- Сконструйовано систему для підсилення потужності електричного двигуна, що дає змогу підвищувати розгін лопатей, які у цієї моделі пасток дуже великі.
- Встановлено стабілізатор для вирівнювання напруги електричного струму. Відхилення напруги спричинює зупинку двигуна.
- Отримано можливість здійснювати калібрування приладу та проводити його Державну метрологічну атестацію в Україні. Для цього використано стандартні ротаметри (рис.1,г), що мали Державну метрологічну повірку. Стандартизований об’єм повітря, що прокачується, становить 10 л / хв. Діапазон вимірювання – 0 – 300 гранул /м^3; 0 – 0,15205 в полі зору на 1 мм^2 [4,11].

Висновки

Проведені дослідження атмосферного повітря на вміст пилку алергенних рослин показали, що додаткові технічні вдосконалення подовжують термін експлуатації приладу " Burkard Pollen Trap" та покращують задовільність результатів аеробіологічних досліджень. Використання стандартизованих ротаметрів дає змогу здійснювати калібрування приладу та проводити Державну метрологічну атестацію цього обладнання в Україні.

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PLASMONICS AND EYE-LIKE STRUCTURES FOR LIGHT-TRAPPING IN SOLAR THIN FILMS

Solar energy presents a promising alternative as abundant, largely untapped resources. The amount of energy striking the Earth from sunlight in one hour is equal to 4.3×10^{20} J. This value is more than the total energy consumed on Earth planet in one year 4.1×10^{20} J. Variable energy sources such as wind and solar power could provide 19–63% of required electricity in many countries, according to the International Energy Agency.

Photovoltaics, the conversation of sunlight to electricity, are a promising technology which is expected to make a considerable contribution for solving the energy problems. Nanotechnology will have a significant role within photovoltaics over the coming years. In particular the application of plasmonics and bio-like structures appear exciting prospects with a number of recent advances and insights. The particular strength of each system lies in the ability to control sizes and distributions to features and thereby match the solar spectrum. The particular opportunities appear to lie in the reduction reflection using animals (human)-eyes antireflection and focusing schemes and the reduction of semiconductor layer thickness by using plasmonics that enhance light-trapping and the filtering of spectral components in multi-junction devices.

Now researchers in photovoltaic field are turning their attention to plasmonics [1-4]. New design of solar cells based on plasmonics allows to huge improve their absorption and considerable reduce of the physical thickness of conventional semiconductor films (in most case Si wafers). The enhanced coupling of sun light into the semiconductor thin solar films has yielded due to guiding and localizing light at the nanoscale dimensions by plasmonic nanoparticles which covers such structures [1,3]. Resent research in photovoltaic has shown a high level of absorption for thin films due to excellent light trapping [1]. In our recent work [3] we have found that randomly oriented plasmonic nanoparticles embedded in dielectric matrix promote to increase the optical path length (the probability of light-trapping) for incident light by a factor of 50 due to scattering of light on nanoparticles and its total internal reflection. This experimental fact shows that such great light-trapping path length exceeds the average path-length of a trapped beam for randomly oriented scattering assembly (Lambertian surfaces) limit $2n_{Si}$~25 [5]. In Ref. 2 it was demonstrated that for ordered arrays of silicon nanowires the enhancement of the path length of incident solar radiation can be reached up to a factor of 73.

In this work we show that nanoscale waveguiding structure assembled in forms of the main components of human eyes can be used advantageously in high-efficiency photovoltaics. Observing eye systems in nature has inspired human to create similar optical vision designs. Our eye can adapt to very different illumination conditions. It is well known that eyes can be optimized for day and night vision, for near and far, for wide and narrow fields of view, and so on [6]. For example, the intensity of sunlight is billion times larger than one of starlight in night but the eye works surprisingly well in both conditions. This is partially due to using two specialized classes of photoreceptor, the rods and cones. On the other hand, the light at way to the photoreceptor must pass through lateral tissues (inner and outer plexiform layers) which optically distort and scatter the light [7]. The expansion of new reconfigurable soft lithography and three-dimensional microscale processing techniques allows to rapidly fabricating polymeric optical systems similar to biological ones. In this study, we have borrowed from biology the wave propagation method in eye, and its most important part of the light guiding and scattering within the retinal volume to enhance the concentration energy in solar cells.

In this work has pointed out the striking analogy between light and retinal receptors on one side and electromagnetic waves and dielectric waveguides on the other. For this connection it is most probable that the tapered part of a retinal cone carries out functions of the local concentration of incident light energy [7, 8]. If precisely looks on the internal structure of the human eyes it is possible to remark that the crystalline cones in their external shape and optical properties strikingly resemble ideal light concentrators. Ideal light concentrator is convex (parabolic) shaped light guide designed to maximize the concentration of diffuse light within a broad angular acceptance. Figure 1 illustrates the model of convex shaped light collector and its retinal cone eye analogy. This similarity in shape of the retinal cone and the light guide concentrator promotes to build same light collector for solar cells. The tapered dielectric rod of parabolic shape (analogy of part of retina cone) is capable of focusing light energy into region as small as few ten of nanometers with a substantial local electromagnetic field enhancement [6-8]. We proposed to use the focusing part of integrated retina functions in the new conception of light trapping elements in solar cells.

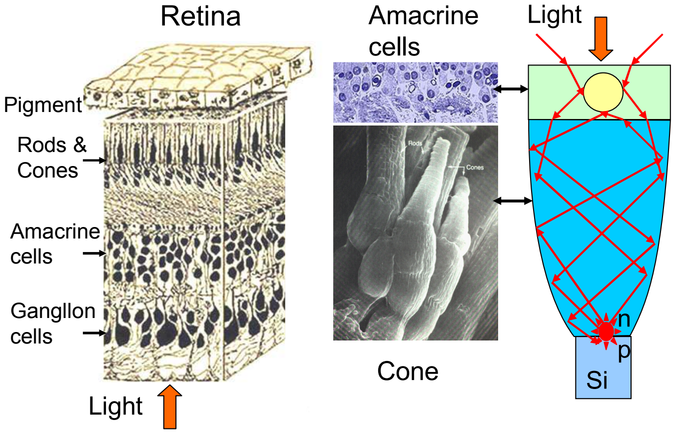

Fig. 1. From the retina of human eye to solar cell. The left panel shows the schematic of the retina, the middle panel demonstrates zoomed amacrine cells and cones, and the right panel shows a single element of the suggested photovoltaic cell structure

The simplest optical mechanism, by which such light collectors should act, involves total internal reflection of the incident light at the interfaces between the polymer cone-like rods and the surrounding media. For the poly (methyl methacrylate) (PMMA) rods with the refractive index n=1.49 in optical contact with the air the collection of light would be highly efficient up to the critical angle nearly $\theta_{cr,max}=30^{\circ}$ (the angle of total internal reflection [3]). Fig. 1 demonstrates that all light incidents on the cone-like concentrator at angles $-30^{\circ}\leq\theta\leq30^{\circ}$ will be collected on bottom area of concentrator. We should determine all geometrical parameters of cone-like light concentrator. The simple theory of ideal light collectors links the entrance aperture θ_{max} and the ratio of diameter D_1 (entry) and D_2 (exist). This relation is: $D_2 / D_1 = \sin\theta_{\max}$. If we set D_1=1000nm and $\theta_{max}=30^{\circ}$ this leads to D_2=500nm. For ideal light concentrator exist no only optimal values of D_1 and D_2 but also the length L. The four geometrical factors are related as follows:

$L = 1/2(D_1 + D_2)\cot\theta_{\max}$ [7,8]. This corresponds to L=1550nm. By varying the diameter of concentrator D_1 and consequently D_2 we can determine the light power in the centre of exit aperture D_2. The total collected power of the cone-like guide can be expressed as a function of the aperture diameter D_2:

$$G_{cone} \cong 4\pi k^2 D_2^2 \cos^2\theta \left(\frac{2J_1(kD_2 \sin\theta)}{kD_2 \sin\theta} \right)^2$$

where $k=2\pi/\lambda$ Here, the power is expressed through the spherical Bessel function of the first kind $J_1(x)$. This dependence is valid for cone eyes theory and for conical subwavelength aperture model [8]. This imply that for wavelengths of maxima solar light (400-900nm) and for suggested design of cone-like collector the light concentrates with maximum intensity when D_2 changes between 500-750nm and D_1 in range of 1000-1500nm.

Next question is how to couple freely propagating plane waves from the Sun into cone-like light concentrators and than fold this light into a thin (few microns) semiconductor layer. To solve this problem we again turn our attention on the structure of eyes. Declare that nature is very clever. This means there is enough separated designs in the eye for capturing and transmitting as much light as possible. Considering these facts it seems no surprising that images projected onto eye retina have to pass several layers of randomly oriented and irregularly shaped cells with intrinsic scatters [6-8]. The main locations of light scattering are both plexiform layers and the axon bundles, which contain numerous light-scattering objects with sizes on the order of the wavelength of visible light. In construction of solar cell we can use the plasmonic nanoparticles as a subwavelength scattering elements with similarity to the functionality of eye scatters. We can replace two layers of the eyes by one in this analogous due to the fact that scattering from plexiform membranes and the axon bundles (amacrine cells) characterizes similar shapes of spectra [7]. Light scattering from a small metal nanoparticles embedded in a homogeneous medium is nearly symmetric in forward and reverse directions. This situation changes when the particle is placed close to the interface dielectric/air. In this case light will scatter preferentially into the dielectric due to the total internal reflection on the interface [1,3]. In Figure 1 (right panel) we added the scattering part to our light-trapping element. With this aim the cone-like light concentrator should be covered by layer which contains the metal nanoparticles embedded in a dielectric matrix (possible PMMA). The thickness of this layer is 20-50 nanometers larger than nanoparticle diameter. For structure showed in Fig. 1 the scattered light will spread in the dielectric guide at a broad range of angles of light incidence. Moreover, light scattered at these angles will remain trapped in the cone-like concentrators. In addition light reflected from semiconductor solar cell active layer towards the top surface of concentrator will couple to the nanoparticles and be partly reradiated again in direction of active (Si) layer. In order to increase the numbers of passing light through Si thin layer its bottom surface can be covered by thick (~50nm) metal film with high reflective properties. As a result, such cone-like concentrator together with nanoparticle-scatters may create the resonator and the incident light will pass a lot of times through the concentrator and Si film that effectively increase the optical path length. We can suggest that in cone-like concentrator with subwavelength size scattered light can be localized likewise of Anderson localization of light. Note that the nature of such type of plasmonic light scatters and cone-like resonator can convert optical radiation into intense localized field distributions on top of Si films. We experimentally shown that a 100-120nm diameter Ag particle in Al_2O_3 can emit fraction of light as large as 85 %.

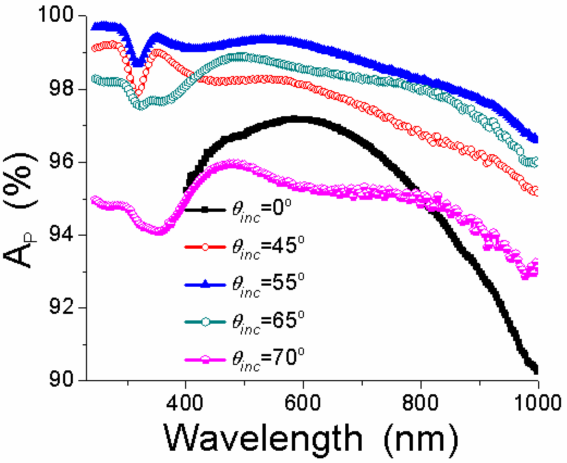

Fig. 2. Optical properties of the Ag-Al_2O_3 nanostructures with f=0.15 and D≈120nm.
The absorption spectra for the light of p-polarization

We measured reflection $R(\lambda)$ and transmission $T(\lambda)$ coefficients for Ag-Al_2O_3 nanostructures with different volume concentration of Ag. The transmission of less than 3 % is observed for wide spectral region 250-800 nm for concentration of Ag nanoparticles about 15 vol. %. Our measurements reveal that the smallest value of $R(\lambda)$ and $T(\lambda)$ is very sensitive to the volume concentration of Ag nanoparticles. Thus we conclude that the changes in concentration of Ag particles embedded in Al_2O_3 matrix (and their sizes) strongly affect the enhancement of absorption (Figure 2).

We found that the optimal geometrical parameters for design of light-trap nanostructures are next: volume filling factor f≈0.15, diameter of silver particular D≈100-120nm and thickness of layer h≈160nm. More importantly, it was found that the reflection and transmission can show low values in a large wavelength range (≤2 % for some angles of incidence). Note that the absorption can be approximately enhanced by two orders of magnitude over bulk Ag.

Measurements of optical transmittance, $T(\lambda)$, and reflectance, $R(\lambda)$, were made over the spectral range 250-1000 nm at angles of incidence, θ, from 0° to 70° for both incident p - and s –polarized radiations. The results are shown in Fig. 2 and the most important features of these curves are as follows. For incident angles up to 65° the reflectivity is close to 2 % for p- polarized light at the wavelength range of 240-1000 nm. For these angles of incidence we observed pronounced reflectivity plateau with values of $R_p(\lambda)$ as low as 2 % in the spectral range 400-1000 nm. Note that the intensity of transmission spectra drop below 5 % in the spectral region λ=800÷900nm, which is important due to light trapping at wavelength near the band gap of Si, commonly used in solar cells.

We can therefore associate attenuation of a light coming through our samples with scattering and absorption. The extinction cross section is therefore the sum of the scattering and absorption cross-sections: $\sigma_{ext} = \sigma_{sca} + \sigma_{abs}$.

Applying Lambert-Beer's law the resulting intensity transmitted through a monolayer of the non-interacting metal particles is: $T \propto \exp(-N\sigma_{ext}h_{eff})$ (where the particle number density, $N = \frac{3f}{4\pi a^3}$, is related to the filling factor f and the particle radius a; h_{eff} is the effective thickness of particle layer and its magnitude is more higher than geometrical thickness of layer, h). In our simulation we set $h_{eff}\approx 10\lambda$ (λ is the wavelength). This value is consistent with the average path-length of a trapped beam for Lambertian surfaces estimated by Yablonovich (Ref. 5).

We stress again that light concentrators together with plasmonic nanoparticle-scatters trap the light forcing incident light to pass several times through p-n active regions effectively increasing the optical path length (providing an analogy with the human retina). According to Ref. 8 significant coupling of light in eye cones can occur for higher incidence angles. It was shown that light which is not coupled within the central cells of cone guides can still be sensed by the cones due to the fact that the light, being scattered still arrives at the photoreceptor layer. Our textured solar cells act in the same way.

To conclude, we have proposed a new design for solar cells which is loosely based on the design of human retina (possible to use the design of other animal's eyes, for example fly mouse-eye, direct octopus eye). It has been demonstrated that a significant amount of light (>90%) can be trapped by cone-like guides covered with plasmonic layer placed on the surface of a thin Si p-n layer. We showed that the suggested photovoltaic cells work well over a broad range of wavelengths in the visible and near IR for both cases of collimated illumination (direct sunlight) and scattered light illumination (cloudy conditions). The parameters which guarantee the optimal efficiency of the proposed textured cells are calculated.

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ФОРМУВАННЯ ЕКОБЕЗПЕЧНОГО РІВНЯ ПРОЦЕСІВ РОЗРОБКИ ТЕХНОГЕННИХ РОДОВИЩ ПРИ СТВОРЕННІ ЕКОМЕРЕЖІ ДОНЕЦЬКОГО РЕГІОНУ

Традиційна технологія видобутку вугілля пов'язана з складуванням породи на поверхні шахт. В середньому за рік гірничі підприємства утворюють майже 40 млн. т. накопичень у відвалах. На території Донецького регіону розташовано близько 600 техногенних родовищ корисних копалин (ТРКК) гірничодобувної промисловості, які займають площу більш 4 тис. га, їх об'єм 2 млрд.т. Ситуація, що склалася, у сфері використання ТРКК небезпечна в екологічному плані: запиленість атмосфери, забруднення водоймищ, деградація земель. Використовується зараз не більше 1% об'єму ТРКК. Перспективою є потреба переорієнтації гірничорудної промисловості на технології, що зменшують накопичення ТРКК з урахуванням заходів по охороні навколишнього середовища з можливістю зменшення об'єму існуючих родовищ на 30% [5,7].

Аналізуючи джерела утворення породи можна виділити ті, які необхідно анулювати – варто вести розробки в усіх напрямках, але роблячи їх акцент на залишення породи в шахті і находження в шахту порід, що утворюється при збагаченні. Залишення породи в шахті дозволяє позбавитися виникнення ризику порушення і забруднення земель, атмосфери, гідросфери та позбавитися негативних факторів впливу породних відвалів на здоров'я людини [3,4,12]. До цих факторів слід віднести утворення шкідливих газів, пилу, вимивання та видування речовин з поверхонь відвалу і потраплянню їх у довкілля (рис.1).

Поряд з негативним впливом породних відвалів слід визначити їх корисні властивості, а саме – всі відвали необхідно розглядати як техногенне родовище корисних копалин та потенційними кладовими великої кількості компонентів так необхідних народному господарству [17, 9].

Окрім шкідливого впливу породних відвалів необхідно урахувати що це техногенні родовища, які містять (по даним «Укргеології») – золи 57,05%, летучих сполук – 29,62%, сірки – 1,576%, оксидів – 11,74%. Доля в оксидах –