properties were studied by X-ray diffraction (XRD), atomic force microscope (AFM) and four point probe (FPP) measurements, respectively. By varying the films thickness the significant changes were observed in the films surface morphology due to the mechanism of films growth. Finally, the relationship between film resistivity and Cu film thickness are investigated in this paper.

Keywords: *Copper Thin Films, Electrical Resistivity, X-ray diffraction (XRD),*

INTRODUCTION

Now a day scientists and researchers are focused on film formation processes in order to obtain the insight into mechanisms leading to special structural properties. The studies on physical properties of Cu thin films have been the object of investigations for many years. Many parameters can influence on the thin films structure such as time, Ar gas pressure, kind of substrate and also the thickness, which determines the physical properties of the thin films. Cu thin films with nano structural dimensions have more applications in electronic devices because of both high electro movement resistance and high electrical conductivity.

Due to these characteristics; Cu thin films are widely used for many applications a like diodes , solar cells and high-speed integrated circuits.

The electrical conductivity of commercially pure copper is second only to silver, but lower costs and accessibility causes that Cu is the metal used most often in electronic applications.

Cu thin films fabricated by different technique, including Reactive Pulsed Laser Deposition (RPLD),DC magnetron sibilating , RF magnetron sibilating , ion beam assisted DC magnetron reactive sibilating and molecular beam epitaxy (MBE).

A more papers have been reported on the Cu thin film; however, most of them were using si substrates to deposit the films, while few reports treated the glass substrates.

In this study, the copper thin films have been prepared on glass substrates by DC planar magnetron sibilating at different time depositions.The effect of thickness on the structure and resistivity of the film will be briefly discussed.

EXPERIMENTAL PROCEDURE:

In this method, Cu thin films with different thicknesses have been deposited on glass substrate by DC magnetron sibilating technique

The substrate was fixed above the Cu target (99.9% in purity) of 870mm in diameter with a distance of 7 cm.

The sputtering deposition was carried out in a pure argon (Ar) gas (99.999%) at a pressure from 6×10-5 to 8×10-2 torr

The size of glass substrates are 2 cm×3.5 cm and cleaned in acetone and alcohol each for 15 min to 20 min and blown dry in N2 gas before they were sending into the chamber.

The effect of the thin film thickness, four copper thin film samples with thicknesses at

around 50–220 nm were prepared at room temperature.
The deposition conditions of the Cu thin films are showed in Table 1.

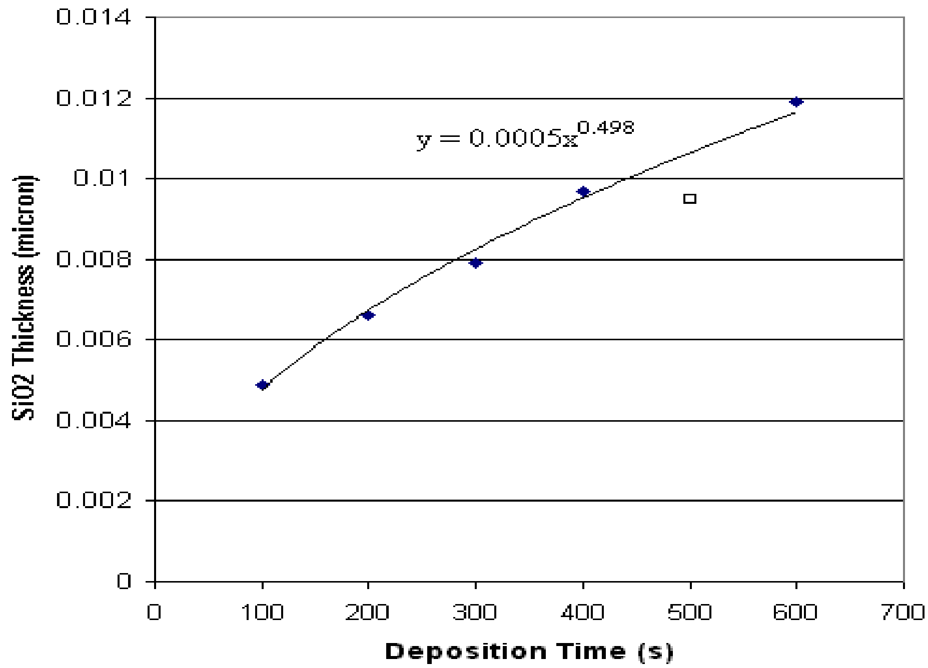


Figure 1

Table-1

Voltage (V)	300
Current (mA)	100
Sputtering power (W)	30
Deposition rate (nm/min)	~ 12.5
Deposition time (min)	4-8-12-16
Film thickness (nm)	50-220

The Cu samples illustrated clearly that their surface morphologies are strongly affected by thickness. The grain size of the films clearly increase as the thickness rises, which is consistent with the XRD results.

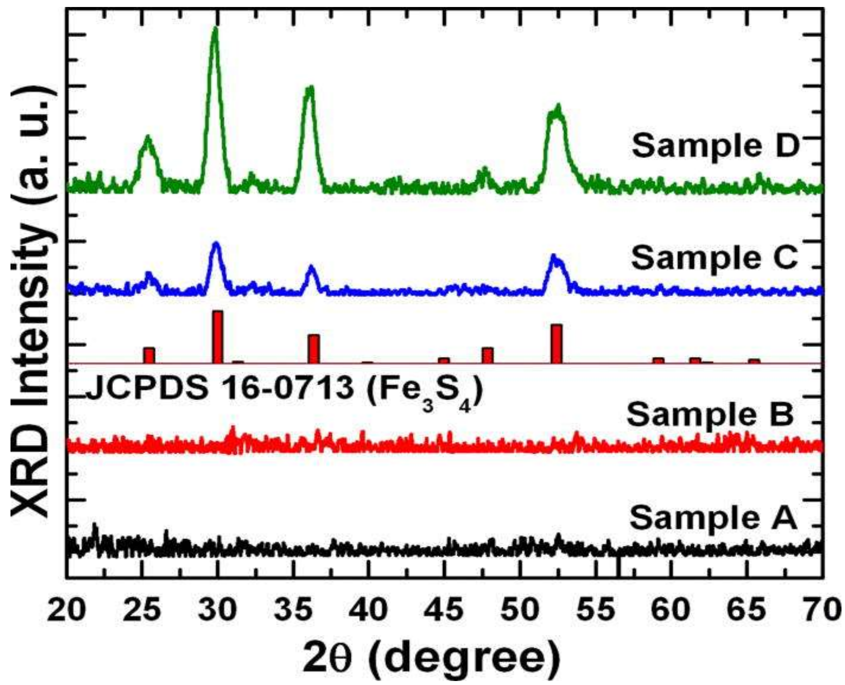


Figure 2.

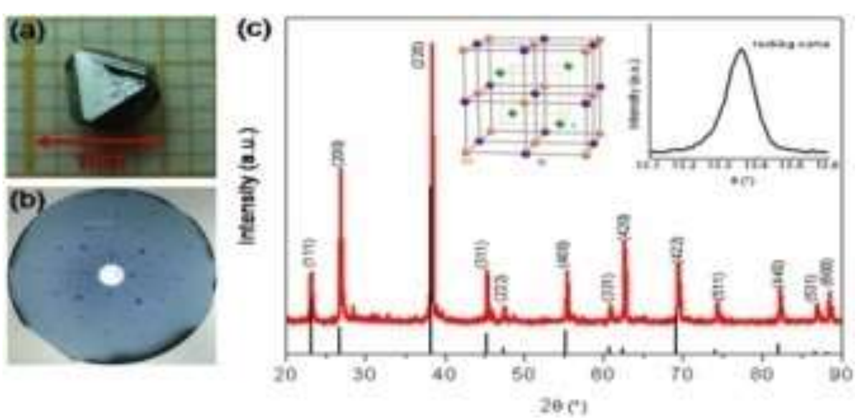


Figure 3.

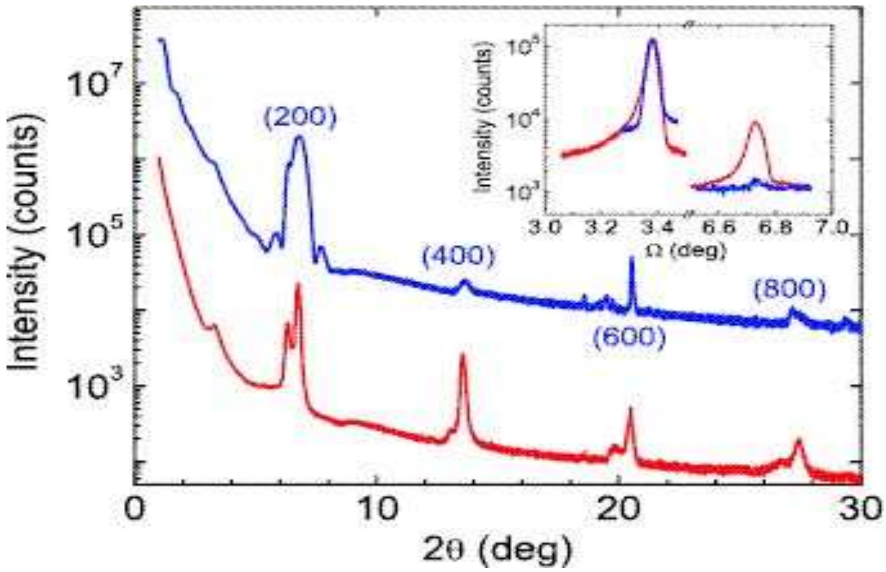


Figure 4.

The diffraction patterns of all the samples were similar except the variation of the peak intensities due to the differences in thickness.

When the thickness of samples is increased the crystalline and the mean grain size improved.

One can notice small differences in the RMS roughness values of DCMS films with the same average thickness

The RMS roughness increases with the thick-ness of the studied Cu films, It is associated with the increase in grain size at higher can notice small differences in the RMS roughness values of DCMS films with the same average thickness

The _120 nm thick films appear to be rougher when deposited than by DCMS, which may be associated with the large grains present in the films deposited by the pulsed technique.

The large grained, dense, columnar morphology found in the Cu films is related to the increased adatom mobility and enhanced diffusion processes,

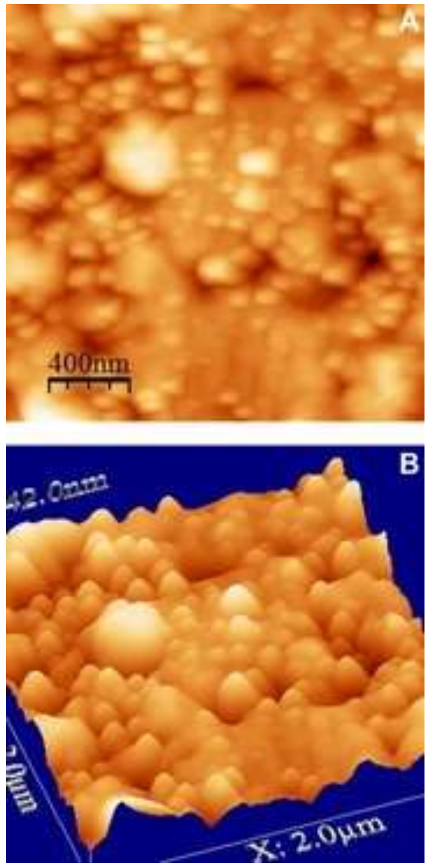


Fig. 5

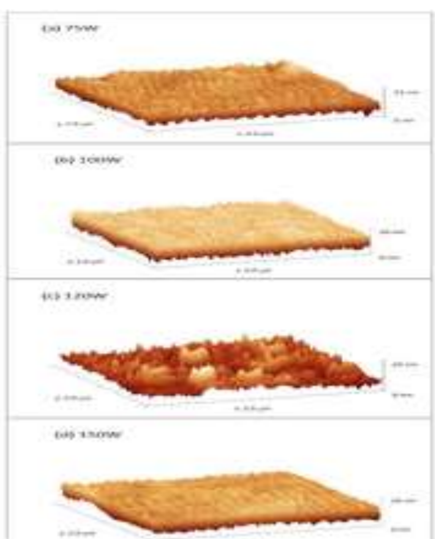
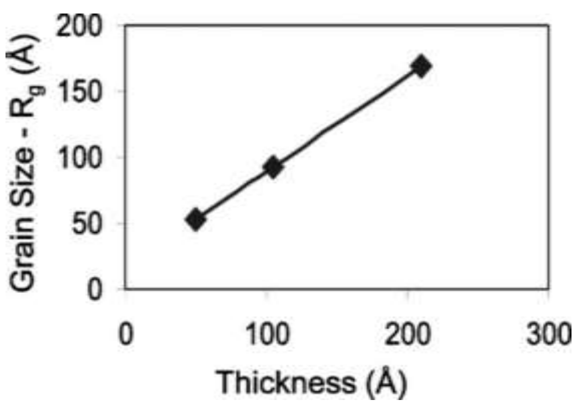


Fig. 6

Columnar structures for thin film were observed, which were tiny, dense, and vertical. By increasing thickness, these small grains gradually combine and make bigger grains.

The grains become bigger and at last it can cause to create clusters, which these clusters combine and create big grains.

It results in increased self-diffusion of surface and grain boundaries promoting grain coarsening during growth, which ultimately leads to larger grain size



The dependence of the electrical resistivity at room temperature on the thicknesses of Cu films deposited by DCMS

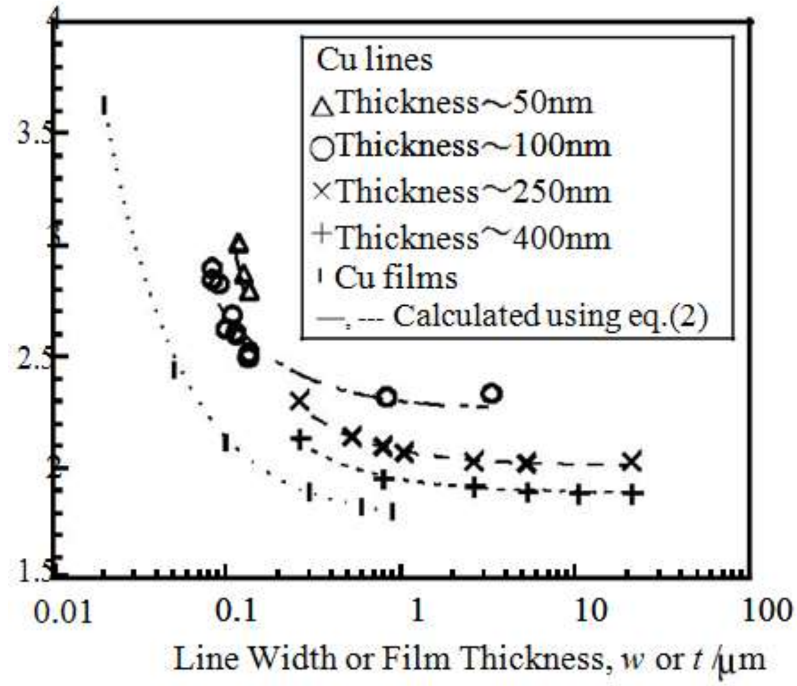
The electrical properties of Cu thin films with different thicknesses from 50 to 220 nm were investigated.

The resistivity decreases with increasing film thickness and eventually approaches the bulk value.

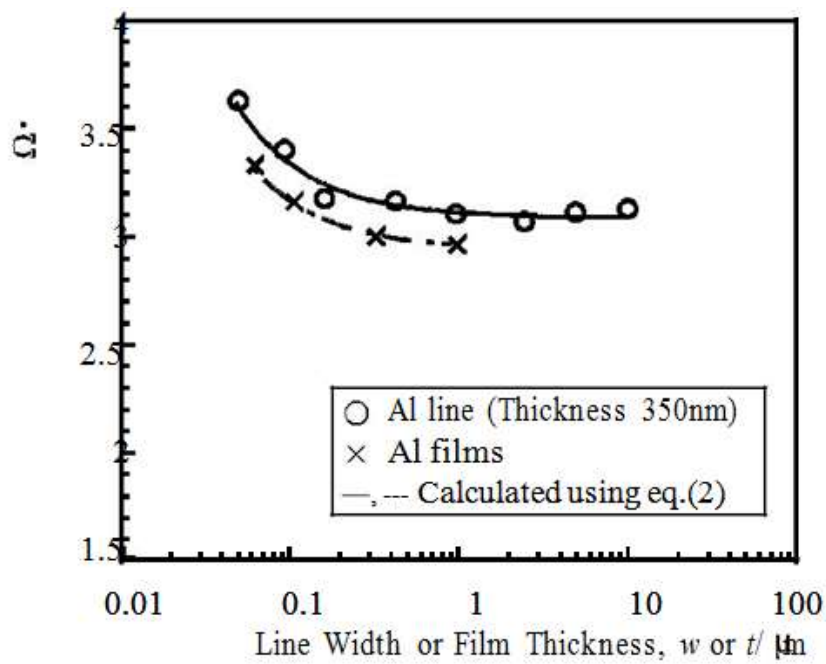
The Cu thin film resistivity further decreases to 3.83 μΩ -cm as the film thickness increases to 160 nm, after which the resistivity is almost independent of the film thickness and the value varies .

The resistivity caused by impurity and the defects should be the same under the same deposition conditions except varying deposition time. Also, the resistivity due to surface scattering should not play its role in the decreasing resistivity trend in our experiment due to film thicknesses of our Cu films ranging from 50 to 220 nm are much higher than the electron mean free path of Cu (39 nm) [16].

The Cu film resistivity decreases with increasing film thickness to 220 nm, in which the decreasing trend can be attributed to the inverse linear dependence of film resistivity increase on grain size.



Graph 1.



Graph 2.

CONCLUSION:

We precisely evaluated the resistivity of Cu fine lines, Cu films using a resistance ratio method. The results show that this method can predict precise resistivity without the need for precise and detailed line-dimension measurements. We deduced electron mean free path values of 55 nm in Cu film . The resistivities of the fine line were much greater than those of films, depending not only on the width but also on the thickness. We proposed a simple equation for expressing the line resistivity, which can explain the measured values. The re-sistivity of Cu samples increased faster than that of Al, be-cause Cu has a longer electron mean free path than Al. There is some possibility of occurring the turn-over at a width and thickness less than several tens of nano meters.

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