New Solar Thermal Materials

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Abstract

A number of chemical ion materials were used as an absorber against solar energy. These materials were selected according to their absorption spectra in the wavelength range 300-800nm where the solar spectrum is concentrated. A solar collector was designed and constructed for this purpose. The ability of each material inside the collector for absorbing the solar radiation was examined by a converter parameter "R".According to the "R" parameter, the cobaltous and copperic ions material seems to be of higher capability for absorbing solar energy than the other materials.All the results were analyzed by means of a least-squared fitting program.

Introduction

In the last three decads, the solar energy applications were expanded by many authors. These applications were focused on solarponds [1], selective surfaces [2], photo chemical conversion [3-5] ...etc. A comprehensive literature on the many types of chemical conversion in solar energy up to 1979 has been given by Mariano et al. [6].More recent publications concentrated on both chemical conversion and collector efficiency were reviewed elsewhere [7-9].This study focused on using some ion materials as a photochemical converter against solar energy. The aqueous solution of these ions was used as an absorber in a solar collector designed and constructed for this purpose. The converter parameter was calculated for each system of ions in order to mention the one of higher capability for absorbing solar energy among the others.

Experimental Work

In this investigation all the materials used were from BDH. They were used without further purification. Five samples were prepared as follows: (i).A mixture of aqueous solution of cobaltous and copperic ions with a concentration 10^{-3} M (brownish color). (ii) & (iii) A Mixture of aqueous solution of chromate and manganate ions with a concentration 10^{-2} M and 10^{-3} M respectively (orange color). (iv) & (v) Adding dichromate ions to (i) with a concentration 10^{-2} M and 10^{-3} M respectively (yellowish color). A liquid

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solar collector was constructed. It consists of shallow metal troughs of equal depths (2cm) covered by 3mm thick glass sheet. Each of the samples (i)-(v) can be pour into the collector. The heat exchanger of the collector is made of two parallel horizontal tubes connected by six vertical tubes of equal length. For each sample in the collector, the following measurements were done every one-half hour: the insolation I ($mWcm^{-2}$), the lower and upper temperatures of the sample T_l and T_u (^oC) respectively. All experimental details of the collector were presented in ref. [8].

Results and Discussion

The samples under investigation are chosen according to their absorption spectra in the range 300-800nm where the solar spectrum is concentrated.Two methods can be followed [4] to improve the ability of the photochemical conversion of any material; firstly: adding photosensitizers that strongly absorb in the visible region, hence transfer the excitation to the original material. Secondly: using a mixture of non-reacting materials to enhance the absorption of solar energy. In this study, the two methods are applied to achieve suitable materials in solar energy applications.Fig. 1-a shows the behaviour of I, T_l, T_u with the local time t (hr) for the sample (i). A lease square fitting program is used to transform the behaviors in Fig. 1a into three different equations for I, T_l and T_u as a function of t (Fig.1-b). From this figure it is noted that the increasing in the insolation giving rise to increase sample temperature because the molecules of the sample absorb photons light and generate heat by some fast reversible photochemical processes. Since the sample (inside the collector) is solution, there should be a temperature gradient between the upper and lower levels of the sample (usually $T_u > T_l$).

Figs. (2-5) illustrate the variables I, T_l and T_u of the samples (ii)-(v) respectively with their own equations.The quantity converter parameter "R" can be defined as:

$$R = \frac{\int_{8.5}^{16} \left(T_u - T_l\right) dt}{\int_{8.5}^{16} I \, dt} \quad \dots (1)$$

which gives a good indication about the efficiency of each sample to convert light into heat. The nominator in eq. 1 represents the area between the curves $T_u(t)$ and $T_l(t)$, this area should be divided by the area under the insulation curve I (t) in order to normalize each system to its own environment (i.e. solar radiation). The (R) parameter is defined for the first time in this study.

Table-1 summarizes the calculated values of (R) for the samples (i) –(v). The table demonstrates that the ability of these samples can be listed in the sequence (i) > (iii) > (iv) > (ii) > (v).

Conclusion

Using these ion materials ((i)- (v)) as a photochemical conversion in the solar collector provide an advantage due to the 4π absorption, since the heat exchanger of the collector is embedded into the body of the sample, while the collectors using other materials (such as selective surfaces) the absorption takes place only on the face side. Consideration of the cost of the materials involved in this study show that the photochemical conversion path to solar energy collection to be economically the more viable among other paths.

Fig.1-a-b

Table-1 The calculated values of the converter parameter "R" for the samples (i)- (v) according to equation (1).

Sample	$\int_{8.5}^{16} (T_u - T_l)\,dt$	$\int_{8.5}^{16} I\,dt$	R(°C.cm².mW⁻¹)
(i)	55.700	468.426	0.1189
(ii)	29.395	437.489	0.0672
(iii)	57.907	492.739	0.1175
(iv)	30.513	425.997	0.0716
(v)	29.759	471.713	0.0631

Acknowledgement

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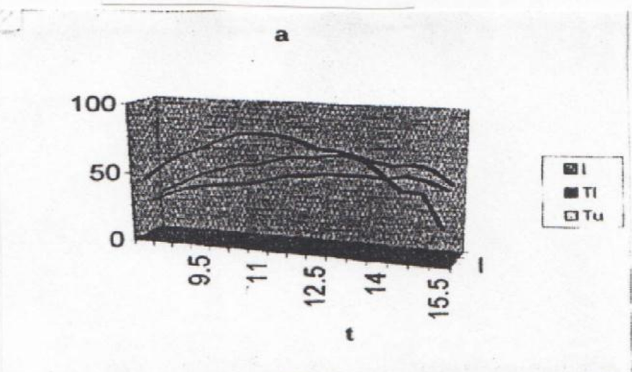
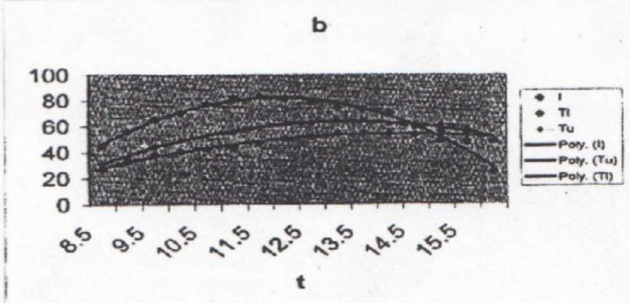
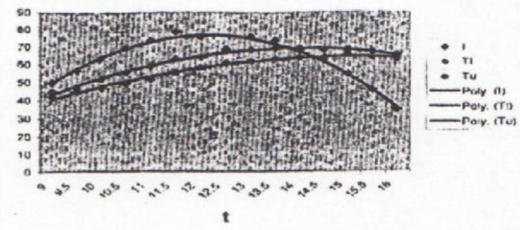
Fig.1 a) the behavior of insolation (I) and temperatures T_l and T_u with time (t), and b) the fitted curves and equations of I, T_l and T_u for sample (i).





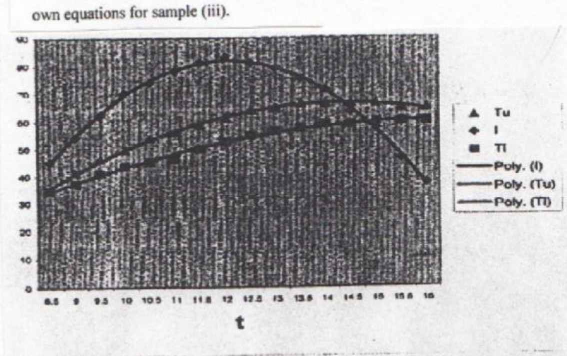
$I = -0.7847t^2 + 12.172t + 34.782$
$T_l = -0.2117t^2 + 5.1423t + 23.018$
$T_u = -0.3654t^2 + 7.5995t + 24.129$

Fig.2 the behavior of the variables I, T_l, and T_u as a function of (t) with their own equations for sample (ii).



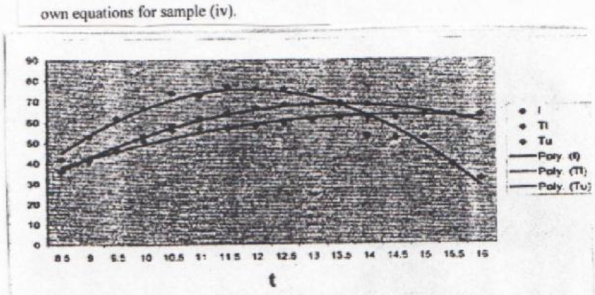
$I = -0.6854t^2 + 9.9943t + 40.435$
$T_l = -0.1543t^2 + 4.1776t + 36.634$
$T_u = -0.2483t^2 + 5.5753t + 38.127$

Fig.3 the behavior of the variables I, T_l, and T_u as a function of (t) with their own equations for sample (iii).



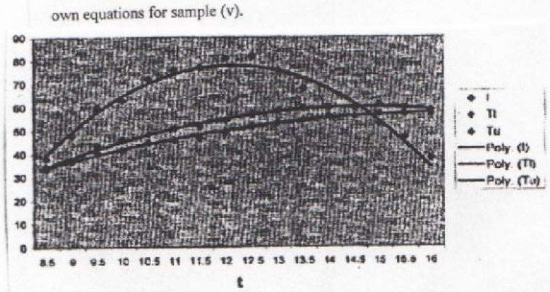
$I = -0.7311t^2 + 11.861t + 33.539$
$T_l = -0.1048t^2 + 3.5129t + 30.656$
$T_u = -0.2248t^2 + 5.7067t + 30.073$

Fig.4 the behavior of the variables I, T_l, and T_u as a function of (t) with their own equations for sample (iv).



$I = -0.687t^2 + 10.576t + 35.089$
$T_l = -0.1781t^2 + 4.6114t + 33.678$
$T_u = -0.3319t^2 + 7.2105t + 29.559$

Fig.5 the behavior of the variables I, T_l, and T_u as a function of (t) with their own equations for sample (v).



$I = -0.7229t^2 + 11.931t + 28.609$
$T_l = -0.0931t^2 + 3.1363t + 31.05$
$T_u = -0.167t^2 + 4.4687t + 30.132$

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الخلاصة

يتضمن البحث استخدام عدد من المواد الكيميائية والتي تحتوي عدة أيونات لاستخدامها كمواد ماصة للطاقة الشمسية. اختيرت هذه المواد استناداً إلى أطياف امتصاصها ضمن المدى ٣٠٠– ٨٠٠ نانو متر الذي يتركز فيه طيف الانبعاث الشمسي. تم تصميم وبناء مجمع شمسي مخصص لغرض استخدام هذه المواد فيه واختبار قابلية كل منها لامتصاص الأشعة الشمسية من خلال عامل التحويل "R". استناداً إلى قيم R المحسوبة أبدت المادة الحاوية على أيونات الكوبلت والنحاس على قابلية عالية لامتصاص الطاقة الشمسية مقارنة مع باقي المواد المدروسة. تم تحليل جميع النتائج بأستخدام برنامج ملائمة المربع الاصغر.