Nanocrystalline β-Silicon Carbide Films Prepared by $TEACO_2$ Laser

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Abstract

Thin films of microcrystalline and nanocrystalline β-silicon carbide and silicon, where deposited on glass substrate with substrate temperature ranging from 350-400°C, with deposition rate 0.5nm per pulse, by laser induced chemical vapor deposition. The deposition induced by $TEACO_2$ laser. The reactant gases (SiH_4 and C_2H_4) photo decompose throughout collision associated multiple photon dissociate. Such inhomogeneous film structure containing crystalline silicon, silicon carbide and amorphous silicon carbide matrix, give rise to a new type of material nanocrystalline silicon carbide in which the optical transmittance is governed by amorphous SiC phase while nanocrystalline grain are responsible for the conduction processes. This new material is promised for many new applications, lick high efficiency solar cell.

X-ray diffraction patterns and scanning microscope images revealed that nanocrystalline SiC and Si films grew at substrate temperature above 400°C, while completely amorphous films grew at substrate temperature 350°C.

Key words
laser applications, thin films, nanostructures

Article info
Received: Oct. 2010
Accepted: May. 2011
Published: Oct. 2011

أغشية كاربيد السليكون بالطور بيتا نانوية البلورات المحضرة بليزر $TEACO_2$

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الخلاصة

استعملت طريقة الليزر الحاث على ترسيب البخار كيميائياً في تحضير أغشية كاربيد السليكون بالطور β بلوراتها ذات أحجام نانوية ومايكروية على قواعد من الزجاج وبدرجات حرارة ترسيب 350-400 درجة مئوية وبمعدل ترسيب 0.5 نانومتر لكل نبضة. وقد أنجز ذلك بليزر$TEACO_2$. الغازات المتفاعلة (SiH_4 and C_2H_4) تفككت ضوئياً عبر التفكك متعدد الفوتونات المعزز بالتصادم. الأغشية المحضرة كانت ذات بنية تركيبية متنوعة من بلورات السليكون وكاربيد السليكون المغمورة داخل ماتركس من كاربيد السليكون ذو تركيب عشوائي. هذا التنوع في البنية التركيبية للغشاء جعله مادة جديدة من أغشية كاربيد السليكون النانوية. فيها النفوذية البصرية محكومة بالخواص العشوائية للـ SiC والتوصيلية تحكمها الخواص البلورية النانوية للغشاء. أغشية بهذه الخواص تُعّد بتطبيقات جديدة ومتنوعة منها الخلايا الشمسية عالية الكفاءة. بينت نماذج حيود الأشعة السينية وصور المجهر الإلكتروني الماسح أن الأغشية المحضرة عند درجة حرارة 400 درجة مئوية ذات تركيب نانوي لكل من SiC و Si والأغشية التي حضرت بدرجة حرارة 350 ذات تركيب بنائي عشوائي.

Introduction

To gain high solar cell efficiency, the window layers should have high electrical conductivity, along with wide optical band gap. The only known possibility of incorporating the high parameters of band gap and conductivity is to produce the structure consisting of

amorphous network with embedded micro or nanocrystalline grains. Such heterogeneous film structure containing crystalline silicon (C-Si) crystalline silicon carbide (C-SiC) grains and amorphous SiC network give rise to a new of material [1].

It is well known that the one of the third generation of semiconductor material, silicon carbide (SiC) films with the wide band gap, high break down-field and high thermal conductivity are potentially useful in sever conditions such as high voltage and high temperature as well as radioactive and corrosive environments[2].

We know that cubic SiC (β-SiC) and (C-SiC) have similar structure, this similarity give the heterogeneous films (consisting of Si and SiC) films high homogenous and new good optical and electrical properties; that is not find in each one of these two materials when used
independently. Also it was reported that nanosized (β-SiC) films show a blue emission of more intense and have capability to light in the full visible wave length range which an ideal candidate used for large area color displays [2].
In present work heterogeneous films containing nano and micro crystalline Si, SiC and amorphous matrix, was grown by $TEACO_2$ laser induced chemical vapor deposition on glass substrates at low temperature (350°C-400°C) with thickness about 700nm. Furthermore we also investigated the substrate temperature effect on films structure, to development low-temperature < 400°C deposition techniques for crystalline SiC where this deposition technique is absolutely imperative for thin films application in solar cells. The reason is that the strain point of glass substrates is (500°C-700°C) and that evolution of hydrogen for the films occurs above 500°C, where all films grown by decomposition SiH_4 or C_2H_4 gases content hydrogen in their structure when the substrate temperature below 500°C [3].
The structural information of the films where acquired by x-ray diffraction and scanning electron microscope measurement.

Experimental Work

Silicon carbide films were deposited by laser induced chemical vapor deposition (LICVD). Fig.(1) shows a schematic diagram of the (LICVD).The laser beam is directed parallel to the substrate, the laser excited the reactant gas without any interaction with substrate. The gas molecules are directly vibrationally hated by absorption laser energy, and then dissociate and decomposed through collision assisted multi photon dissociation [4].

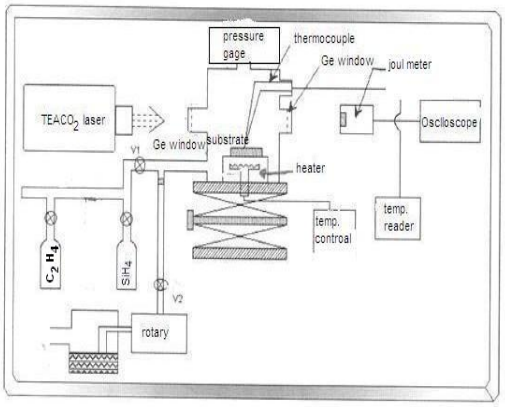

Fig.(1) A schematic diagram of the (LICVD).

$TEACO_2$ laser (2J) emitting at a wavelength of (λ=10.6nm) with pulse duration (100ns). The beam shaped to have square cross section (3×3cm). Reactant gases SiH_4 and C_2H_4 are mixed in reacting chamber with the same ratio. The total gas pressure was (300mbar). Films were deposited on glass substrates with deposition rates (0.5nm/pulse) and thickness of (700±25nm) and that thickness controlled by the total gas pressure and laser pulse number. The substrate temperature varied between (350°C-400°C) by using resistively heated element and controller.

The thickness and surface morphology were characterized by scanning electron microscopy (SEM). X-ray diffraction (XRD) patterns were measured over the range of (2θ=20-60°).

Results and Discussion

Fig.(2) shows x-ray diffraction (XRD) spectra and typical scanning electron microscope (SEM) surface topography for films deposited at substrate temperature 350°C and 375°C. The SEM image and x-ray diffraction pattern clearly show the amorphous nature (short range order) of the films deposited at 350° and 375°C substrate temperature. The SEM images for films deposited at substrate temperature 375°C shows that crystallization has started in the samples.

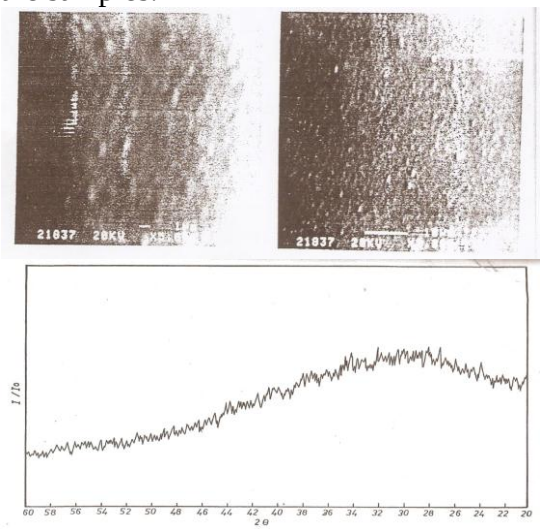

Fig.(2) x-ray diffraction (XRD) spectra and typical scanning electron microscope (SEM) surface topography for films deposited at substrate temperature 350°C and 375°C.

Fig.(3) shows XRD pattern and SEM surface topography for films deposited at substrate temperature 400°C. From the XRD pattern of the films, the strong diffraction peak at 2θ=35.8° is due to the reflection of β-SiC (111) planes [5,6] and the strong peak at 2θ=49.2° is due to the diffraction of Si (220) planes [7]. Peaks corresponding to the (200), (220) β-SiC orientations are not present may be because there is favorable direction in crystallite. These values are well agreed with the known values for β-SiC and Si [8].

The XRD data reported here in agreement with the data reported in reference [9].

The mean crystallite size was estimated from the full width at half maximum (FWHM) of the β-SiC (111) and Si (220) XRD peaks using Scherer's formula [2, 9].

$$d = \frac{0.9\,\lambda}{B\cos\theta}$$

where d is the crystallite size.

B is the FWHM

λ is the x-ray wavelength. 1.937°A for K_αFe.

θ is the angle of incidence

The mean crystallite size was found to be around (3-4nm). As seen from SEM images the surface roughly consists of cubes (belonged to β-SiC and Si grains) imbedded in matrix formed from amorphous particles. This indicates that the full crystallization not be obtained during deposition of this heterogeneous β-SiC films at substrate temperature 400°C.

From Fig.(2) and Fig. (3) it can be see that substrate temperatures plays a big role in crystalline of amorphous SiC and Si during the processing of deposition also there is a difference between the grains size estimated from the (FWHM) of the β-SiC (111) and Si (200) XRD peaks using Scherer's formula, and that estimated from SEM images This difference may be belonged to the agglomerate phenomena.

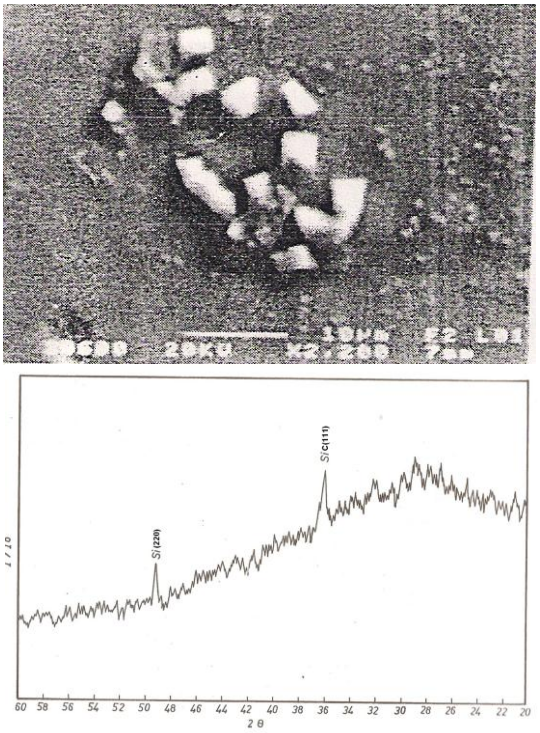

Fig. (3) XRD pattern and SEM surface topography for films deposited at substrate temperature 400 ℃.

Conclusions

1- Heterogeneous SiC films of nano-sized B-SiC were deposited on glass substrates at low substrate temperature of 400°C.

2- X-ray diffraction patterns revealed that the SiC crystallites grew at substrate temperature above 400°C and amorphous SiC grew at substrates temperature below 400°C, when the total gas pressure was (300mbar)

3- Pulse LICVD is new technique for gas phase synthesis of nano-structured thin films.

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