Morphology, chemical and electrical properties of CdO Nanoparticles on porous silicon

Wafaa K. Khalef, Hasan Hadi Hussein, Amna A. Salman, Uday Muhsin Nayef

Department of Applied Science, University of Technology, Baghdad - Iraq

E-mail: unayef@yahoo.com

Abstract

In this paper, CdO nanoparticles prepared by pulsed laser deposition techniqueonto a porous silicon (PS) surface prepared by electrochemical etching of *p*-type silicon wafer with resistivity (1.5-4Ω.cm) in hydrofluoric (HF) acid of 20% concentration. Current density (15 mA/cm^2) and etching times (20min). The films were characterized by the measurement of AFM, FTIR spectroscopy and electrical properties.

Atomic Force microscopy confirms the nanometric size.Chemical components during the electrochemical etching show on surface of PSchanges take place in the spectrum of CdO deposited PS when compared to as-anodized PS.

The electrical properties of prepared PS; namely current density-voltage characteristics under dark, show that the pass current through the PS layer is more than that obtained from the CdO/PS/Si which is related to increasing junction resistivity that come from increasing in depletion width.

Key words

CdO nanoparticles, Porous Silicon, AFM, FTIR, Electrical properties.

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الخواص الطبوغرافية، الكيميائية و الكهربائية لدقائق اوكسيد الكادميوم النانوية على السليكون المسامي

وفاء خالد خلف، حسن هادي حسين، امنة علي سلمان، عدي محسن نايف

قسم العلوم التطبيقية، الجامعة التكنولوجية، بغداد، العراق

الخلاصة

في هذا البحث، تم تحضيردقائق اوكسيد الكادميوم النانوية المحضرة بتقنية الترسيب بالليزر النبضي والمرسبة على السليكون المسامي المحضر بالتنميش الكهروكيميائي لشريحة سليكون من النوع (p) بمقاومية 1.5-4 أوم.سم، باستخدام حامض الهيدروفلوريك بتركيز 20%. كثافة تيار التنميش 15 ملي امبير/سم^2 وزمن تنميش 20 دقيقة. تم دراسة الخصائص الطبوغرافية (AFM) ومطيافية تحويلات فورير للاشعة تحت الحمراء والخواص الكهربائية.

مجهر القوى الذري يؤكد الحجم النانومتري. كما اظهرت المركبات الكيميائية خلال التنميش الكهروكيمياوي على سطح السليكون المسامي ويحدث تغيرات في الطيف لاوكسيد الكادميوم المرسب على السليكون المسامي عند مقارنة مع طيف السليكون المسامي المحضربالتنميش الكهروكيمياوي (بالانودة).

الخواص الكهربائية لطبقة السليكون المسامي المحضرة؛ اي المتمثلة خصائص كثافة تيار- جهد تحت الظلام، أظهرت ان التيار المار خلال طبقة السليكون المسامي اكبر مقارنة التيار الحاصل من المفرق CdO/PS/Si والذي له علاقة بكبر مقاومية المفرق الذي ياتي من زيادة عرض منطقة الاستنزاف.

Introduction

Cadmium oxide (CdO) is a wide band gap (3.37eV) semiconductor with large exciton binding energy investigated as a short wavelength light emitting, transparent conducting and piezoelectric material. CdO nanoclusters and thin film have also been shows to exhibits room temperature UV lasing properties. CdO is used as a

transparent conductive material which was prepared as a transparent conducting film back in 1907 Cadmium Oxide in the form of thin films has been used in applications such as photodiodes, phototransistors, photovoltaic cells, transparent electrodes, liquid crystal displays, IR detectors, and antireflection coatings [1,2].

The nanostructured transparent conducting oxides have also gained tremendous importance due to their size dependent optical properties and possible applications in near future. Recently, various research groups around the world are working on the synthesis of several II–VI n-type transparent semiconducting oxide thin films by deferent processes. Previously, thin films of CdO have been synthesized by various techniques [3,4].

Porous silicon (PS) consists of a network of nanoscale sized silicon wires and voids which formed when crystalline silicon wafers are etched electrochemically in hydrofluoric acid based electrolyte solution under constant anodization conditions [5]. The optical properties of porous silicon (direct gap, low reflectivity, variable refractive index, red photoluminescence, randomized morphological structure and possibility of band gap engineering) make this material to be a good candidate for photovoltaic applications. [6,7].

Combining basic materials, such as porous silicon, with semiconductor nanoparticles one can change optical properties of PS and it enables producing of low-cost light emitting materials [8].

Experimental

Porous silicon films were obtained on p-type Si surface by electrochemical anodizations. Before anodization the samples were boiled in isopropyl alcohol and immersed into HF aqueous solution to remove native oxide from the silicon surface, washed in distilled water and finally dried in air. Anodization was carried out under the following conditions: current densities of 15mA/cm^2, etching time of 20min. and electrolyte was prepared by mixing HF (20%) and ethanol in 1:2 ratio. Anodization was carried out in the Teflon electrochemical cell with a gold cathode. The samples were then immersed into ethyl alcohol, dried in nitrogen (N_2), and placed in pulsed laser deposited chamber for deposition of the CdO layer by using Q-switching laser energy of 700mJ number of pulses 50 pulses.

The PS and CdO/PS layers on the surface of these samples were characterized surface chemical composition by FTIR IRAffinity-1 Fourier Transform Infrared Spectrophotometer SHIMADZU, and morphological by the atomic force micrographs (AFM) type AA3000 Scanning Probe Microscope Angstrom Advanced Inc.

Results and Discussion

Fig.1 shows Atomic Force Microscopy micrographs of the as-prepared PS. Circular pores with average diameter of 44.28 nmare observed over the entire surface. The 3-dimensional (3D) AFM image of porous silicon in which the irregular and randomly distributed nanocrystalline silicon pillars and voids over the entire surface can be seen with a maximum value of 5.04 nm exhibits morphology with a root-mean-square (RMS) roughness of 0.587 nm and CdO deposited onto the PS surface. When AFM images of as-anodized PS samples are compared to AFM images of CdO deposited PS, it is clear that crystalline CdO is deposited along the outer walls of the pores of PS either partially by filling or completely covering them.

The FTIR spectra of as-anodized PS and CdO/PS structures are shown in Fig.2(a) and (b) respectively. The absorbance peak at 2112.05 and 2258.64 cm^{-1} are, respectively, related to Si–H stretch (Si_3-SiH) and C-H stretch (CH_2). The bond vibrations around 1082.07cm^{-1} correspond to a stretching mode of Si–O–Si while vibrations around 898. 83cm^{-1} are

attributed to scissors mode of Si–H_2. The absorption band between 630.72 and 682.8cm^{-1} caused by combination of stretching mode of Si–Si and wagging mode of Si–H_n (n=1 and 2) is also observed. The bond vibrations around 476.42 Si-O stretching in Si-O-Si.All the peaks observed in Fig. 2 are in identical with the previous data reported in the literature [9-13].

It can also be seen from Fig. 2b that significant changes take place in the spectrum of CdO deposited PS when compared to as-anodized PS.From the FTIR spectrum it is conformed that presence of Cadmium and Oxygen in the range between 1242.16 to 1627.92 cm^{-1} respectively [1].

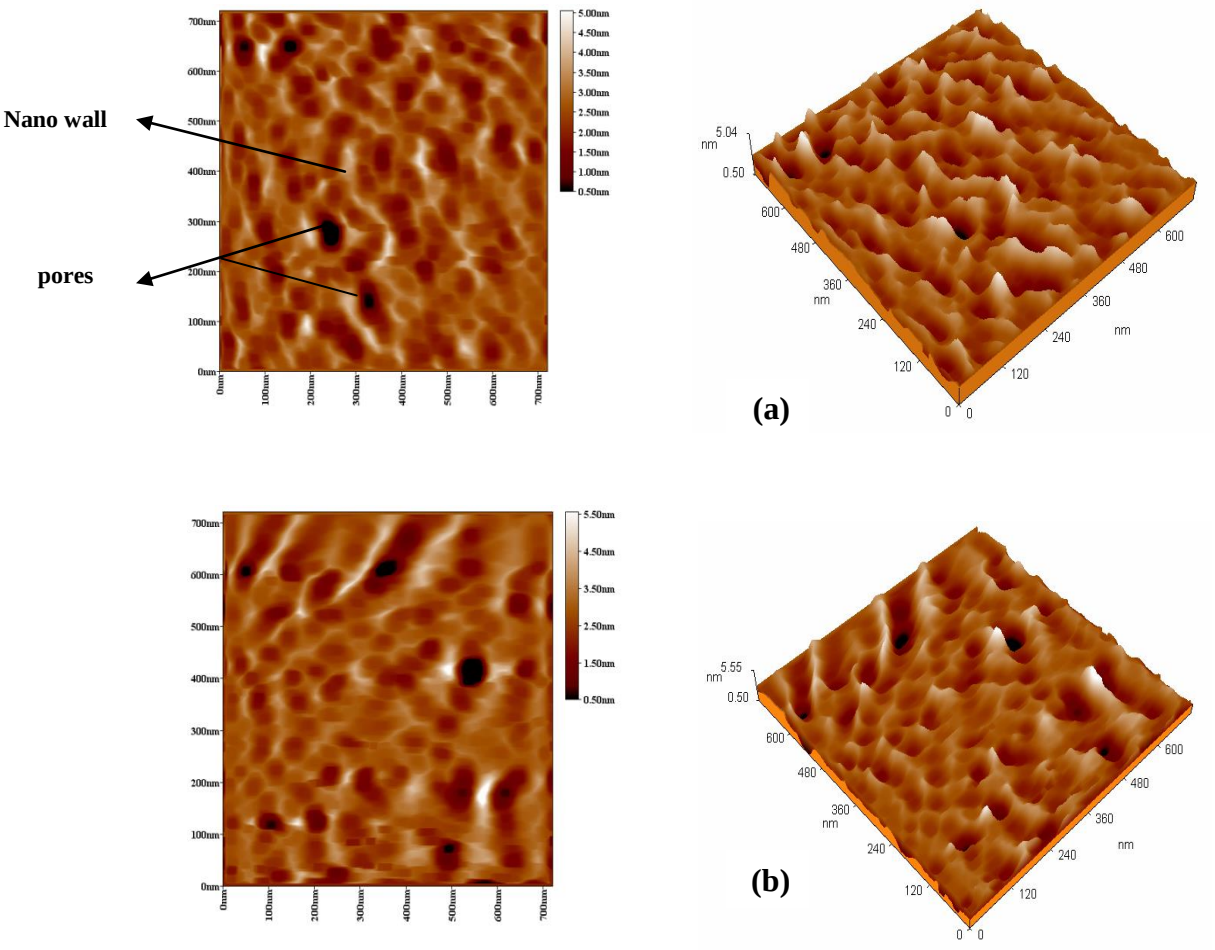

Fig.1: AFM images of PS: (a) as-anodized (b) CdO film on deposited PS.

Electrical Properties

The current density-voltage characteristics, measurements were achieved in dark at room temperature. Fig.(3a), a typical diode behavior can be seen. This figure shows the Current density-Voltage characteristics of Al/PS/p-Si/Al sandwich structure device prepared at current densities of 15 mA/cm^2, etching time of 20 min. and electrolyte was prepared by mixing HF (20%).The J-V curves were obtained by applying a varying the applied bias (sweeping from -5 V to +5 V) and then measuring the resulting current.

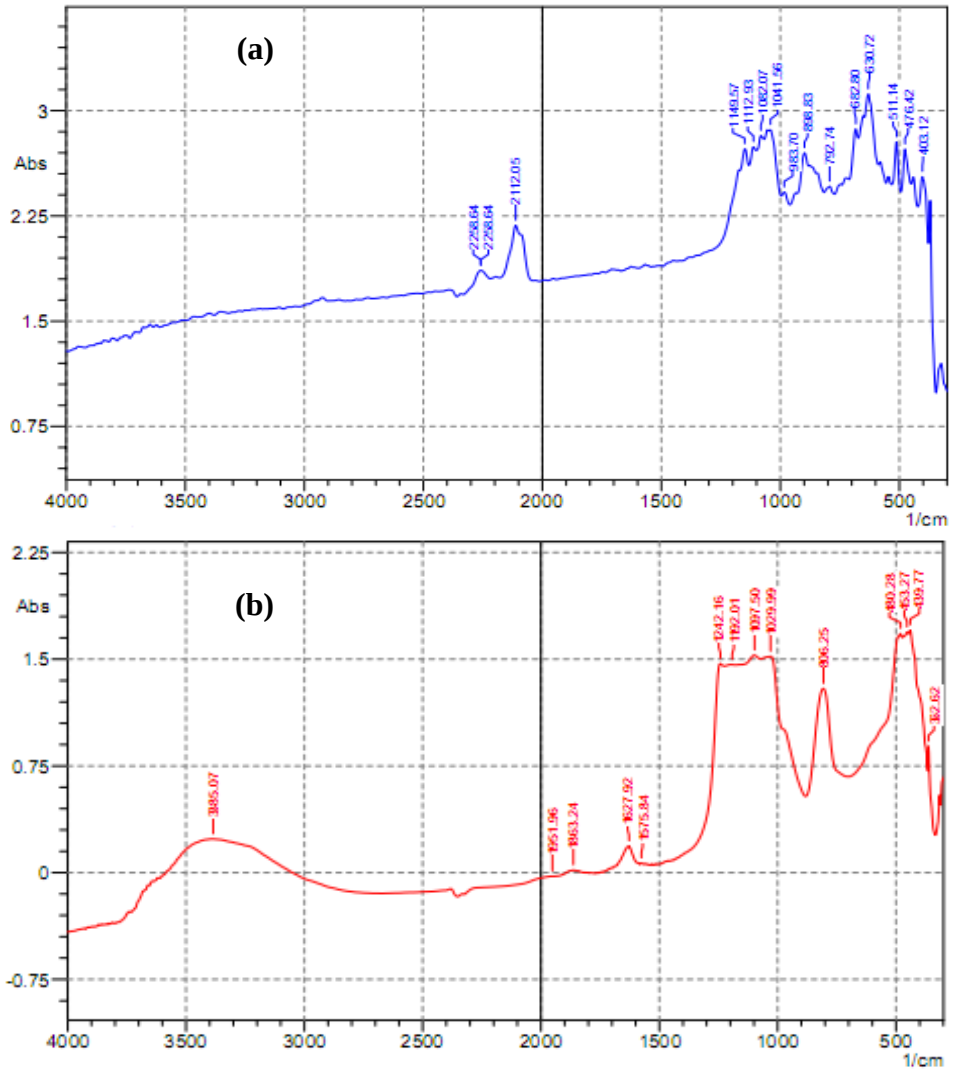

Fig.2: FTIR spectrum of (a) PS/Si (b) CdO/PS/Si.

The onset of forward current density is found to be about (~1V). Under reverse bias conditions, the current density is significantly low, and even to be zero. The characteristics show rectifying behavior.

Generally the forward current shows presence of distinguish stable region. First region at low voltage (V<1Volt), the recombination current is dominant, because the concentration of charge carriers is greater than the concentration of intrinsic ($np>ni^2$), therefore for equilibrium case recombination process will take place and this means that each excitation electron from valance band to conduction band will recombine with a hole in valance band. Second region at high voltage (V>1Volt) shows forward current increase exponentially with the applied voltage because the applied voltage exceeds the potential barrier. This voltage gives the electron enough energy to overcome the barrier height and that is what called diffusion current. In the reverse bias, one region is existing, where the current increases with the applied voltage and the generated current is dominant [14].

From the obtained results it is clearly that the current produced by CdO/PS/Si is less than PS/Sithat obtained from the CdO/PS/Si which is related to the large junction resistant which reduces the leakage current.

It can be noticed from this Fig.3 that the junction exhibits rectifying behavior. This rectifying behavior is attributed to heterojunction potential barrier at the CdO/PS interface. The formation of the heterojunction structure is referred to the difference in energy gap between the CdO and PS.

The *J-V* characteristic under dark of PS/Si and CdO/PS/Si shown in Fig.3, that we note from Figure decreasing in output current when applying bias voltage (-5 to 5*V*) more than PS only this decreasing due to increasing resistivity that come from increasing in depletion width of the sandwich structure (Al/CdO/PS/p-Si/Al).

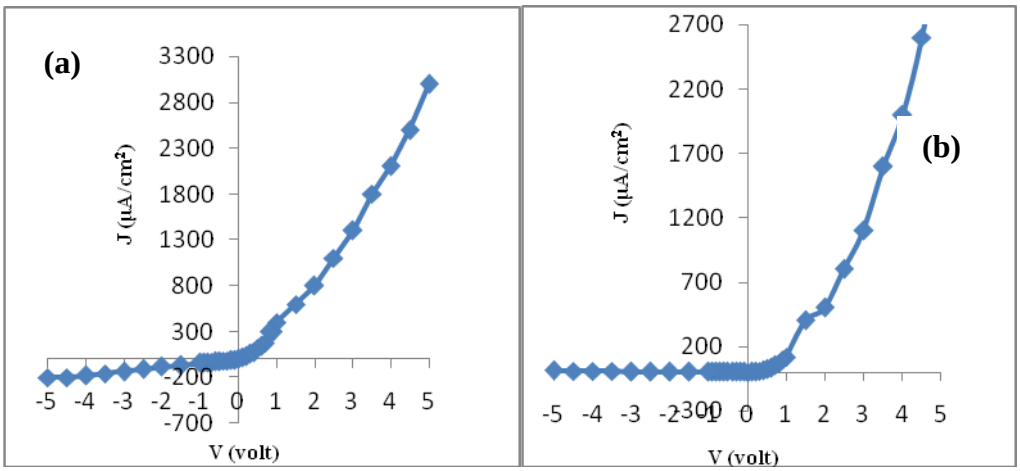

Fig.3: Dark, forward bias and reverse bias I –V characteristics of (a) Al/PS/Si/Al (b) Al/CdO/PS/Si/Al.

Conclusions

AFM image of porous silicon in which the irregular and randomly distributed nanocrystalline silicon pillars and voids. The FTIR spectra of as-anodized PSand CdO/PS structures are shown changes take place in the spectrum of CdO deposited PS when compared to as-anodized PS.The current produced by PS/Si is more than that obtained from the CdO/PS/Si which is related to the large junction resistant which come from increasing in depletion width.

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