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Obtaining Thin Films of Silicon-Carbon Method of Reactive Magnetron Sputtering are used as Solar Cells

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ABSTRACT

In the work of the various parameters studied film amorphous and nano-crystalline alloy silicon-carbon ($a\text{-nc-Si}_{1-x}\text{C}_x\text{:H}$ ($x=0\div1$)) doped with phosphorus (PH_3) and boron (B_2H_6). Studied the properties of these films on different substrates derived from quartz, glass and Silicon-coated Fe, Al, Pd, Ni, Ti, Ag. Using transmission electron microscopy (TEM) studied the morphology obtained nano tubes. Also examine the structural properties of films by using infrared spectroscopy and x-ray diffraction of x-rays. Created by cascade solar cells area $S = 1.2 \text{ cm}^2$ and have a coefficient of 11.2%.

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Introduction

Film and hydrogenated amorphous and crystalline silicon alloy nano-carbon ($a\text{-nc-Si}_{1-x}\text{C}_x\text{:H}$ ($x=0\div1$)) compared with films of amorphous silicon and germanium are large width of forbidden zone and the best optoelectronic properties in visible part of the spectrum, as well as thermal dynamically stable and radiation-resistant [1-5]. These properties allow you to use them in a number of ways the nano and microelectronics, as well as to create solar cells [6-8].

Experiments show that changing the technological parameters and conditions, amorphous films deposited on various structural phases. In addition, depending on the deposition conditions, as the structure of the films and their optoelectronic properties strongly depend on the deposition rate, temperature, substrate, substrate type and geometry of metal coatings.

The paper considers some of the parameters of thin films of amorphous and crystalline silicon nano-carbon $a\text{-nc-Si}_{1-x}\text{C}_x\text{:H}$ ($x=0\div1$). Also, the mechanism of the phosphorus-doped films (PH_3) and boron (B_2H_6). Transmission electron microscopy (TEM) studied the morphology obtained nano tubes length depending on the deposition conditions, is $1 \div 4$ microns. Structural properties of films analyzed by IR spectroscopy and x-ray diffraction method (OM). It is noticed that depending on the conditions for obtaining such a change occurs, the film that is characteristic of nano-crystalline thin films.

The Experimental Part and the Results

In this paper studied the films of amorphous and nanocrystalline alloy silicon-carbon ($a\text{-nc-Si}_{1-x}\text{C}_x\text{:H}$ ($x=0\div1$)) doped with phosphorus (PH_3) and boron (B_2H_6) on different substrates, glass, quartz and silicon with coating of Fe, Al, Pd, Ni, Ti, Ag. Because Al and Ag have small diffusion barriers and have bad water spray the surface with one wall carbon nanotubes (OWCNT), they seek to aggregate and form large clusters. On the other hand, the energy relationship between Fe and OWCNT is great, but because of the great energy of corrosion and poor wetting Fe can form isolated clusters. Note that OWCNT is produced using a gas mixture of CH_4 and Ar. The Jet tweeter microplasma at atmospheric pressure is generated using the one tubes electrode and directed onto the substrate c-Si coated film Fe.

Changing parameters in a wide range of synthesis (internal diameter of electrode nozzle, flow rate and substrate temperature methane) are such carbon microstructures, as diamond particles, carbon, carbon nanotubes and nanowires cone-shaped micro-Si.

Also the influence of growth conditions, flow rate and substrate type on methane distribution structures and properties of carbon nanotube two wall (CNTW). At a flow rate of $600 \text{ cm}^3/\text{min}$ obtained DUN with a predominantly semiconductor properties. If a higher flow rate ($700 \text{ cm}^3/\text{min}$) formed a mixture of single- and double-walled nanotubes, most of which are solid. At lower speeds ($300 \div 500 \text{ cm}^3/\text{min}$) is dominated by metal multi-walled carbon nanotubes. The length of the nano tube is received $1 \div 4$ microns [5].

Found that derived from gas mixture of $\text{SiH}_4 + \text{H}_2 + \text{PH}_3$ or $\text{SiH}_4 + \text{H}_2 + \text{B}_2\text{H}_6$ on quartz or silicon substrate films, with increasing concentration of PH_3 , decreases the average grain size (d) and the proportion of crystalline grains volume (V_c). When alloying with increasing concentration of boron, B_2H_6 , d is not changed, and V_c decreases [9].

In nano crystalline films SiC of thickness $0.5 \div 1 \mu\text{m}$ obtained in plasma $80\% \text{H}_2 + 20\% \text{Ar}$ quartz substrate, substrate temperature increases from 200 to 600°C , there was an increase in the density of nano crystals, the average size of the SiS which was $\sim 12 \div 24 \text{ nm}$ [5]. The results were checked and also the method of IR absorption spectrum. Based on these results, it can be argued that Mono hydride Si-H and Si digidridnye- H_2 , which behave like the spatial barrier in the volume of films and alter the growth of nanocrystals (Figure1) [9].

Figure 1: (a, b, c, d).Schematic model for the structure of films a-Si:nk-Si.

For the analysis of paintings from debaegramme, use the submission of Bragg-Wolf. To obtain a specific order reflection from some series planes, Crystal should be oriented in such a way that these planes were with falling beam angle θ that satisfies the equation:

$$2d \sin\theta = n\lambda, \quad (1)$$

Knowing the beam angle and wavelength, from equation (1) can be used to determine the diameter of nanocrystals. Take this formula (1) for each line, you can define a relationship between integrated distance reflects a series of grids to order reflection:

$$\frac{d}{n} = \frac{\lambda}{2\sin\theta}, \quad (2)$$

$\frac{d}{n}$ for all lines is the end result obtained directly from the chart.

Ternary amorphous alloys $\text{a-Si}_{1-x}\text{C}_x\text{H}_x$, were obtained from gas mixtures SiH_4 , CH_3 , H_2 . Hydrogen is added in the following ratios:

$$\frac{[\frac{PH_2}{SiH_4} + CH_4]}{H_2} = \frac{1}{20}, \quad \text{for n-type films,}$$

$$\frac{[\frac{B_2H_6}{SiH_4} + CH_4]}{H_2} = \frac{1}{10}, \quad \text{for p-type films,}$$

Films a-Si_{1-x}C_x:H and nc-Si_{1-x}C_x:H получаются при осаждении газовой смеси are obtained by deposition of gas mixture [SiH_{4(1-x)} + CH₄]_x. It is expected that in films, the proportion of carbon and Silicon must match the aspect ratio of the: ((1-x))/x. Alloyed layer was as follows:

$$\frac{B_2H_6}{SiH_4 + CH_4} = 0,01\% \text{ and } \frac{PH_3}{SiH_4 + CH_4} = 0,05\%, \quad \text{when } x=0 \div 1.$$

Note that the films also differ in morphology and structure.

Conducted analysis of x-ray films, as well as remove the range of IR absorption spectroscopy, IKS-29. Using an analysis of x-ray diffraction lines (half the peak reflection from the planes <111>, <220> and <311>) was calculated the average size of crystallites (δ), which is for films area 95 NM² and alloyed with phosphorus, with the power of high-frequency discharge W_{rf} = 250 W and substrate temperature T_a = 600 °C, amounted to 12 nm.

Distance from x-ray planes <111> of crystalline silicon angular position peaks 2θ, their height J_p and half width Δ(2θ), alloyed and unalloyed films differ (Figure 2). The following illustration shows the dependence of the J_p, 2θ, and Δ(2θ) for maximum reflection of x-rays from a plane <220> for unalloyed nk-Si_{1-x}C_x:H films. With increasing temperature annealing in the range 300- 500 °C with a magnitude increases monotonically J_p while half width Δ(2θ), which determines the size of nano crystals, up to the temperature of annealing T_a = 500 °C, remains constant. This means that with increasing annealing temperature in the specified interval, the number of nanocrystallites in the film grows, and their average size remains constant.

With further increases in temperature annealing T > 500 °C, J_p speed increases dramatically with simultaneous reduction of Δ(2θ), which shows an increase in the size of nano crystallites in the film. As shown above, the film received nk-Si_{1-x}C_x:H of which completely removed the hydrogen, the results in this temperature range, checked and also the method of IR absorption spectra. After the increase in temperature after heat treatment at 700 °C with the hydrogen effusion occurs, its concentration in the film decreases (fig. 1, b).

Figure 2: Dependence of values Ip, 2θ and Δ(2θ) for x-ray diffraction peak along the direction (100) in non-alloyed films a-Si:H annealing temperature Ta.

However, in the case at higher flow rates, about 700 cm³/min, while increasing concentrations of long-lived radicals, increases the mobility of atoms on the surface of the film, and also reduces the content of digidride (SiH₂) and hydrogen, compared with films from the same temperature in high-frequency system. Decrease of digidride, as shown in [9] reduces the heterogeneity of the microstructure of the films, the number of without the radiative recombination, the density of localized States in the gap. In the case of reactive magnetron sputtering, the minimal content of digidride is 20% monogidride (γ = SiH₂/ SiH = 0,2) [10].

When different densities relative discharge carbon content in films more than the proportion of carbon in the gas mixture. This means that the Jet CH₄ content compared to SiH₄, flows more effectively. However, if you increase the power of high-frequency discharges, these values are compared. The concentration of carbon and hydrogen in films a-Si_{1-x}C_x:H depends on the deposition conditions, even in the case of unchanging content in the source gas mixture SiH₄, CH₄, H₂.

The results showed that freshly precipitated unalloyed films Nano crystalline phase in amorphous grid is 70% of the total film. For films пленок nk-Si_{1-x}C_x:H doped phosphorus (PH₃) the entire volume of crystallites in the film is 50%, boron alloying it is 30%. Similar results are observed also for planes <220> and <311> crystal lattice Silicon.

Figure 3: Dependence of the speed of deposition from gas pressure upon receipt of a-Si:H magnetron sputtering method.

Figure 3: shows the change in deposition rate as a function of the pressure of hydrogen. As you can see from the picture, the dependency takes the value zero when 5·10⁻⁴ Torr, and gas pressure increases the deposition rate increases. Deposition rate 0.5 Å/s at pressure order 10⁻³ Torr., was comparable with the data method of high-frequency sedimentation.

Figure 4: Relationship between power level and gas pressure while getting films a-Si:H magnetron sputtering method.

Figure 4: RF power dependence of discharge in high pressure areas. Also widely varied gas penetration and in areas of high pressures, because the value of the initial gas pressure was constant ($5 \cdot 10^{-4}$ Torr). Gas pressure is regulated by a valve. With the increase in the RF power level, the gas pressure is reduced and becomes a constant in the area of 100-250 W. This phenomenon is not observed in the argon gas discharge, and is similar to the result of the dissolution and reaction gas mixture due to high-frequency discharge.

Figure 5: The relationship between speed and power deposition charge while getting films a-Si: H magnetron sputtering method. Curves: 1-film deposited in vacuum $5 \cdot 10^{-3}$ Torr., 2- $5 \cdot 10^{-4}$ Torr. Substrate temperature $T = 300^\circ \text{C}$.

Figure 5: shows the correlation between RF power level and speed of deposition. When the RF power is below 100 W, increases the deposition rate and gas penetration is not dependent on the RF power. If power HF 100 W above the deposition rate increases, but increases dramatically at high values of the penetration of gas. This means that some gas is activated at high RF power values, and only activated part reacts. As a result of the carried out works, it can be concluded that the deposition is controlled by the RF power at constant temperature and permanent cathode potential.

Figure 6: Relationship between the activation energy of electrical conductivity and pressurized hydrogen when receiving films a-Si: H magnetron sputtering method.

Figure 6: shows the temperature dependence of the conductivity activation energy (ΔE) films a-Si_{1-x}C_x:H. From these data that the films received in HF discharge, activation energy is greater than in the case of the low-frequency level. In the first case, the dependence of the activation energy of the band gap (E_a from E_g opt) approximated by the equation: $E_a = 0,5 E_g$ opt.

As can be seen from the above data, temperature range electrical conductivity is not hopping, and the activation character. In this case, the concentration of paramagnetic centers has a low value, and depending on the pressure of hydrogen ($P_{H_2} = 0 \div 4.0$ mTorr) varies between $10^{18} \div 10^{16} \text{ cm}^{-3} \text{ eV}^{-1}$. When sufficiently low temperatures ($T \leq 80 \text{ K}$), one would expect a hopping conduction mechanism, as it is inherent to all amorphous materials, including a-Si_{1-x}C_x:H [11].

pressurized hydrogen when receiving a-Si:H magnetron sputtering method.

Figure 7: Infrared absorption Spectra for films a-Si1-xCx:H (x=0,25).

Figure 7: shows the IR absorption spectra of amorphous films a-Si_{1-x}C_x:H obtained by the method of magnetron sputtering in the RF System. As you can see in the infrared part of the spectrum have been observed on three major areas: broad absorption peak zone at 760 cm^{-1} , in form resembling a shoulder; peaks at 1000 cm^{-1} , refer respectively to vibrations of stretching of Si-C and vibrations of CH₃ swing groups attached to the silicon atoms and C-H stretching fashion communication $2800\text{-}3000 \text{ cm}^{-1}$ [9, 12].

Figure 8: IR absorption Spectra of amorphous films of a-Si: H obtained under pressure of hydrogen:

$P_{H_2} = 0,6 \text{ mTorr}; 1,4 \text{ mTorr}; 2,4 \text{ mTorr}; 3,8 \text{ mTorr}$.

Figure 8: shows the IR absorption spectra of amorphous films of a-Si: H obtained under pressure of hydrogen: $P_{H_2} = 0,6 \text{ mTorr}; 1,4 \text{ mTorr}; 2,4 \text{ mTorr}; 3,8 \text{ mTorr}$; As seen from Figure 8 absorption band for mono hydride SiH corresponds to 2000 cm^{-1} , and SiH₂ digidrid-match 2100 cm^{-1} and 875 cm^{-1} [9, 13].

1 – x=0; 2 – x=0,06; 3 – x=0,17; 4 – x=0,25; 5 – x=0,32. Conditions of modes are described in the text.

Figure 9: The dependence of the optical absorption coefficient α from the photon energy $h\nu$ for films a-Si_{1-x}C_x:H ($x=0 \div 1$), doped with phosphorus.

Figure 9 shows the optical absorption edge (α) in films a-Si_{1-x}C_x:H ($x=0 \div 0,32$) doped with phosphorus. Optical absorption coefficient (α) for a-Si: H, doped with phosphorus, approaching 10^5 cm^{-1} , with increasing carbon content $x = 0 \div 0,32$ its value decreases to $6 \cdot 10^4 \text{ cm}^{-1}$.

With a view to determining the band gap dependence $(\alpha h\nu)^{1/2}$ from the photon energy $h\nu$. Optical absorption coefficient is expressed as a ratio (3). Found that with the change in $x = 0 \div 0,32$, width of forbidden zone corresponds to $E_0 = 1.75 \div 2.14 \text{ eV}$ and lower E_0 in all samples of absorption varies exponentially from energy and is determined by the formula (6). To determine the appropriate model used E_0 [9-11].

IR Absorption Spectra were Calculated According to the Formula

$$T = \frac{(1-R_1)(1-R_2)(1-R_3)\exp(-ad)}{(1-R_2R_3)\{1-[R_1R_2+R_1R_3(1-R_2)^2]\exp(-2ad)\}}, \quad (3)$$

Where is, R_1 , R_2 , R_3 - reflectivity's, by air-film-substrate and substrate-air, respectively. For strongly absorbing areas $R_1=R_2=R_3=R$, that defines the width of the forbidden zone E_0 .

Reflectance of R_1 , R_2 , R_3 , also theoretically is defined by the following ratios for different types of watermarks:

$$\begin{aligned} R_1 &= \left| \frac{(n-I)^2 + k_o^2}{(n+I)^2 + k_o^2} \right| \\ R_2 &= \left| \frac{(n-n_1)^2 + k_o^2}{(n+n_1)^2 + k_o^2} \right|, \\ R_3 &= \left| \frac{(n_1-I)}{(n_1+I)} \right|^2 \end{aligned} \quad (4)$$

n and n_1 ($=1,5$), respectively show the film and substrate uptake. In here $k_o^2 \ll (n-1,5)^2$, this relationship holds for weakly absorbing light areas. From here the film thickness is determined from interference stripes reflection (transmitting) near strongly absorbing spectral regions.

Refractive index is determined also by the following formula [14]

$$n(\lambda) = \left[\left(\frac{2n_1(T_{\max} - T_{\min})}{T_{\max}T_{\min}} + \frac{n_1^2 + 1}{2} \right) + \sqrt{\left(\frac{2n_1(T_{\max} - T_{\min})}{T_{\max}T_{\min}} + \frac{n_1^2 + 1}{2} \right)^2 - n_1^2} \right]^{\frac{1}{2}},$$

where is $T_{\max}$ and $T_{\min}$ – functions of the wavelength λ , n_1 – index of refraction of the substrate, which is defined by the expression:

$$n_1 = \frac{1}{T_1} - \sqrt{\frac{1}{T_1^2} - 1},$$

where is T_1 – deletion of the substrate, which is almost always in the area of transparency. As for glass substrates $T_1 = 0,91$, $n_1 = 1,554$.

Film thickness (d) at a known coefficient of refraction is defined in the face of interference phenomena known formula:

$$d = \frac{A\lambda_1\lambda_2}{2[n(\lambda_1\lambda_2) - n(\lambda_2\lambda_1)]},$$

where is λ_1 and λ_2 – wavelengths which correspond to the neighboring extreme points on the spectrum band width, $A=1$ for two extremes of the same type (max– max, min– min) and $A=0,5$ for two adjacent extremums of the opposite type (max– min, min– max).

To escape from the complex calculations and have not been observed interference phenomena, then used the silicon substrate.

When using silicon substrate absorption coefficient is beyond the scope of the fundamental absorption edge is defined by the formula [9, 13]:

$$T = \frac{4T_0^2 e^{-ad}}{(1+T_0)^2 - (1-T_0)^2 e^{-2ad}}, \quad (5)$$

In here T_0 - transmittance silicon substrate, $T=T_0=0,54$; $n_{\text{под}}=n_{\text{пленка}}=3,42$, ($\alpha=0$). Here also the thickness of the film is derived from the interference stripes reflection near strongly absorbing spectral regions.

Equation (4) is true with an error $\pm 10\%$ when $ad \geq 0,1$.

From equation (5), α is calculated according to the following:

$$\alpha = \frac{1}{d} \ln \frac{T(1-T_0)^2}{\sqrt{4T_0^2 - T^2(1-T_0)^2} + 2T_0^2},$$

$$\alpha = \frac{1}{d} \ln x. \quad (6)$$

In most amorphous materials, including films of a-Si: H and its alloys, with photon energies below E_0 in all investigated samples absorption varies exponentially with energy and is described as a formula:

$$\alpha = \text{const} \exp[-\beta(E_1 - h\nu)], \quad (7)$$

where is $\text{const}=4\pi/nc$; n – refractive index (determined from interference peaks in the Spectra transmission and reflection, c -the speed of light, E_1 -energy order E_0 . β does not depend on the temperature near 300 K and is defined by the formula $\beta \approx 0,8/kT$. Optical absorption coefficients α is determined from equation (3) to read as follows:

$$\alpha = \frac{1}{d} \ln \left[\frac{1}{2T} (\sqrt{(1-R)^4 + 4R^2T^2} + (1-R)^2) \right], \quad (8)$$

$$P = \frac{(1-R)^2}{T}; \quad \alpha = \frac{1}{d} \ln \frac{1}{2} \sqrt{(P^2 + 4R^2 + P)}. \quad (9)$$

Equations (9) are working formulas for determination of optical absorption coefficient of thin films on different substrates at different wavelengths.

Create Cascading Solar Cells

For manufacturing electronic devices often used amorphous films of a-Si:H and their alloys [1-4]. Such alloys are characterized by two phases: amorphous and nanocrystalline, the most interesting of which are the phases are on the border of crystallinity, which are considered the most stable to create electronic devices.

Cascade glass structure element //OIO/p⁺-a-SiC:H/i-a-Si:H/n⁺-nk-Si:H/p⁺-nk-Si:H/i-nk-Si:H/n⁺-nk-Si:H/Ag/Al obtained in the following way: layer a-SiC:H-type, die spiel die Role von Windows, mit Bor dotiert [B₂H₆/(SiH₄+CH₄)=0,1%] and thickness 300 Å deposited on a transparent conductive oxide film from india-pewter(OIO), preliminary spraying on a glass substrate. Then besieged, not alloyed i-layer a - SiC:H thickness d=5000 Å with the subsequent drawing on it a layer of nc-Sin-type, doped with phosphorus (PH₃/SiH₄=0,5%), thickness 400 Å. Accordingly, the next layer is deposited p⁺-nk-Si:H, i-nk-Si:H, n⁺-nk-Si:H, the above mentioned method. The last contact inflict alloys Ag/Al (fig.10). If you use too fine a “window” for radiation output increases the voltage open circuit (V_∞), while too large thickness of the window increases the short circuit current density (J_{sc}). Therefore, selected the best thickness for “window”. It is the largest V_∞ and J_{sc}. Retrieves the window thickness 300 Å. This, in turn, characterizes the efficiency of elements. Optical absorption coefficient (α) for i-layer in the visible spectrum reaches 8•10⁴ cm⁻¹ and described by the ratio:

$$\sqrt{\alpha h\nu} = B(h\nu - E_0) , \quad (10)$$

where the coefficient B=530 eV⁻¹cm⁻¹determined by extrapolation of the linear dependence $\sqrt{\alpha h\nu}$ the energy of photons $h\nu$; E₀ = 1,85 eV – the width of the for bidden zone.

To obtain the photovoltaic effect elements covered light source with intensity ~100 mWt/cm², wavelength interval 300÷900 nm. The element has a square 1,2cm² and possessed the following characteristics. V_∞ = 0,882 V, J_{sc} = 18,0 mA/cm², fill factor (ξ) = 0,709, coefficient of performance (η)=11,2% (fig.10). Items highlighted in the stream of photons N=10¹⁷÷18¹⁸m⁻²•c⁻¹. In short-circuit mode. The effectiveness of the media collection (ЭC) Y(□) When different wavelengths was defined as the ratio of the number of photons incident among the free carriers collected external circuitry [14, 15].

$$Y(\lambda) = J_p(\lambda) / eN(\lambda) , \quad (11)$$

where is J_p(λ) – the density of the photocurrent has a value 10 mA/cm², N(λ) -falling stream of photons, e-free media charge.

For elements with the structures of the short-circuit current is calculated in the supposition of a complete depletion of all layers, in the absence of direct bias. Thus, the short circuit current for the first, second, and third elements is given by the following expressions:

$$I_{sc3} = q \int_0^{1,24/E_{03}} (1-R) N_{ph} \exp(-3\alpha_n W_n - 2\alpha_n W_n - 2\alpha_p W_p - \alpha_1 W_1 - \alpha_2 W_2) [1 - \exp(-\alpha_3 W_3)] d\lambda \quad (12)$$

Where is field distribution inside the *i*, *n*, *p* layer, respectively, *N_{ph}* – the number of photons incident on the surface of the elements, *R*-reflectivity at film, α –absorptions coefficient fur jaden layer-elements. Idling voltage for cascading elements with two and three transitions is represented as:

$$V_{oc}(II) = 0,5(E_{01} + E_{02}) , \quad (13)$$

$$V_{oc}(III) = 0,5(E_{01} + E_{02} + E_{03}) . \quad (14)$$

The fill factor for all elements of the set value of 0.5. Short-circuit current of a cascading element with two transitions *I_{sc}* (II) sets the lower value *I_{sc1}* or *I_{sc2}*. Short-circuit current of a cascading element with three passages is determined by the smallest amount of *I_{sc1}*, *I_{sc2}* or *I_{sc3}*.

$$\eta(i) = 0,5 \cdot 0,5 \left(\sum_i E_{0i} \right) \frac{I_{sc}(i)}{P_{in}} \quad (15)$$

Where is *i* = 2 or 3 – shows the number of layers, *P_{in}* – power of incident light on a surface element, its value is 100 mV/cm², *E₀₁*, *E₀₂*, *E₀₃* – width of the forbidden zone, respectively, for each of the *i*- layers.

To enhance the η for solar cell, you want to increase the number of layers reduce the area elements, the choice of metal wires to reduce the resistance of the metal contacts, etc.

Measurement of spectral sensitivity is usually produced at a constant illumination with white light, the intensity of which corresponds to the normal conditions of work (AM-1~100 mW/cm²), at the same time an element falls modulation calibrated monochromatic radiation. Photocurrent and its dependence on wavelength of monochromatic radiation is measured in shorten circuits by using synchronized amplifier.

To determine the effectiveness of collecting important knowledge of the electric field which is passed to the element. It has been noticed that in device dependently to the configuration collection efficiency is offset from red light in the blue spectrum.

It is known that the photon energy and momentum *P** of the corresponding electromagnetic wave with frequency *ν* and wavelength λ in vacuum is equal to:

$$W = h\nu = \frac{hc}{\lambda} ; P^* = \frac{h\nu}{c} = \frac{h}{\lambda} ,$$

Where is, h- Planck’s constant. When small frequencies *ν* - the preponderant role played by wave properties, at large *ν* - particle properties of light. If *P** - electromagnetic radiation energy feeding okay on some surface area per unit 1 sec, c- the speed of propagation of light waves in a vacuum, R- reflectivity surface pressure P – light on this surface as well:

$$P = (1+R)N \frac{h\nu}{c} = P^* / c (1+R) , \quad (16)$$

light pressure (P) is defined by equation (20) and represent the following form:

$$P^* = \frac{W}{S} = \frac{hc}{\lambda S} \frac{N}{t} , \quad (17)$$

N- the number of incident photons during *t*. W- photon energy falling at all wavelengths of the body surface. *P**- the momentum of the light falling on the dies surface 1 sec. Then the pressure of the incoming light is defined in the following form: *F* = *P*•*S*

$$F = \frac{hcNS(1+R)}{\lambda Stc} = \frac{hN(1+R)}{\lambda t},$$

$$F\lambda t = hN(1+R),$$

$$N = \frac{F\lambda t}{h(1+R)}, \quad (18)$$

F - power light pressure ($F=10^{-8}$ H) at the surface of ($S = 1 \text{ cm}^2$), λ - length of incident wave, t - time of incidence of the light for 1 sec. with energy and its value is $Nh\nu$ (photons, and the momentum of each photon is h (written with radiation reflection-and wavelength, the number falling photon is $10^{17} \div 10^{18} \text{ m}^{-2} \text{ s}^{-1}$, R 0,2÷0,8; $\lambda = 300 \div 900 \text{ nm}$.

To obtain the cascading solar cells based on a-Si:H/nk-Si:H the study was conducted in one Chamber. To reduce pollution - and p- layers of elements used and 20 minute loop pumping before deposition. i- and p- layers of carefully isolate (in the form of complexes B-P) most atoms r on the walls of the Chamber, resulting in a high quality items and a slight deterioration. Unlike the majority of production technologies, this method does not require cleaning after each deposition Chamber p-layer.

Conclusion

The results of this work show the prospect of obtaining films of amorphous and nano crystalline silicon carbon besieged reactive magnetron sputtering method. Experiments show that changing the technological parameters and conditions, amorphous films deposited on various structural phases. Also determined that technological parameters (substrate temperature, sedimentation speed films, power RF level) affect the physical properties of amorphous and crystalline silicon nano-carbon. The results of the research conducted in this paper show that film a-Si_{1-x}C_x:H and nk-Si are promising materials for creating cascading solar cells. As well as films studied are promising material in micro and nano electronics.

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