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Effects of Discharge Current and Target Thickness in Dc-Magnetron Sputtering on Grain Size of Copper Deposited Samples

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Abstract:

A study of the effects of the discharge (sputtering) currents (60-75 mA) and the thickness of copper target (0.037, 0.055 and 0.085 mm) on the prepared samples was performed. These samples were deposited with pure copper on a glass substrate using dc magnetron sputtering with a magnetic flux density of 150 gauss at the center. The effects of these two parameters were studied on the height, diameter, and size of the deposition copper grains as well as the roughness of surface samples using atomic force microscopy (AFM).The results of this study showed that it is possible to control the specifications of copper grains by changing the discharge currents and the thickness of the target material. The increase in discharge current values led to a decrease in height copper grain's values of 20% at a current of 75 mA and target thickness of 0.085 mm. Furthermore, the increasing in the current caused a decrease in the diameter and size values of deposition copper grains. Finally, the surface roughness of the samples was reduced by a 15% by changing the current and target material thickness at 75 mA and 0.085mm respectively.

Key words: Copper grain size, Dc magnetron sputtering, Sputtering current, Surface roughness.

Introduction:

Copper is an important and inexpensive metal that enters effectively into electronic industries because of its high electrical and thermal conductivity (1-3).There are different methods to obtain a copper thin film such as, pulsed laser deposition (PLD), chemical vapor (CVD) and magnetron sputtering(4-8).The sputtering method is one of the leading and important simple low cost methods used in semiconductors interconnects and manufacturing of integrated circuits(9,10).In precision electronic industries required a purity and homogeneity in the coating, and thus the grain size must be controlled in these processes(11,12).In this work, the effects of the sputtering current and copper target thickness were investigated for controlling copper grain size in a dc planar magnetron sputtering system.

Materials and Methods:

A dc planar magnetron sputtering source as in Fig.1 are used for depositing a pure copper on a cleaner glass substrate (1x1 cm^2). A plasma between two a circular stainless steel electrodes (φ =5.7cm) was generated by using argon gas (99.99%).

The surface morphologies of cu depositions were studied for different sputtering currents I_S=(60, 65, 70 and 75) mA and cu thickness target Th= (0.037, 0.055 and 0,085) mm by using atomic force microscopy (AFM).

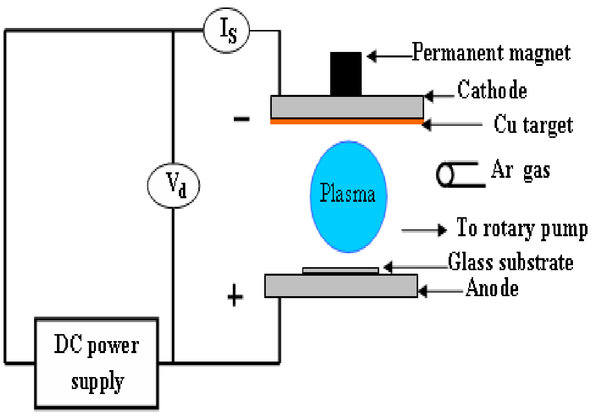

Figure 1. Schematic diagram of experimental setup.

The operation conditions for the system are shown in Table 1.

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Table 1. Deposition sputtering operation conditions for DC planar magnetron sputtering system.

Interelectrode distance	4cm
Pressure chamber	$1x10^{-2}$ mbar
Working pressure	0.2 mbar
Magnetic flux at the center distance between electrode	150 gauss
Applied voltages (V_d)	(505,518, 525, 540) volt
Discharge(Sputtering)currents (I_S)	(60, 65, 70, 75) mA
Sputtering deposition time	90 sec

Results and discussion:

Figures 2 and 3 shows the surface morphologies with 3-D images of cu deposition samples prepared under the operation conditions for the system in Table 1 with different values of sputtering currents and target thickness respectively.

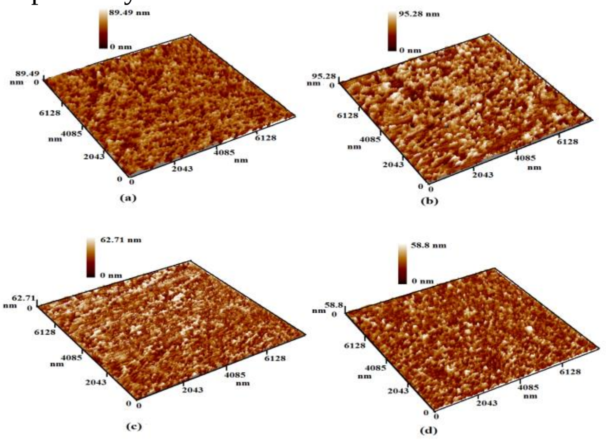

Figure 2. 3-D AFM images at copper target thickness 0.037 mm for different values of sputtering currents: (a) I_S = 60 mA. (b) I_S = 65 mA , (c) I_S = 70 mA. (d) 75 mA.

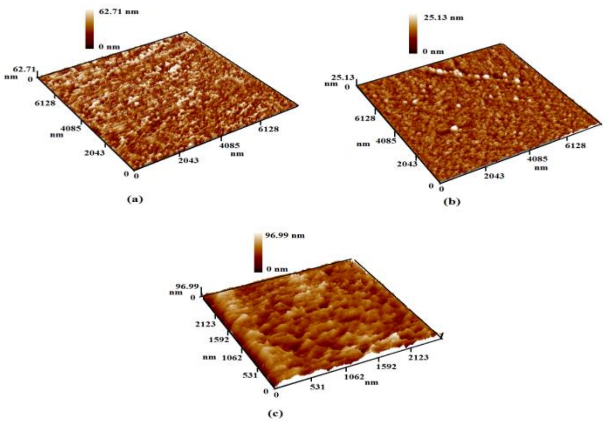

Figure 3. 3-D AFM images at sputtering current I_S = 70 mA for different values of copper target thickness: (a) Th= 0.037 mm. (b) Th= 0.055 mm. (c) Th = 0.085 mm.

The show Figures the clearly effects of sputtering currents and target thickness for the copper grain size as in the following:

Influence on grain's number

The effects of the sputtering current and the thickness of the copper target were studied on the number of deposition grain as shown in Fig.4.

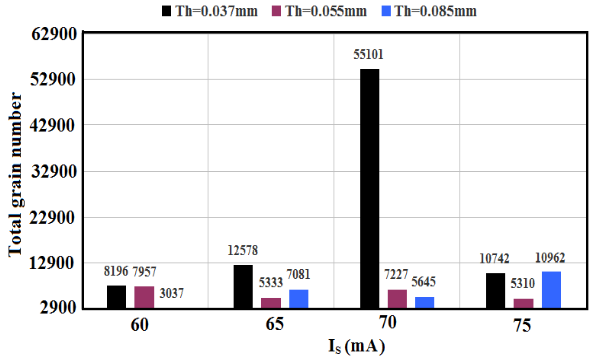

Figure 4. Total copper grain numbers versus sputtering currents for different values of targets thickness.

It is noticed from the Figure that the maximum grain sized obtained at sputtering current 70 mA and copper thickness 0.037 mm. On the other hand, the minimum value of the grain's number was obtained at sputtering current 60 mA and copper thickness 0.085 mm.

Influence on grain's height

Figure 5 shows the effects of variation in copper grain's height, G_H, by changing the sputtering current and target thickness

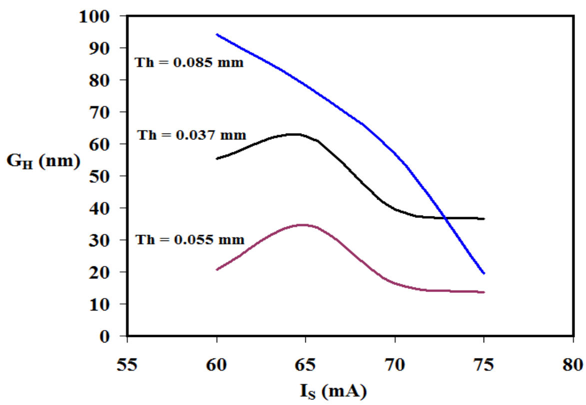

Figure 5. Copper grain's height as a function of sputtering currents for different values targets thickness.

It is noticed that by increasing the sputtering currents, the copper grain's height decreases. In addition, by changing the target thickness, the lowest grain height values were obtained at thickness 0. 055mm.

Influence on grain's diameter

The effects of the sputtering currents and the thickness of the target material on the diameter of copper grains, G_D, were studied as in Fig. 6. One can notice from this Figure the effect of this sputtering current on the grain diameter.

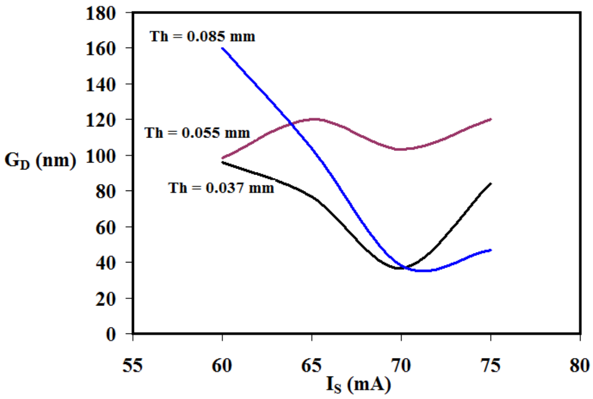

Figure 6. Grain's diameters of copper versus sputtering currents for different values of target thickness.

By increasing the currents and changing the thickness, the values of the grain diameters decreased, and the lowest value was obtained at 70 mA for all the target material thickness values.

Influence on average grain's size

Figure 7 illustrates the behavior of average copper grain size, GS, as a result of changing the sputtering currents and the target thickness. It is noted that as the current increases, the grain's size decreases and reached the lowest value at current 70 mA for all target thickness. Furthermore, a small rise for grain size was obtained at 75 mA at thickness 0.055 mm.

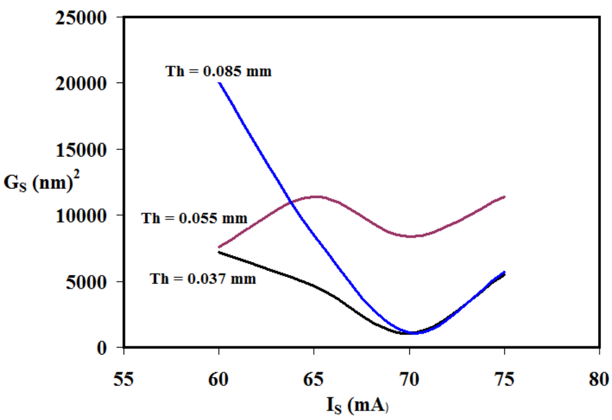

Figure 7. Average grain's size of copper versus sputtering currents for different values of target thickness.

Influence on maximum grain's size

The maximum values of copper grain's sizes, G_{MS}, are shown in Fig. 8.The upper and lower values of G_{MS} was obtained at sputtering current 65 mA and 75 mA respectively at target thickness 0.085mm.

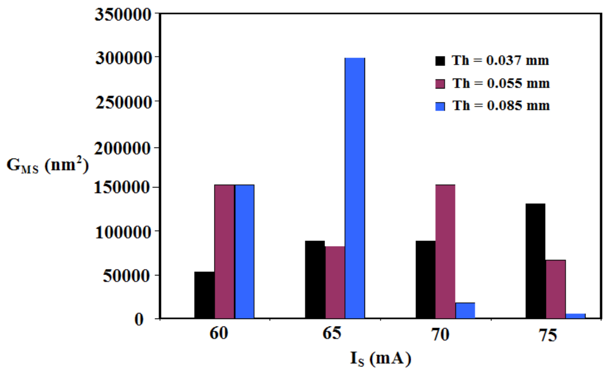

Figure 8. Maximum grain's size versus sputtering currents for different values of target thickness.

Influence on roughness parameter

The roughness parameter is an important factor whose values must be controlled, especially in the coating processes and some industrial applications. This can be done by varying the values of sputtering currents and target thickness as shown in fig.9.

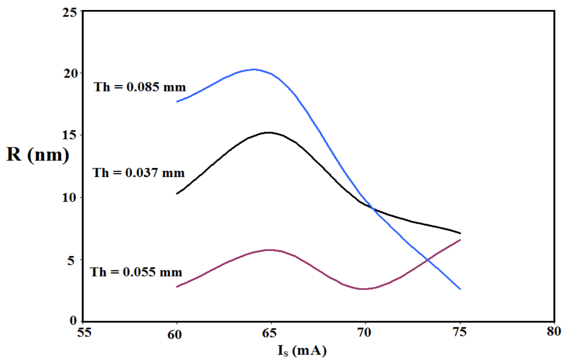

Figure 9. Roughness values versus sputtering currents for different values of target thickness.

It is observed from the Figure that the roughness values, R, increased, as the sputtering currents increased, and reached a max value and then started to decrease at high currents. At target thickness 0.055 mm, the value of roughness was increased at higher sputtering with low values of roughness comparing with another target thickness.

Conclusions:

The study shows the effect of the sputtering currents and the thickness of the target in controlling the copper grains.

The increase in sputtering current's values leads to a decrease in grain's height by 20% at a target thickness of 0.085 mm and current 75 mA. Also, the lowest value of the grain's height is obtained at target thickness 0.055 mm and current 75 mA. The change in the values of the sputtering currents and the thickness of the target led to the control of the diameter and size of the copper grains. These two properties are important in the practical applications, where it obtained the lowest value of the diameter and size of the deposited copper grains at current 70 mA

Finally, the increase in sputtering currents has resulted in the reduction of the roughness values of the deposited copper samples by 15% at target thickness 0. 085mm at current 70 mA.

Conflicts of Interest: None.

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تأثير تيار التفريغ وسمك الهدف في الترذيذ المغناطيسي المستمر على حجم حبيبات النحاس في النماذج المرسبة

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الخلاصة:

ان تأثير تيار التفريغ (الترذيذ) (60-75) ملي امبير وسمك النحاس الهدف (0.037، 0.055، 0.085) ملم على النماذج الزجاجية المحضرة والمرسب عليها النحاس النقي بواسطة منظومة الترذيذ بالماكنترون المستمر قد تمت دراستها في هذا البحث. درس تأثير هذين العاملين على ارتفاع وقطر وحجم حبيبات النحاس المرسبة وكذلك تمت دراسة الخشونة لسطح النماذج المحضرة بأستخدام مجهر القوة الذرية (AFM). تبين من النتائج انه بالامكان السيطرة على خصائص حبيبات النحاس المرسية عن طريق تغيير تيار التفريغ وسمك مادة النحاس الهدف. ان زيادة تيار التفريغ ادى الى تقليل ارتفاع حبيبات النحاس بنسبة 20% عند تيار 75 ملي امبير وسمك هدف 0.085 ملم.اضافة الى ذلك ان زيادة تيار التفريغ ادى الى تقليل قطر وحجم الحبيبات، وكذلك فان خشونة السطح قلت بنسبة 15% بتغيير التيار الى 75 ملي امبير عند سمك هدف 0.085 ملم.

الكلمات المفتاحية: الترذيذ المغناطيسي المستمر، حجم حبيبات النحاس، تيار الترذيذ، خشونة السطح.