Optik 125 (2014) 5532–5537

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Incidence angle dependence on structural and optical properties of UHV deposited copper nano layers

Haleh Kangarlou*, Maryam Motallebi Aghgonbad

Faculty of Science, Department of Physics, Urmia Branch, Islamic Azad University, Urmia, Iran

ARTICLE INFO

Article history:
Received 25 September 2013
Accepted 1 May 2014

Keywords:
Copper nano-layers
Optical properties
Structural properties

ABSTRACT

Copper nano-layers with different incident angles as vertical, 20 and 30 degrees, same 73.3 nm thicknesses, and same deposition rate, were deposited on glass substrates, at 373K temperature, under UHV conditions. Their nano-structures were determined by AFM and XRD methods. Their optical properties were measured by spectrophotometry in the spectral range of 300–1100 nm. Kramers–Kronig relations were used for the analysis of the reflectivity curves of Cu films to obtain the optical constants of the nano layers. Different incident angles show important effects on both structural and optical properties. The effective medium approximation was employed to establish the relation between structure zone model (SZM) and EMA predictions. By increasing incidence angle the separation of metallic grains increases, hence the volume fraction of voids increases. That is in agreement with AFM analysis. The predictions of Drude free-electron theory are compared with experimental results for dielectric functions of these nano layers. There is a good agreement between our optical results and Hangman's optical results for a bulk standard Cu sample.

© 2014 Elsevier GmbH. All rights reserved.

1. Introduction

Due to its good electromigration resistance copper has become the most promising interconnect material for deep submicrometer integrated circuits [1]. Copper is replacing aluminum in microelectronic interconnections because copper circuits are faster and last longer [2]. It has low resistivity, low electromigration and a high melting point compared with aluminum [3]. Pure copper is defined as having a minimum copper content of 99.3%. Copper with oxygen content below 10 ppm is called oxygen free [4].

The structure zone model (SZM) consisting of three zones, separated by two boundary temperatures, proposed by Movchan and Demchishin [5] for the broad description of polycrystalline film structure and refined by Thornton [6] for coating of metals produced by sputtering, in which an additional zone (transition zone T) appear between zone I and zone II, has been further refined by many investigators [7–11] are reviewed by Barna and Adamik [12], Petrov et al. [13] and Thompson [14].

In general, SZM consist of three zones; zone I ($T_s \sim 0.3\,T_m$) consist of porous structure (tapered crystallites separated by voids), zone II ($0.3\,T_m < T_s < 0.45\,T_m$) consists of columnar grains with smooth surfaces and zone III ($T_s > 0.45\,T_m$) consists of re-crystallised grains.

Although many researchers work on different deposition conditions, incident angle has been worked very few. This factor is important because voids play important role on structure and other properties (optical, electrical and etc.) of thin films.

In this work we want to study the effects of voids and incident angle on structural and optical properties of thin copper films. Using EMA method we want to investigate the correlation between nanostructures, optical constants and EMA predictions. We also study energy loss function and Drude theory predictions.

2. Experimental details

Copper nano layers of vertical, 20 and 30 degrees to the direction of the evaporated beam were deposited on glass substrates at 373K temperature. The residual gas was composed mainly of H_2, H_2O, CO and CO_2 as detected by the quadropole mass spectrometer. Distance between the evaporation crucible and substrate was 45 cm. Just before use, all glass substrates were ultrasonically cleaned in heated acetone, and then in ethanol. Other deposition conditions were the same during coating. An ETS160 coating planet with a base pressure of 10^{-6} mbar was used. The Argon gas pressure for the plasma formation was 10^{-2} mbar, before evaporating copper cleaned pieces. Deposition rate was 2 Å/s. Thickness of the

* Corresponding author. Tel.: +98 9143457951.
E-mail addresses: h.kangarlou@iaurmia.ac.ir (H. Kangarlou), m.motallebi89@gmail.com (M.M. Aghgonbad).

http://dx.doi.org/10.1016/j.ijleo.2014.06.079
0030-4026/© 2014 Elsevier GmbH. All rights reserved.

layers was determined by quartz crystal technique, that is about 73.3 nm. The nanostructure of these films were obtained by using a Philips XRD X'pert MPD Diffractometer (CuK$_\alpha$ radiation) with a step size of 0.03 and count time of 1 s per step, while the surface physical morphology and roughness was obtained by means of AFM (Dual Scope ^{TM} DS 95-200/50) analysis. The reflectance spectra of these nano layers were obtained by using spectrophotometer (Hitachi U-3310) instrument. The spectra of layers were in the range of 300–1100 nm wave length range (VIS), corresponding to 1.13–4.1 eV, energy range.

3. Results and discussion

3.1. Structural analysis

Fig. 1 shows AFM images for Cu/glass layers of 73.3 nm thicknesses at 373 K deposition temperature and different deposition angles.

Layers are in zone I ($T_s/T_m \sim 0.27$) of structure zone model. In general for the layers produced in this work, zone I consist of porous structure (tapered crystallites by voids), that is obvious from Fig. 1(a–c). By increasing deposition angle from vertical to 20 and 30 degree, more voids form on layers (Fig. 1(a–c)). Also there are needle like grains at vertical deposition angle and by increasing deposition angle grains get dimed (Fig. 1(b–c)).

Fig. 2 shows roughness for the layers produced in this work. As it can be seen, by increasing incident angle, roughness increases, that is in agreement with AFM images.

Fig. 3 shows XRD patterns for Cu/glass layers. As it can be seen, at vertical deposition angle copper crystallographic directions, especially at $2\theta = 25$ begin to grow. Also oxygen impurity has penetrated to Cu layers and it seems that CuO and Cu_2O crystallographic directions begin to grow for the layers produced in this work. By increasing deposition angle, metal oxide directions get clearer. In general, because of no clear crystallographic direction in XRD patterns, layers are amorphous.

3.2. Optical analysis

3.2.1. Optical constants

Fig. 4 shows the real part of refractive index for Cu/glass thin layers of 73.3 nm thickness, at different deposition angles. Hagemann et al.'s [15] data for a bulk standard sample is also included for comparison. As it can be seen, the general trend of our samples is the same as Hagemann et al.'s [15] results, especially in the energy range of 1.9–3.5 eV. There is an extra wide peak in our samples at about 1.5 eV energy that can be result of nano-metric thickness of these samples and presence of impurity as oxygen on layers. By increasing deposition angle from vertical to 20 and 30 degrees, real part of refractive index (n) increases. Also more voids form on layers as well as separated clusters in homogeneous layer's configuration. That is the result of this increasing trend.

Fig. 5 shows the imaginary part of refractive index (k). Hagemann et al.'s [15] result for a bulk standard sample is also included for comparison. As it can be seen the general trend is the same for all curves. A minimum point at 2.2 eV for Hagemann et al.'s [15] data has been shifted back to 1.9 eV for the layers produced in this work. Additionally a wide minimum can be seen at 1.5 eV for our layers. Both can be the result of low thickness and presence of impurity for the layers produced in this work. As it can be seen, by increasing deposition angle, because of formation of more voids on layers transmittance increases, therefore absorbance and extinction coefficient decreases.

Fig. 6 shows the real part of dielectric constant (ε_1). Hagemann et al.'s [15] results for a bulk standard sample is also included for comparison. As it can be seen the general trend is the same. All curves begin from a negative minimum point at about −25 for our layers and −50 for Hagemann et al.'s [15] data. Because of bulk Cu samples for the energy range of 1 eV up to 4 eV (the range discussed in this work), Hagemann et al.'s [15] results are negative. The layers produced in this work, because of low thickness ($d = 73.3$ nm) and glass substrate, show conducting property. There is an extra wide peak at 1.5 eV for our results that is discussed before. As it can be seen from Fig. 6, by increasing the deposition angle, dielectric

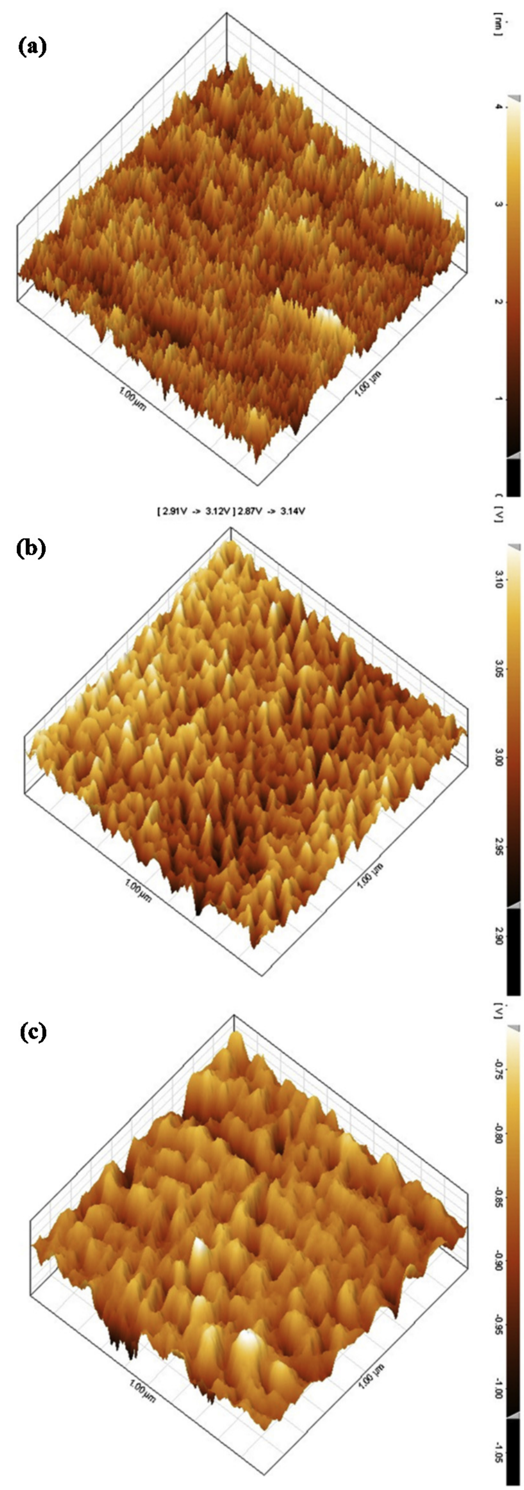

Fig. 1. AFM images for Cu/glass layers of 73.3 nm thickness at 373K deposition temperature and different deposition angles.

Download English Version:

https://daneshyari.com/en/article/848450

Download Persian Version:

https://daneshyari.com/article/848450

Daneshyari.com