A Study of the Dependence of the Reflectance of the Anti-reflective Material Ta_2O_5 on the Wavelength of Laser Radiation

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□ ABSTRACT □

The study of the dependence of reflectance of the Ta_2O_5 antireflection coating with wavelength. Experiments were carried out using spectrophotometer based on a prismatic monochromatic SPM covering the spectral rang (*450 – 1000) nm*. It can be seen from these results that the reflectance of the antireflection layer of the unirradiated sample is less than *10 %* the above mentioned spectral range and decreases as the wavelength decreases. Its value is about *7%* at *1060 nm* and (1-*2) %* at *532 nm*.
Irradiation of the si solar cell samples by laser pulses had been found to have an observable effect on the reflectance of their antireflection layer; the effect being dependent on the laser radiation wavelength and the number of pulses. For radiation of wavelength *1060 nm*, the reflectance for the sample irradiation by a small number of pulses (λ *= 1060 nm 1 and 3 pulses*) becomes ≈ *12%*. Since this small number of pulses causes a small heating of the sample surface, in the increase of reflectance may be a result of some sort of cleaning process of the surface antireflection layer, which in turn causes the observed increase of reflectance. As the number of pulses at this wavelength is increased, the reflectance decreases. This is due to the thermal damage of the surface antireflection layer.

Keywords: solar cell irradiate by laser, antireflection layer of solar cell

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دراسة اعتماد الانعكاس للمادة Ta_2O_5 المانعة للانعكاس على الطول الموجي لإشعاع الليزر

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☐ ملخّص ☐

دراسة اعتماد الانعكاس للمادة Ta_2O_5 المضاد للانعكاس على الطول الموجي. أجريت التجارب باستخدام مقياس الطيف الضوئي على أساس موشوري أحادي اللون SPM يغطي النطاق الطيفي*nm* (*1000 – 450)*. يمكن أن نرى من هذه النتائج أن انعكاس الطبقة المضادة للانعكاس للعينة غير المشععة أقل من 10٪ من النطاق الطيفي المذكور أعلاه وينخفض مع انخفاض الطول الموجي. تبلغ قيمته حوالي 7٪ عند الطول الموجي 1060 nm و(1−2)٪ عند الطول الموجي*532 nm*.

وجد أن تشعيع عينات الخلايا الشمسية Si بواسطة نبضات الليزر له تأثير ملحوظ على انعكاس الطبقة المضادة للانعكاس ؛ يعتمد التأثير على الطول الموجي لإشعاع الليزر وعدد النبضات. بالنسبة للإشعاع ذي الطول الموجي 1060 nm ، يصبح الانعكاس لإشعاع العينة بعدد صغير من النبضات (*□□= 1060 nm 1 and 3 pulses*) يصبح تقريباً *12%* . نظرًا لأن هذا العدد الصغير من النبضات يسبب تسخينًا طفيفًا لسطح العينة ، فإن زيادة الانعكاس قد تكون نتيجة لنوع من عملية التنظيف للطبقة المضادة للانعكاس السطحي ، والتي تؤدي بدورها إلى الزيادة الملحوظة في الانعكاس. مع زيادة عدد النبضات عند هذا الطول الموجي ، يقل الانعكاس. هذا بسبب الاثر الحراري على الطبقة السطحية المانعة للانعكاس.

الكلمات المفتاحية: تعريض الخلايا الشمسية لاشعة الليزر، الطبقة المانعة للانعكاس للخلايا الشمسية.

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Introduction:

Laser induced damage in solids irreversibly and destructively alters the material properties, leaving permanent damage in the material. An intense laser beam can cause damage in either absorbing or transparent media. In absorbing materials, the laser deposits energy to the material from linear absorption, and increases the temperature in the material.

The Silicon Solar cells structure:

After development of first reasonably efficient Silicon Solar cells, these cells found a major application in generating electricity for spacecraft. The standard technology for making cells is broken down into the flowing stage: [1,2]

1- Reduction of sand to metallurgical grades Silicon.

2- Purification of metallurgical- grade Silicon to Semiconductor- grad Silicon.

3- Conversions of semiconductor-grade Silicon to single crystal silicon.

4- Solar cell encapsulations into weatherproof solar cell modules.

Figure 1 shows the structure diagram of solar cell used in this work. The thickness of silicon solar cell is 0.67 mm coated with Ta_2O_5 antireflection lyres of thickness about 20 A^o. [3,4]

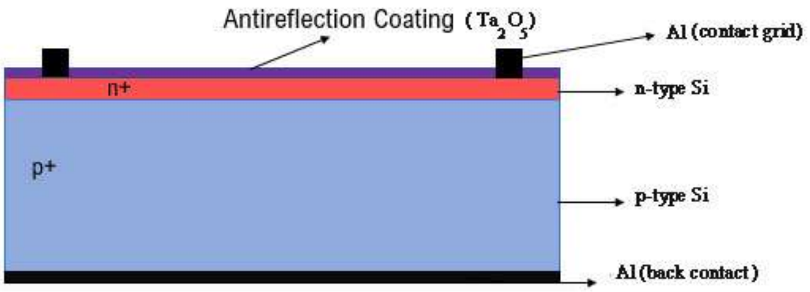

Figure 1 The structure of si solar cell.

- **Reflection Coefficient:** In electrical engineering, the reflection coefficient is a parameter that defines how much of the electromagnetic wave is reflected due to the impedance discontinuity in a transmission path.

This online reflection coefficient calculator calculates the reflection coefficient (Γ) by entering the value of the characteristic impedance Z_0 (in ohms) and load impedance Z_L (in ohms).

What is the reflection coefficient?

The reflection coefficient is the ratio of the amplitude of the reflected wave to the amplitude of the incident wave, with each expressed as phasors, and the symbol of this coefficient is Γ (capital gamma). The reflection coefficient is a function of location and the reflection coefficient at the load is dependent on the load impedance and the transmission line characteristic impedance. When load impedance is equal to the characteristic impedance of the wave, there is no reflection on the transmission line.

Reflection coefficient (Γ) is calculated by using the following formula. [5]

$$\boldsymbol{\Gamma} = \frac{V^-}{V^+} = \frac{Z_L - Z_0}{Z_L + Z_0} \quad (1)$$

Γ: Reflection coefficient

$\mathbf{Z_0}$: Characteristic impedance in ohms

$\mathbf{Z_L}$: Load impedance in ohms

$\boldsymbol{V^-}$: Amplitude of reflected wave in Volts

V^+ : Amplitude of incident wave in Volts

- **Reflection of the Ta_2O_5 Antireflection layer:**

the study of the dependence of reflectance of the Ta_2O_5 antireflection coating with wavelength [6]. Experiments were carried out using spectrophotometer based on a prismatic monochromatic SPM covering the spectral rang (*450 – 1000) nm*. Unfortunately, the experimental work could not be extended to the ultraviolet range of the spectrum.

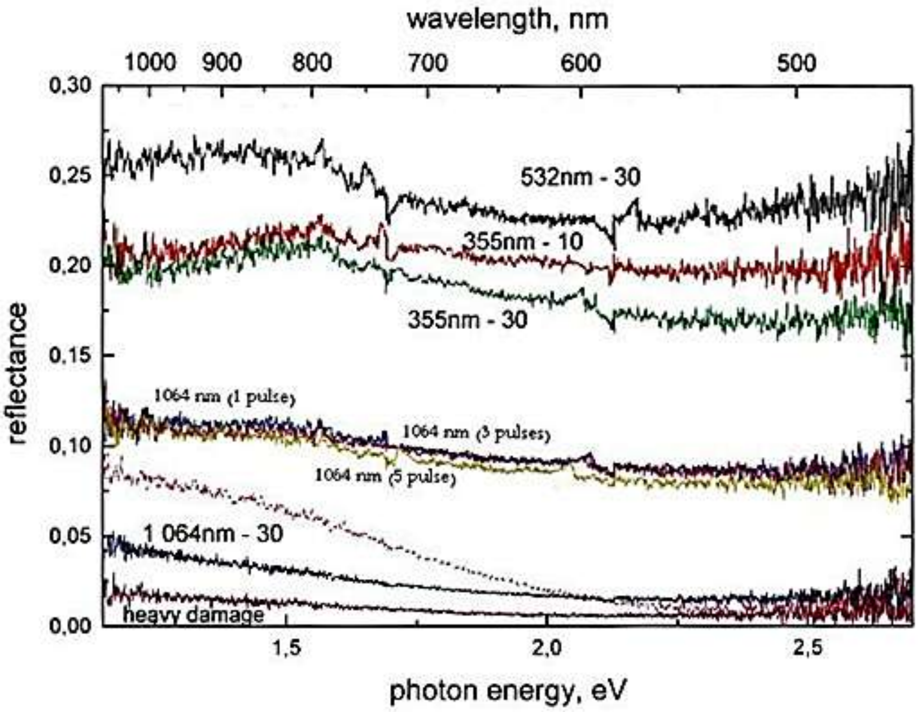

Fig.2. Illustrates the experimentally obtained dependence of the reflectance of Ta_2O_5 antireflection layer of the Si solar cell samples on wavelength.

It can be seen from these results that the reflectance of the antireflection layer of the unirradiated sample is less than *10 %* the above mentioned spectral range and decreases as the wavelength decreases. Its value is about *7%* at *1060 nm* and (*1-2)%* at *532 nm*.

Irradiation of the Si solar cell samples by laser pulses had been found to have an observable effect on the reflectance of their antireflection layer; the effect being dependent on the laser radiation wavelength and the number of pulses. For radiation of wavelength *1060 nm*, the reflectance for the sample irradiation by a small number of pulses (□□= *1060 nm 1 and 3 pulses*) becomes ≈ *12%*. Since this small number of pulses causes a small heating of the sample surface, in the increase of reflectance may be a result of some sort of cleaning process of the surface antireflection layer, which in turn causes the observed increase of reflectance.

As the number of pulses at this wavelength is increased, the reflectance decreases. This is due to the thermal damage of the surface antireflection layer. At a high number of pulses, e.g. 30, the reflectance becomes smaller than that of the fresh unirradiated sample ≈ *4%* in the highly damaged zone and ≈ *2 %* the heavily damaged area compared with ≈ *7%*; and this is an indication of the strong damage occurring. In this case the heat effect is strong enough to complete melting. After its subsequent solidification, the sample surface

becomes irregular and rough enough to cause refection of the incident light in all directions with a corresponding decrease of the measured reflectance.
In the green region of the spectrum (□ = *532 nm*), as seen from Fig.2, the reflectance is less *2%* for the unirradiated sample. The same may be assumed true in the UV region (□ = *532 nm*). Irradiation of Si solar cell samples by laser pulses of these wavelengths increases reflectance by a factor of about *2*, which means that the surface antireflection layer is highly transparent in these two spectral regions. Accordingly, the cleaning process of the surface layer is much more effective in this case than with the □ = *1.06* □*m* radiation. Furthermore, the reflectance was observed to decrease with the number of laser pulses. In fact, as the number of pulse increase, the per cent transmission of incident laser radiation increases. The heat supplied to the sample thus increases, leading to some small damage of the samples.

Conclusions and Recommendations:

Irradiation of the Si solar cell samples by laser pulses had been found to have an observable effect on the reflectance of their antireflection layer; the effect being dependent on the laser radiation wavelength and the number of pulses.
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