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Research paper

Effects of Pulsed Nd:YAG Laser on Pt/Ag Thin Film Metal Contacts

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Abstract

This study focused on the effect of laser annealing on Pt/Ag metal contacts deposited on Silicon, (Si) substrates. DC sputtering was used to deposit the metal thin films on the Si. The samples were treated by annealing using pulsed Nd:YAG laser. Then, the samples were characterized based on its morphological, optical, structural and electrical properties. From surface morphological, it is clearly shown that the surface roughness of the laser annealed sample is smoother than the as-deposited sample. The calculated energy band gap was obtained as 1.38 eV. For electrical properties, the resistivity for laser anneal was lower compared to as-deposited sample, which are 5.10×10^{-4} ohm-cm and 1.37×10^{-3} ohm-cm respectively. The conductivity increases when the resistivity decreases.

Keywords: *Band gap, DC magnetron, Nd:YAG laser, Pt/Ag, Thin films*

1. Introduction

The invention of semiconductor devices is a revolution that would not be an exaggeration. It invented the way for development in semiconductor industry. Nowadays, semiconductor devices included transistors, diodes, light emitting diodes, and solar cells are getting consideration due to its uses. These devices need a low resistance of contacts, which is between metal and semiconductor. Metal contacts such as Ni/Ag [1], Pt/Ag/Au [2], Ag/Ni [3], and Au/Pd [4] have been reported and used as an ohmic contacts to semiconductor devices.

Fabrication of deposition thin films, which have been widely used in devices in the making of semiconductor involves MOCVD [5], thermal evaporation, sputtering [6], and electron beam evaporation. MOCVD produce good crystal, however it is high cost compared to thermal evaporation. Thermal evaporation much cheaper than MOCVD, but it produces low quality of thin films. Sputtering offer good quality deposited thin films and have least cost than thermal expansion. Moreover, these technique have controllable sputtering parameter and high reproducibility [7][8][9]. However, the as-deposited metal thin films show low quality characteristics. Sample treatment can be performing in order to improve the structural quality the metal thin films. There are many annealing techniques such as in-situ annealing and post annealing [10]. Optical annealing or known as laser annealing offer more controllable deposition area as compared to the thermal annealing. Pulsed laser offer as a good candidate for laser annealing of metal thin films since it produces high energy at short duration. Besides that, the pulsed laser parameters such as pulse energy and repetition rate are easy to control.

In the present work, this study investigate the effects of pulsed laser annealing on Pt/Ag double layer metal thin films on Si and glass substrate based on surface morphology, optical, structural and electrical properties.

2. Methodology

The Si substrate were cut into small pieces and a cleaning process was done prior to the Si samples by using heated acetone solution in order to remove the contamination on top of surface of substrates. Pt target were deposited on Si and glass substrate and followed by Ag target by using DC magnetron sputtering system (Model Quorum Q150R) as shown in Fig. 1. Si substrates were used for surface morphology and electrical properties, meanwhile glass substrate for optical properties.

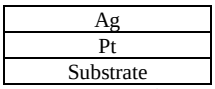

Fig. 1: The schematic diagram of Pt/Ag metal contacts.

Plasma vacuum pressure during sputtering is 6×10^{-2} mBar for Pt material, and 7×10^{-2} mBar for Ag material. The sputtering rate for Pt and Ag are 60 s and 10 s under set sputtering current of 30 and 50 mA was employed. Thus, the thicknesses were measure by surface profiler. The thickness measured for Pt and Ag were 70 nm and 10 nm. After deposition, the samples were anneal with laser. Nd:YAG pulsed laser (Model Litron Nano Series) was used to anneal the sample at pulse energy of 165 mJ under nitrogen ambient. The sample were bombarded with the Nd:YAG laser anneal for 1 shot. The samples were characterized based on its morphological, optical, electrical and structural properties. Atomic force microscope (AFM), Dimension Edge with ScanAsyst, Model BRUKER was used to characterize the surface morphological. UV-Vis Model: Shimadzu UV-3600 Plus was used to scan the optical properties based on reflectance and absorbance. The structural was performed by using x-ray diffraction and electrical properties using four point probe measurement.

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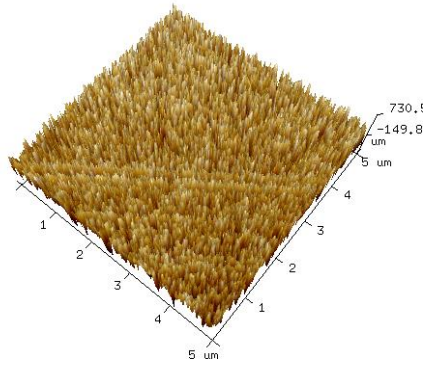
3. Results and Discussion

The purpose of the development of the laser treatment for Pt/Ag thin films was to achieve the surfaces with as smooth as possible of morphology. AFM was carried out to study the surface morphological of the as-deposited and laser annealed Pt/Ag thin films for Si substrates.

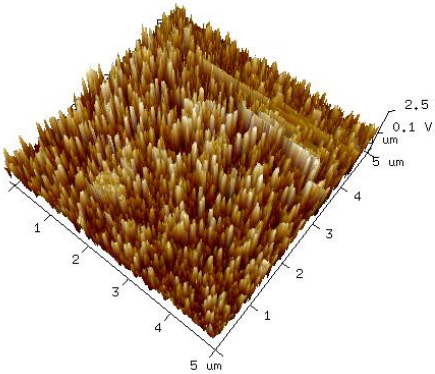
Fig. 2 presents the three-dimensional mode (3D) image of surface morphological for as-deposited and laser annealed of Pt/Ag on Si (100) substrate using pulse energy of 165 mJ. The samples were scanned at 5 × 5 μm^2 area and scale rate at 0.5 kHz. A remarkable difference was observed by AFM system. Here, a small grain sizes were induced by laser-material interaction. The laser anneal sample has a relative smooth and dense surface morphology.

Further inspection of the surface morphologies was carried out by AFM measurement as shown in Table 2. Table 2 shows the data for surface characteristic which scanned by AFM system for average roughness (R_a) and RMS roughness (Rq). As-deposited and laser anneal shows some difference of average roughness. It shows that as-deposited have rough surface compared to laser anneal, which are 0.243 nm, while for laser-anneal are 0.026 nm. The decrement for R_a and R_q on Si substrate contributes to the smooth surface. Comparing Fig. 1 (a) and (b), there is marked differences between the surfaces of as-deposited and laser anneal samples of Pt/Ag thin films metal contacts.

By analyzing the AFM results, it indicates that the surface roughness changes with the laser annealing. The average of grain size of as-deposited of Pt/Ag thin films is much bigger compared to laser-anneal (Energy, E_{laser} = 165 mJ) on Si substrate. As the laser were anneal in sample, it transform with a fine grain size. After treated with Nd:YAG laser, the surface of thin films become smoother due to the film melt and agglomeration of surface grain [11]. This is because the film grain diffuses and interconnects with each other and forming larger grain.



(a)



(b)

Fig. 2: **S**urface morphological characteristics of the (a) as-deposited and (b) laser-annealed for Si substrate of Pt/Ag scanned by AFM.

Table 2: Surface characteristic scanned by AFM.

RMS Roughness, Rq (nm)	As-deposited	0.311
	Laser anneal	0.031
Average Roughness, Ra (nm)	As-deposited	0.243
	Laser anneal	0.026

The optical absorbance of Pt/Ag metal contacts thin films on glass were characterized and analysis by using Uv-Vis spectrometry along the wavelength ranges of 300-1000 nm, as shown in Fig. 3. Photon can be characterized by their energy E (hv is photon energy, eV and λ is the wavelength, nm). The absorption spectrum of Pt/Ag metal contacts deposited on Si substrate is shown in Fig. 3. Eq. (1) give a quick calculation of energy for certain wavelength. The optical absorption coefficient is important optical constant for semiconductor devices such as LEDs and LDs, which convert electrical into optical energy. Where A is the absorbance and d is the thickness of thin films (nm).

$$E = hv = 1240 / \lambda \quad (1)$$

$$\alpha = 2.303\, A / d \quad (2)$$

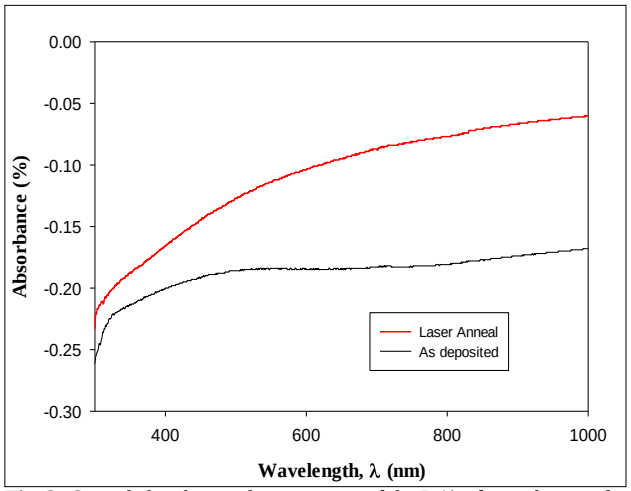


Fig. 3: Optical absorbance characteristics of the Pt/Ag for as deposited and laser-annealed of glass sample.

Optical photon energy related with absorption coefficient for estimation of optical band gap given by Eq. (3) [12]. The optical band gap can be estimated by plotting the α^2 against hv as shown in Fig. 4. From the graph of coefficients absorbance against energy, the energy band gap can be obtained. The optical band gap is found to be 1.38 eV for Pt/Ag metal contacts. Higher energy band gap correspond to lower photon energy absorption for thin films. Higher absorption coefficient in metal contacts, the more light material to absorbs. When temperatures increases, the absorption coefficient increases. Besides, many semiconductors have a significant free carrier concentration under normal temperatures. The electron being excited from valence band to conduction band, due to the broadening in direct band gap increases in Fermi level of semiconductor.

$$\alpha^2 = (hv - E_g) \quad (3)$$

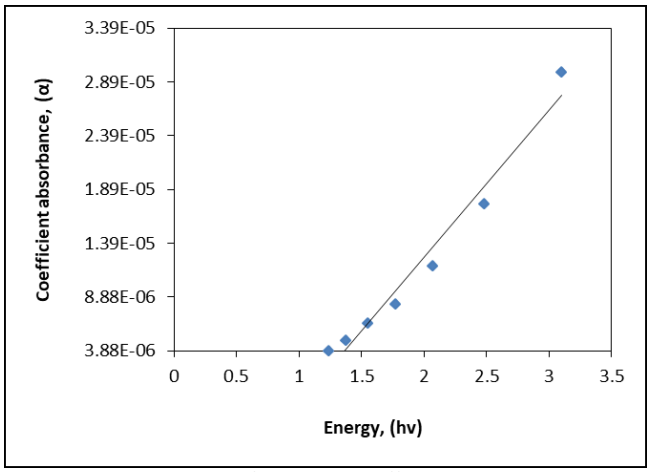
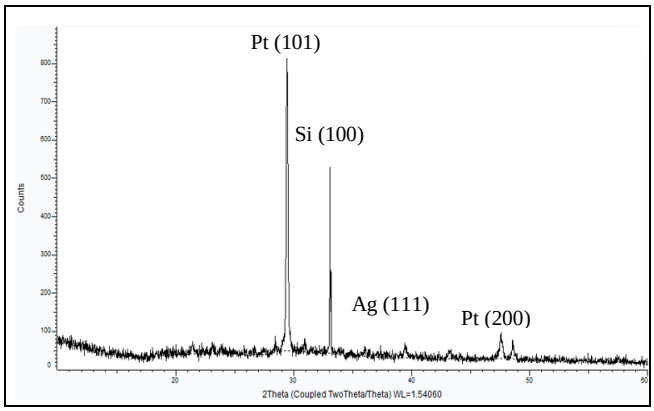
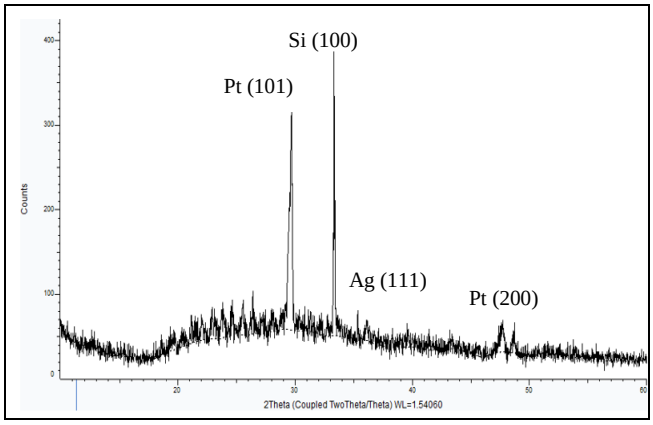


Fig. 4: Calculated value of absorption coefficient with photon energy.

X-ray diffraction analyses were done on Pt/Ag metal contacts for as-deposited and laser-anneal. Fig. 5 shows the XRD pattern of the Pt/Ag metal contacts thin fims. The refinement ranges was set up from 0º to 60º for 2θ. The XRD patterns were then analyzed using Diffrac.Suite EVA software. It's showing no significant differences between these samples, as-deposited and post-anneals laser. The XRD profile contains peaks corresponding to Ag (111) and Pt (200) orientation and indicated at approximately 38.1º and 47.4º [13][14][19].



(a)



(b)

Fig. 5: The structural by XRD of (a) as-deposited and (b) laser-anneal samples.

Table 3: Electrical characteristics of Pt/Ag metal contacts.

	As deposited	Laser anneal
Resistivity, (ohm-cm)	1.37×10^{-3}	5.10×10^{-4}
Conductivity, $(\Omega/cm)^{-1}$	7.29×10^{2}	1.96×10^{3}

The resistivity decreased with the increasing of domain size as resulted in AFM morphology before. The domain boundary might cause the scattering for conduction electron [17]. In addition, as the films were anneal with the laser, it have lower refractive indices and become denser [18] .

4. Conclusion

Pt/Ag was deposited by using DC magnetron and treated with Nd:YAG pulse laser with wavelength, 1064 nm. 165 mJ of energy laser was used to treat the samples. Laser anneal had improved the surface morphology, optical, structural and electrical properties of Pt/Ag thin films. It is shown that the laser treatment give a smaller in grain size for laser anneal samples compared to as-deposited. Hence, laser treatment influences the morphology of the thin films sample. For optical properties, the decrement of optical absorbance was found due to thinning layer after the laser treatment and due to the changes on the surface, as well as the effects of annealing laser. The 1.38 eV, was found as calculated band gap in absorption coefficient graph. For structural, there least different between as-deposited and laser-anneal samples. Laser anneals shows the low resistivity compared to as-deposited samples which are 5.10×10^{-4} ohm-cm and 1.37×10^{-3} ohm-cm respectively.

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References

[1] Chuah LS, Hassan Z & Hassan HA (2010), Ohmic Contacts properties of Ni/Ag metallization scheme on p-type GaN. Journal Non-Crystalline Solids 356, 181–185.

[2] Reddy VR (2005), Electrical and structural properties of low-resistance Pt/Ag/Au ohmic contacts to p-type GaN 49, 1213–1216.

[3] Ali AH, Shuhaimi A, Bakar A & Hassan Z (2014), Improved optoelectronics properties of ITO-based transparent conductive electrodes with the insertion of Ag / Ni under-layer, Applied Surface Science 315, 387–391.

[4] Varma T, Periasamy C & Boolchandani D (2017), Superlattices and Microstructures Performance analyses of Schottky diodes with Au/Pd contacts on n-ZnO thin films as UV detectors, Superlattices Microstructure 112,151–163.

[5] Vinodkumar R, Navas I, Chalana S R, Gopchandran K G, Ganesan V, Philip Reji, Sudheer S K & Mahadevan Pillai V P (2010), Applied Surface Science Highly conductive and transparent laser ablated nanostructured Al : ZnO thin films. Applied Surface Science, 257(3), 708–716.

[6] Hadi A, Hassan Z & Shuhaimi A (2016), High figure of merit of the post-annealed Ti/Al/ ITO transparent conductive contacts sputter deposited on n-GaN. Journal Alloys Compounds 681,186–190.

[7] Takeda S, Suzuki S, Odaka H & Hosono H (2001), Photocatalytic TiO2 thin film deposited onto glass by DC magnetron sputtering, Thin Solid Films, 392(2), 338–344.

[8] Leem JW & Yu JS (2010), Structural, optical, and electrical properties of AZO films by tilted angle sputtering method. Journal Thin Solid Film. 518, 6285–6288.

[9] Watanabe R, Tsukamoto T, Kamisako K & Suda Y (2017), Crystallinity control of SiC grown on Si by sputtering method. Journal Crystal Growth 463, 67–71.

[10] Cheng Y, Wu H, Lin Y, Lee C & Lin C (2015), Post-annealing effects on pulsed laser deposition-grown GaN thin films. Thin Solid Films 577, 17–25.

[11] Nie M, Zhao Y & Zeng Y (2014), Effects of annealing and laser irradiation on optical and electrical properties of ZnO thin films, Journal Laser Applicaton 26(2), 1–6.
[12] Zhang K, Zhu F, Huan CHA & Wee ATS (2000), Indium tin oxide films prepared by radio frequency magnetron sputtering method at a low processing temperature. Journal Thin Solid Film. 376, 255–263.
[13] Ida SO, Akai AS, Ã ONA, Gawa MO, and Aima SZ (2008), Epitaxial Ag Layers on Si Substrates as a Buffer Layer for Carbon Nanotube Growth Epitaxial Ag Layers on Si Substrates as a Buffer Layer for Carbon Nanotube Growth. Japanese Journal Applied Physics, 47(5), 3742–3747.
[14] Gholami-shabani M & Shams-ghahfarokhi M (2016), Biogenic Approach using Sheep Milk for the Synthesis of Platinum Nanoparticles : The Role of Milk Protein in Platinum Reduction and Biogenic Approach using Sheep Milk for the Synthesis of Platinum Nanoparticles : The Role of Milk Protein in Platinum Reduction and Stabilization.
[15] Khudiar AI, Zulfequar M & Khan ZH (2009), Laser radiation effects on optical and structural properties of nanostructure CdSe thin film, Radiation Effects Defects Solids, 164, no. 9, 551–560.
[16] Khurram M, Atiq S, Bashir S, Riaz S, & Naseem S (2016), Pulsed laser deposition of SmCo thin films for MEMS applications. Rev. Mex. Trastor. Aliment..
[17] Higuchi M, Uekusa S, Nakano R & Yokogawa K (1993), Micrograin structure influence on electrical characteristics of sputtered indium tin oxide films Micrograin structure influence indium tin oxide films on electrical characteristics. Journal of Applied Physics 74, 6710.
[18] Lin HK, Cheng KC, & Huang JC (2015), Effects of Laser Annealing Parameters on Optical and Electrical Properties of ITO / Metallic Glass Alloy Bi-layer Films. Nanoscale Res. Letter, 1–8.
[19] Shah MA (2012), Growth of uniform nanoparticle of platinum by an econimical approach at relatively low temperature 19, 964-966.