The Structural and Mechanical Properties of Ion Beam Sputtered Thin Ni Films

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Abstract

The structural and mechanical (hardness) properties of thin Ni films of different thicknesses (t=4,10 and 36) nm deposited on corning glass substrate using Ion-beam sputtering (IBS) technique under vacuum $<10^{-7}$ Torr have been studied . The TEM and electron diffraction pattern for all film thicknesses show a polycrystalline structure with average grain size (2,4,5)nm respectively .It is also found that the hardness increases as the film thickness increases give a maximum value of 185 kg/mm^2 at t=36 nm .

1- Introduction

The structural properties at thin films give an important information such as crystalline structure , grain size and the d_{hkl} values .The number of Vickers microhardness is obtained by dividing the applied load in kilograms – force by the surface area of the indentation in square millimeters computed from the mean of the measured diagonals of the indentation . It is assumed that the indentation is an imprint of the undeformed indenter [1] .
The Vickers hardness (H_V) number is computed from the following equation [2]:

$$H_V = \frac{P}{M} \text{ ---------- (1)}$$

were P the applied force , M the surface area of indentation :

$$M = \frac{d^2}{2\sin\alpha/2} \text{ ------- (2)}$$

where d is diagonal of the indentation , when $\alpha = 136^\circ$
From equations (1) and (2) the H_V is given by :

$$H_V = 1.854\frac{P}{d^2} \text{ ------- (3)}$$

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The aim of this paper is to report the relation between the hardness and structural measurements of thin Nickel films .

2- Experimental Details

Nickel films (Ni) were prepared by deposition on coring glass (silica) substrates from Nickel target 99.99% purity using ion – beam sputtering technology (IBS) under vacuum $<10^{-7}$ Torr . Different film thicknesses of Ni can be obtained using the rate of deposition curve as shown in Fig.(1) . The deposition rate is in the range (0.15-2.0)A min^{-1} .The samples for transmission electron microscope (TEM) were deposited on NaCl crystal substrates and then the Ni films were removed by immersing the coated crystal in deionised water , the floated films were brought up by using (Cu-200 Hexmesh) .The hardness of the films were examined by A microindentation hardness test using a calibrated machine to force a diamond indenter of specific geometry , under a test load of 1 to 1000gf , into the surface of the test material and to measure the diagonal or diagonals optically [3] .

3- Results and Discussions

1- TEM and electron diffraction studies

Figure(2) shows the transmission electron microscope (mag $3X10^5$) and the electron diffraction patterns for Ni films (4,10,36)nm as deposited on NaCl substrate

The TEM pictures show a polycrystalline structure the microcrystals of these films have a hexagonal form associated with the hexagonal close packed layers for such layers defining the unit cell a_0=3.5238 A° of FCC structure . The electron diffraction pattern of these films shows a polycrystalline structure the measured interplaner spacing from the ring radii at the diffraction pattern is in good agreement with the theoretical d_{hkl} calculated from FCC structure of Ni(a_0=3.5238 A°) as shown in Table (1) which give the values of d- spacing for the as deposited Ni films at different thickness .The missing hkl planes for these films are (024) , (026) due to reorientation of crystallies during the deposition processes .

The average grain size of these microcrystally were measured from Fig.(2) and found to be increase as film thickness increases i.e varying (2,4,5 nm) for (4,10,36 nm) film thickness .

Table (1): The theoretical d- spacing calculated from FCC structure compeared with measured d-spacing for the deposited Ni films at different thickness.

hkl	Theoretical d-spacing	Measured d-spacing		
		4 nm	10 nm	36 nm
(111)	2.0340	2.050	2.050	2.050
(002)	1.7619	1.776	1.776	1.765
(022)	1.2460	1.292	1.254	1.237
(113)	1.0623	1.087	1.076	1.074
(222)	1.0172	1.015	1.015	1.016
(004)	0.8810	0.886	0.866	0.869
(133)	0.8080	0.8075	0.807	0.808
(024)	0.7880	X	X	X
(224)	0.7190	0.711	0.711	0.721
(333) (115)	0.6780	0.666	0.660	0.663
(044)	0.62990	0.634	0.635	0.636
(135)	0.5960	0.592	0.592	0.690
(006)	0.5870	0.576	0.576	0.576
(026)	0.5570	X	X	X
(335)	0.5370	0.533	0.535	0.531

2- Hardness as a function of films thickness

From eqn.3 the variation of hardness vs. film thickness is presented in fig.(3) which shows that as film thickness nerease he icrohardness increases ith aximum alue f 185 kg/mm^2 at t= 36 nm . This result was attributed to the increase of the grain size with increasing thickness as shown in TEM which give a smooth organized film with less vacancies and high hardness [4-5] .

4-Conclusion

From the above results we can conclud that the structure and mechanical properties were affected the film thickness as follows :

1- All films shows as polycrystalline structure with aveye grain size increase us film thickness increases .

2-The microhardness measurements show that when film thickness increases the hardness of the film increase .

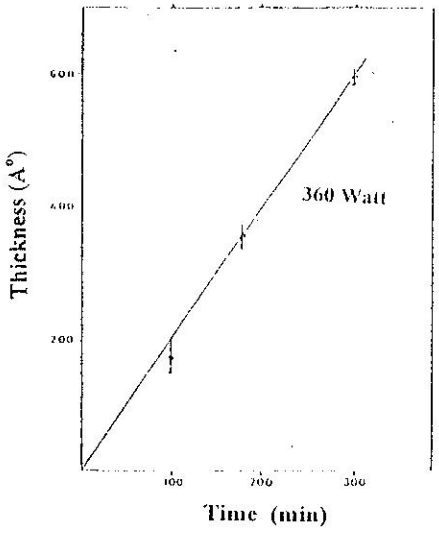
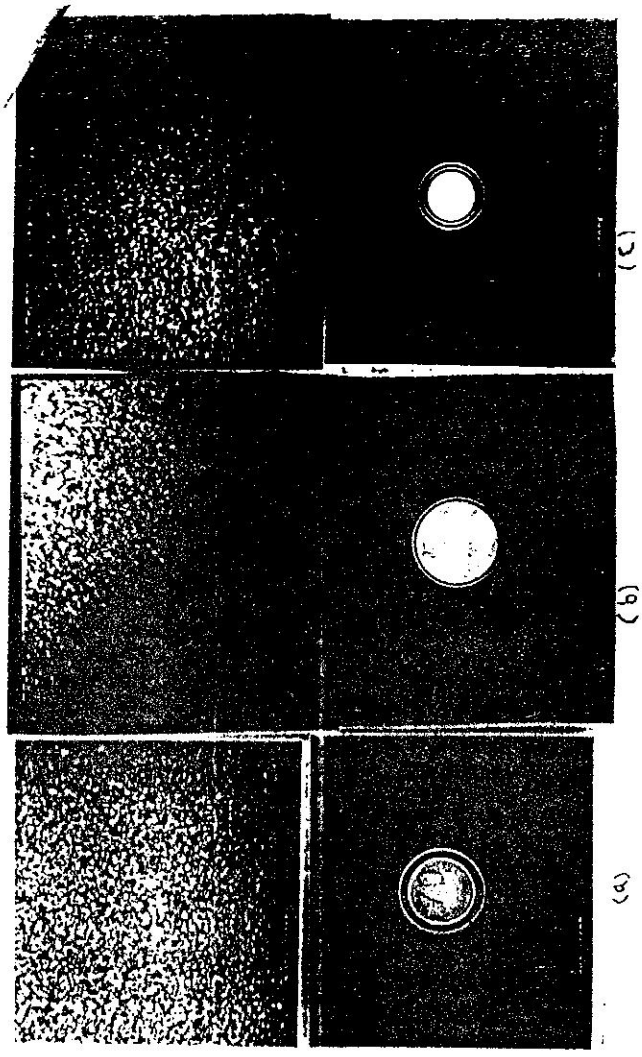


Fig. (1) : The variation of thickness vs. time for Ni films



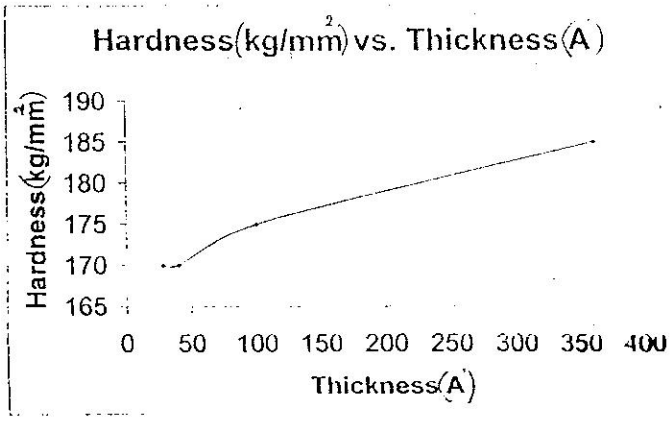


Fig.(3) : The relation between the film thickness and Hardness for Ni Films

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الخواص التركيبية والميكانيكية لاغشية النيكل (Ni) الرقيقة المحضرة بطريقة الرش الايوني

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الخلاصة

تم في هذا البحث دراسة بعض الخواص التركيبية والميكانيكية لاغشية النيكل الرقيقة وبسمك مختلف (4,10,36)nm على ارضية زجاجية والمحضرة باستخدام طريقة الرش الايوني في الفراغ بضغط اقل من 10^{-7} torr .

تم دراسة تأثير سمك الغشاء على هذه الخواص حيث بينت نتائج قياسات المجهر الالكتروني النفاذ (TEM) ودراسة نمط الحيود (EDP) لاغشية النيكل وباختلاف السمك ان لها تركيب متعدد التبلور وان معدل حجم الحبيبات (2,4,5)nm على التوالي .كذلك بينت القياسات الميكانيكية ان صلادة الغشاء تزداد زيادة طردية مع السمك وان اعلى قيمة للصلادة لغشاء النيكل ذو سمك 36nm تساوي 185 kg/mm^2 .