Nano Ni Thin Films Microstructure Evolution and Their Electrical Resistance

Shrok Abdullah Edaan Allami **Mohammed Shaalan Aesa**

Ministry of Science and Technology/ Diredtorate of Renewable Energy

Baghdad-Iraq

E-mail:shrokabdullah@yahoo.com

Abstract

Nano Ni thin films were prepared by thermal evaporation technique, their nanoparticles size controlled via process parameters. Ni thin films were deposited on Si wafers and soft glass sheets. The effects of substrate material and their temperatures during deposition on nanoparticles size and thin films microstructure were studied through AFM surface morphological observations and XRD results respectively. It was found that nanoparticles size increased from 7 to 25 nm with increasing Si substrate temperature during deposition, these affects thin films electrical resistance. It was also found that electrical resistivity decreased with increasing nanoparticles size for Ni thin films deposited on Si wafer, while increased with substrate increasing temperature during deposition.

Keywords: Ni Thin Film Microstructure, Surface Topography and Ni Thin Films Properties.

تقييم تراكيب اغشية النيكل الرقيقة النانوية ومقاومتها الكهربائية

شروق عبد الله عيدان اللامي محمد شعلان عيسى

وزارة العلوم والتكنولوجيا / دائرة الطاقات المتجددة

بغداد- العراق

الخلاصة

حضرت اغشية النيكل النانوية بتقنية التبخير الحراري، والتي تم التحكم بحجوم جسيماتها النانوية من خلال متغيرات عملية التحضير. رسبت اغشية النيكل الرقيقة على شرائح السليكون وعلى قواعد زجاجية. درس تأثير مادة القاعدة المرسب عليها ودرجة حرارتها اثناء الترسيب على حجوم الحبيبات وتركيبها الميكروي من خلال فحوصات طوبوغرافية السطح باستخدام مجهر القوة الذرية وحيود الاشعة السينية. لقد وجد ان حجوم الجسيمات النانوية تزداد من 7-25 نانومتر مع زيادة درجة حرارة قواعد السليكون اثناء الترسيب . تؤثر هذه الزيادة على الخواص الكهربائية لأغشية النيكل الرقيقة والتي درست باستخدام تقنية الاقطاب الاربعة التقليدية. ولقد وجد ايضا ان المقاومية الكهربائية تقل مع زيادة حجوم حبيبات النيكل النانوية المترسبة على قواعد السليكون ، الا انها تزداد مع زيادة درجة حرارة القواعد اثناء الترسيب.

الكلمات المفتاحية: التركيب الميكروي لأغشية النيكل الرقيقة، طوبوغرافية السطح وخصائص اغشية النيكل الرقيقة

Introduction

Transition metals such as Ferro - magnetic metal Ni, Fe, and Co have been extensively studied because of their various applications such as catalysis, solar energy absorption, permanent magnets, magnetic fluids, and magnetic recording media. The performance of thin films influences by their properties including: surface roughness, crystallo-graphic texture, morphology, and practical size (Kumer *et al.*, 2009). New challenges were throwing up with the increased needs to scale down these films thickness in terms of the evolution of microstructure, crystallographic texture and some interesting properties (Electrical and magnetic). Since nickel nano-structures attract much attention recently because of their potential applications in magnetic sensors and memory devices they are synthesized successfully by various methods (Pignard *et al.*, 2000) . Thin film (5-50 nm) growth influences greatly by its early growth stage, which in return influences by structural parameters, that are very sensitive to the processing

techniques used. Although these have been clearly understood there were experimental evidences still lacking tell now: critical thickness for crystallization, film/substrate inter-face and their relationships to electrical properties. The aim of the present work is to demonstrate Ni nanoparticles on different substrates deposited by evaporation and investigate the effect of fabrication condition on microstructures and thin film electrical resistivity.

Materials and Methods

Ni thin films were deposited on different substrates by thermal evaporation technique, their nanoparticles size controlled through some process parameters. Three substrate kinds were prepared prior to deposition: in order to remove a tiny oxide layer from Si (111) wafers they were cleaned by H_2SO_4/H_2O_2 solution followed by dipped in diluted HF and rinsed in deionized H_2O. Second Si wafers set with SiO_2 layer of approximately 270 nm calculated thickness were grown by dry O_2 heat treatment (oxide layers chemical stoichiometric ratio and thickness were identified by ion beam analysis RBS technique at Atomic Energy Commission, Lebanon), and cleaned glasses are used as a third substrate group. Thin films of 4

nm Ni were then deposited onto the substrates using thermal evaporator, at substrate temperatures ranging from ambient temperature to 100°C, thin film thickness measurements were done via crystal thickness monitor during deposition. XRD characterizations were done by a SHIMADZU -6000 diffractometer using Cu Kα radiation. Samples surface morphology was investigated using AFM Advanced

Angstrom Inc-AA3000 and PNI Nano-R-AFM. Hall HMS-3000 demonstrated process parameters and thin film xrd patterns for Ni thin film deposited on Si wafer without native oxide layer had amorphous structure at all substrate temperatures used in this Work shown in Figure 2. All samples showed continue layers with no islands formation as in Figure 3. The lacks of Ni thin films fragmentation on Si surfaces refer to the Ni and Si reaction at interface (Chhowalla *et al.,* 2001)). microstructure impact on electrical resistance.

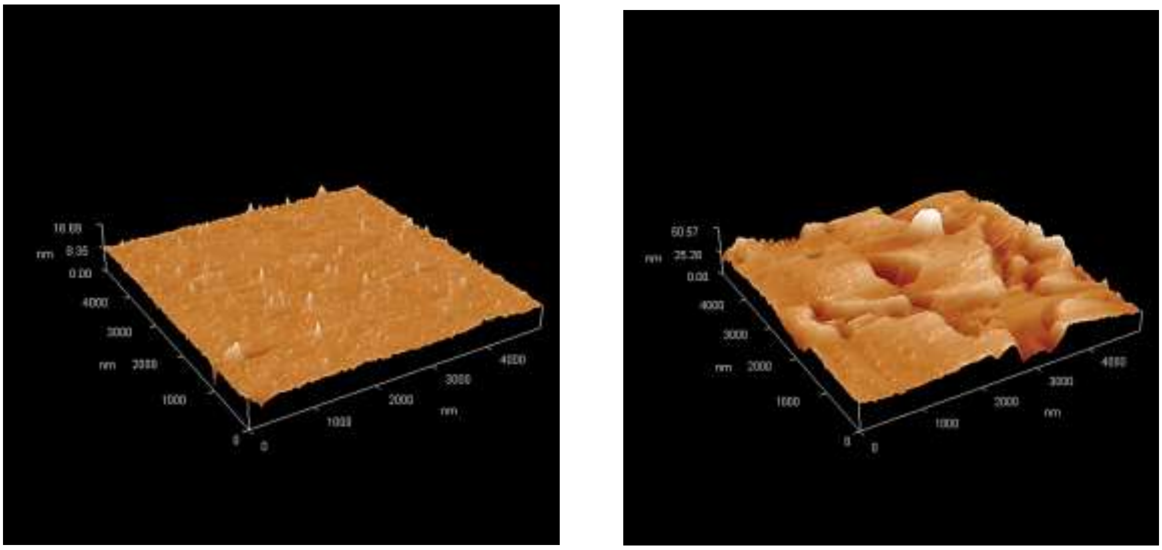


Figure (1) AFM Images for Ni Thin Films Deposited at Different Substrate Temperatures on Glass.

Results and discussions

Ni thin films grown on glass substratehad amorphous structure as XRD pattern show, due to texture disappear and adhesion strength lack thin film contract into islands their sizes depend on substrate temperature during deposition (Wei Li *et al.*, 2009 and Kumar *et al.*, 2009). This can be shown in AFM topographic results presented in figure 1. That shows island size increment with substrate temperature used during deposition.

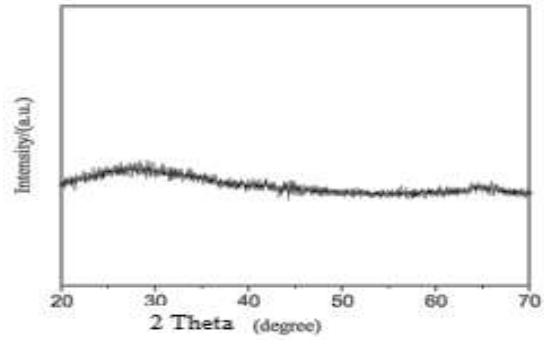


Figure (2) XRD Pattern for Si/ Ni Sample.

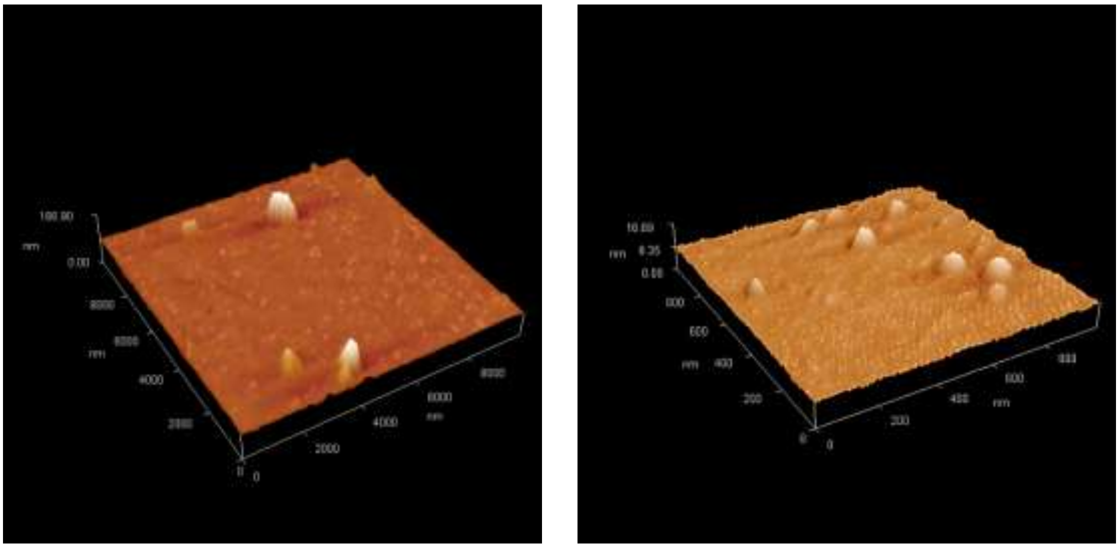


Figure (3) AFM Images for Ni Thin Films Deposited at Different Substrate Temperatures on Cleaned Si.

Ni/Si reactions could be preventing by formation of flattened SiO_2 layer with suitable thickness (≈50 nm) (Chhowalla *et al.,* 2001)). Si thermal oxidation kinetic follows a linear parabolic relationship in wide temperature and thickness ranges (Szekeres *et al.,* 2005), so the oxidation time required to get the specific thickness was calculated by using the widely accepted Deal-grove model. The oxide layers chemical stoichiometric ratio for samples oxidized at 800 and 900°C were identified by the aid of RBS technique, SiO_2 was formed at 900°C while SiO formed at 800°C, Figure 4 shows RBS results. In this work flattened SiO_2 layer was achieved after 30 min oxidation at 900°C as shown in figure 5.

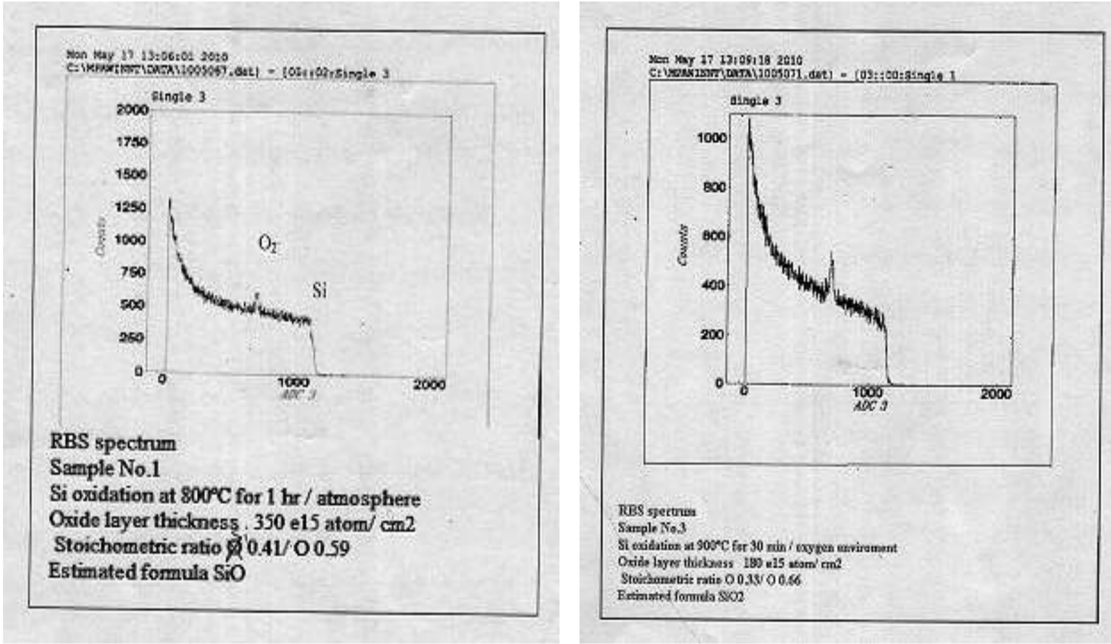
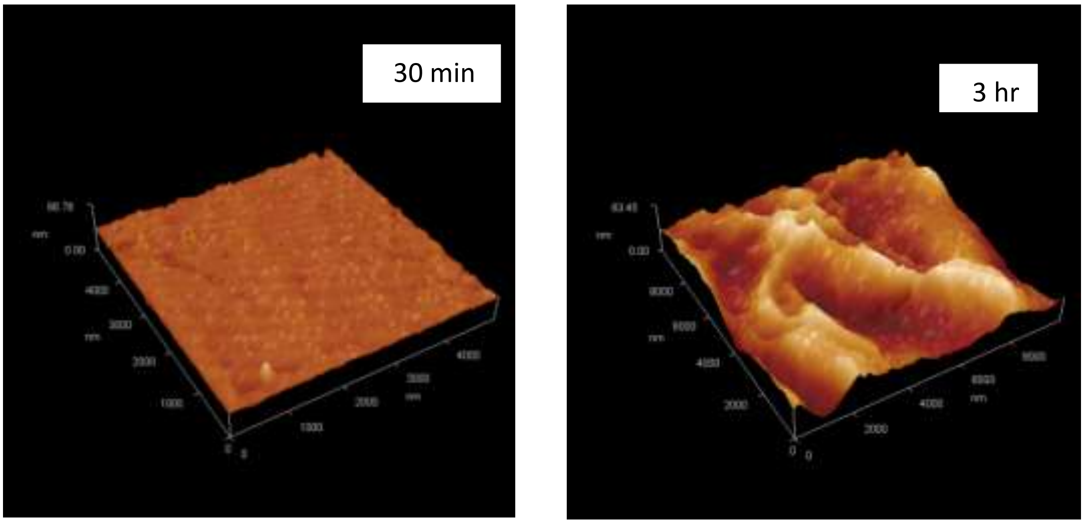


Figure (4) RBS Spectrum for Si Wafer Dry Oxidized at Different Temperatures for 30



min.

Figure (5) AFM Images for Si Oxidized at 900°C for Different Tim

Nanoparticles islands were observed on $Si/SiO_2/Ni$ samples prepared at ambient substrate temperature conditions, which indicate vapor molecules quenching at the substrate surfaces. Ni thin film thickness measured from RBS as shown in figure 6. The nanoparticles growths were observed with increasing substrate temperature from ambient temperature, 50, to 100°C as shown in Figure 7. From AFM result, it is possible to estimate Ni nanoparticles size to be 7, 10, and 25 nm for ambient temperature, 50, and 100°C substrates temperature respectively. Barmak *et al.* (2005) proposed models for grain growth and preferred texture in thin films that

Included ; formed islands will be surrounded by a zone of width d, d is a function of substrate temperature and rate of deposition. Islands growths can be explained by the diffusion of atoms deposited within inter distance to these islands instead of forming new nucleus very large intrinsic stress, induced in the initial stages of growth, and thin film thickness. These stresses and their effect *(Barmak et al., 2005)*. From this, we can propose that: increasing substrate temperatures would induce thermal energy to the deposited atoms that support them to diffuse and increase formed islands size. In addition to that the average nano size influences by the on eliminating nano size could be overcome by increasing substrate temperature during deposition.

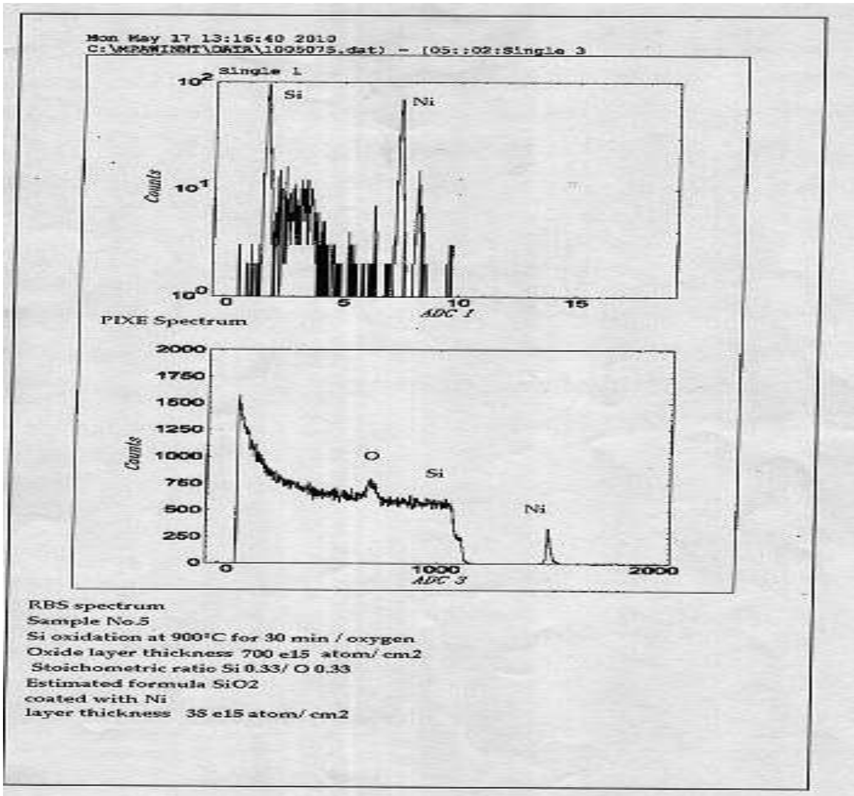


Figure (6) RBS Spectrum for Si/SiO/Ni Sample

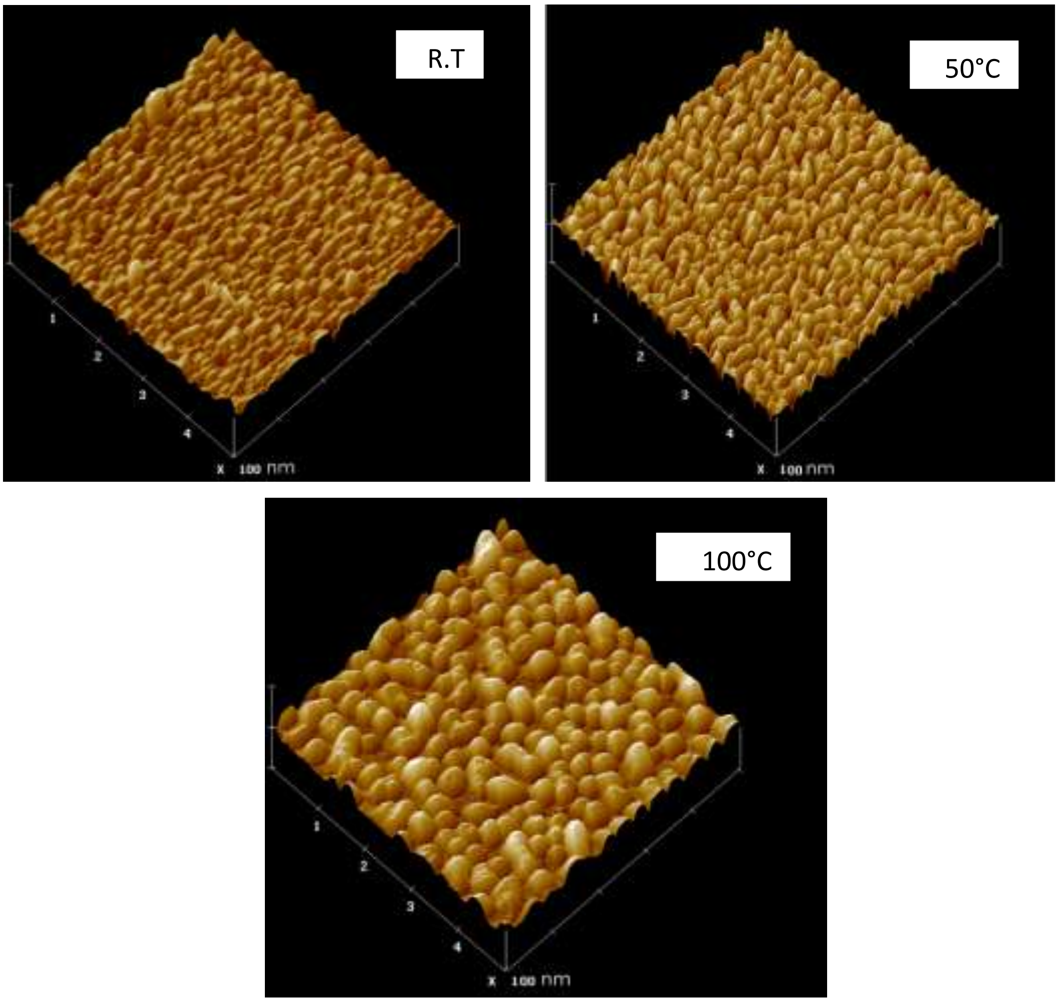


Figure (7): AFM images for Ni Thin Films Deposited on Oxidized Si Substrate at Different Substrate Temperatures.

Ni deposited on Si/SiO_2 clearly had FCC lattice structure with predominately (111) preferred orientation for all substrate temperatures used during deposition according to ICDD card (No: 00-04- 0850) as shown in Figure 8. Gafner *et al.*, (2004) claimed that: the micro-structure of thin film clusters depend on the cooling conditions after the onset of crystallization and due to this claim Ni deposited at slow cooling condition gain FCC lattice structure, while at the rapid cooling condition icosahedra structure evolves (Kumer *et al.*, 2009). These claims are in agreement with this work and other researchers' results (Kumer *et al.*, (2009) and Hemmous *et al.*, 2008).

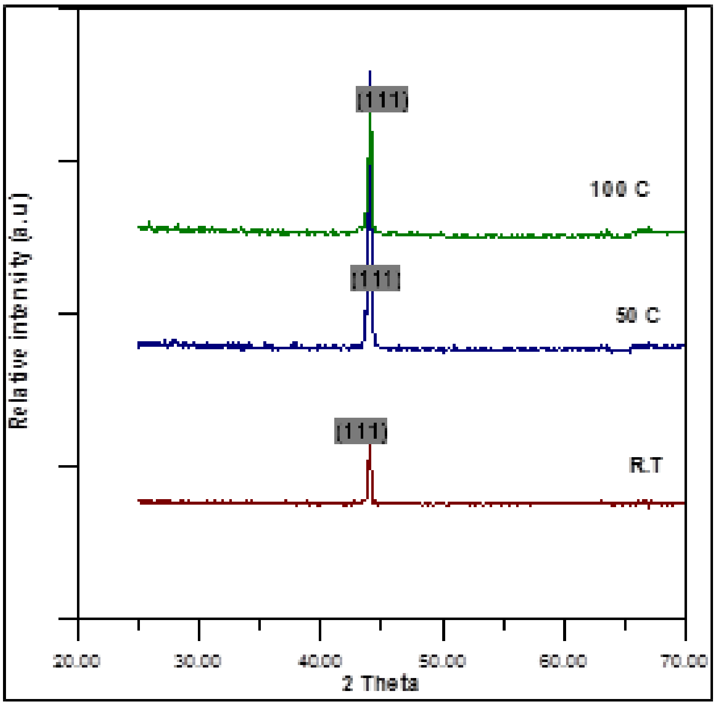


Figure (8) XRD Pattern for Si/ SiO_2/ Ni Samples

The electrical properties of thin films influence greatly by their structural properties variations, where most of the electrical properties phenomena depend on charge carriers and their movements in material media Barmak (2005)).From figure 9 it was found that Si/ SiO_2 /Ni samples resistivity, ρ, decreased with increasing substrate temperature during deposition. This can be referred to thermal energy induced that lead to; increase Ni nanoparticles size, increase electrons mean free path movements through these particles and reduce scattering at obstacles (their boundaries), and reduce interfacial stresses (as mention above) which attribute in establishing stress fields hinder charge carriers movements. While the resistivity ρ increases with increasing substrate temperature used during deposition and with increasing islands size for amorphous Ni/glass samples which refer to highly charge carrier movement scattering through this disorder structure, increasing substrate temperature during deposition would increase islands sizes and distance between them as mentioned at figure 5. (Kumer *et al.*, (2009) proved theoretically the dependent of resistivity ρ on charge carrier mean free path movement length.

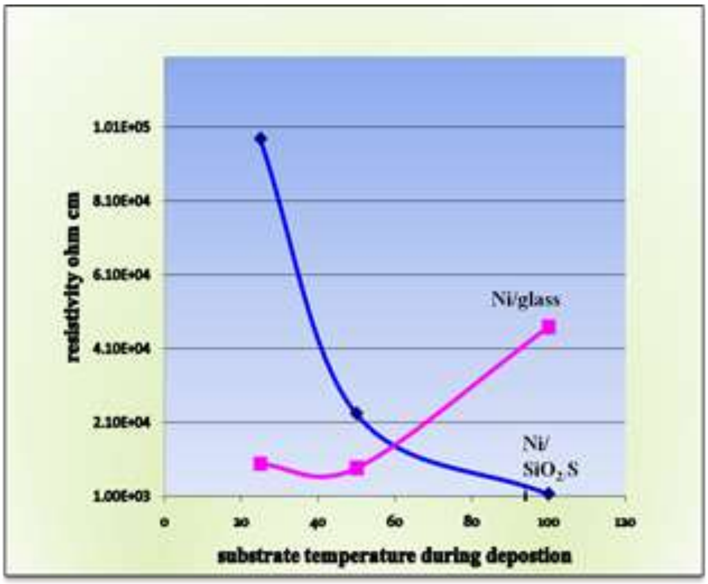


Figure (9) Effect of Substrate Temperature during Deposition on Resistivity

Conclusion

Nano Ni thin films dominate microstructure depends on the substrate material used. Thin film nanoparticles size affected by the substrate material and their temperature during deposition. The electrical resistance of nano Ni thin films depended greatly on their microstructure, where most of the electrical properties phenomena depend on charge carrier movement and its transportation in material media. Resistivity change behavior affected clearly by substrate material and their temperature used during deposition.

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