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Enhance the Insulation Properties of Building Window Glass by Optical Program Band for More Effective Cooling and Heating Process

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Abstract

Providing electricity to energy-intensive residential buildings is crucial worldwide. However, the importance of managing electrical loads, as well as heating and cooling loads, has become increasingly apparent. This research aims to design building windows using Openfilter software, incorporating innovative thin-film and ferro-fluid materials. The refractive index and thickness of these materials enhance the window glass's infrared reflectivity, resulting in superior insulation properties that maintain a stable cooling temperature within the building. This, in turn, improves energy management efficiency during the summer months. The research proposes using TiO2 semiconductor materials with a high thermal dielectric constant and ferro-fluid windows with a dual refractive index. Depending on the applied voltage, the window panes allow maximum light transmission in winter and minimum transmission in summer. The results show a significant improvement in temperature gradient from 80°C to 20°C. This approach will significantly enhance the efficiency of both heating and cooling processes.

Keywords: insulator constant, ferro-fluid, open filter, reflection, window glass.

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تحسين خواص العزل لزجاج نوافذ المباني باستخدام حزمة البرامج البصرية لعملية تبريد و تدفئة اكثر كفاءة

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الخلاصة

يعد توفير الكهرباء للمباني السكنية التي تستهلك طاقة أمرًا بالغ الأهمية في جميع أنحاء العالم. ولكن ظهرت اهمية توفير الأحمال الكهربائية وكذلك أحمال التدفئة والتبريد في المبنى. يهدف البحث الى وضع تصميم لنوافذ المباني باستخدام برنامج Openfilter بادخال مواد مبتكرة من الاغشية الرقيقة ومن البلورة السائلة في التصميم. حيث اعتمادا على معامل انكسار هذه المواد وسماكتها في جعل زجاج النوافذ اكثرانعكاسية للاشعة تحت الحمراء وبالتالي ذات خاصية عزل افضل لتحافظ على درجة حرارة التبريد داخل المبنى ثابته الذي يجعل ادارة الطاقة المستخدمة في المبنى اكثر كفاءة في فصل الصيف. من المقترح في هذا البحث استخدام المواد الشبه موصلة TiO_2 ذات ثابت عزل حراري عالي و نوافذ الفيرو السائلة ذات معامل انكسار مزدوج وحسب الفولتية المسلطة على الواح النوافذ تقوم الالواح بامرار اعظم ضوء نافذ في فصل الشتاء واقل ضوء نافذ في فصل الصيف حيث اعطت النتائج تحسن في انحدار درجات الحرارة من 80 درجة مئوية الى 20 درجة مئوية .وهذه الطريقة سوف تجعل عملية التبريد والتدفئة اكثر كفاءة .

الكلمات المفتاحية: ثابت العزل ، زجاج النوافذ ، الانعكاسية، الفيرو- السائلة ، برنامج open filter .

Introduction:

The thermal insulation field is a tremendous challenge, as it may be articulated as the reduction of heat transfer through an item under the influence of a temperature difference. Or it is the exchange of thermal energy between two physical systems. Thermal insulation can be provided through specially engineered methods, special construction or processes, appropriate object shapes and materials [1]. Heat conduction is something that automatically happens when two objects of different temperatures come into contact. Thermal insulation acts by creating a region of low thermal conductance that either provides a thermal barrier where heat conduction is minimized (thermal break) or reflects instead of absorbs the radiant heat from the hot body to the cold body[2]. Insulation of the materials is represented by their reciprocal of thermal conductivity (k). Low thermal conductivity corresponds to "high insulating value (resistance value).

A significant percentage of the world’s energy goes to keeping buildings at acceptable temperatures (that is, either heating or cooling). The principle of small trapped air-cells is also employed in the case of building insulations, such as glass wool (fiber glass), cellulose, rock wool, polystyrene foam, urethane foam, vermiculite, perlite, cork, etc. Asbestos was also used for some duration, but it is harmful to health [2]. Insulating film can be used in weatherization to cover windows and reduce heat transfer. There are benefits of insulated for a building for examples; require less energy effective, less expensive to keep warm in the winter or cool in the summer, less temperature gradient both vertically (between ankle height and head height) as well as horizontally from exterior walls and windows to the interior walls, making more comfortable occupant environment when outside temperatures are extremely cold or hot [3].

In industrial applications, energy is required to elevate, reduce, or sustain the temperature of materials or process fluids. In the absence of adequate thermal insulation, energy consumption increases significantly, leading to higher operational demands, elevated costs, and greater environmental impact [4].

There are several factors that influence insulation performance, such as: First, thermal conductivity (K- value), Second, surface emissivity (ε), Third, insulation thickness, Fourth, density, and Specific heat capacity.

As a part of this, researchers examined building physics with low heat losses to lower energy requirements for things such as:

B. P.Jelle. Investigated the reflective window 255 steel coated low E glass and their transfer of both heat energy, uv as well as visible light [5], p. Lakshita et. al. Investigation Thermal conductivity of ferro-fluid under external magnetic field [6], also, Seval G. studied the heat transfer performance of ferro-fluid (MF_2O_3) particles in a magnetic field (~1004 kA/m), examining heat transport changes with the form ring and without fields for two sizes particles (50 nm,and55nm.) [7].

It is worth mentioning that in this paper, the investigation of factor affect performance of glass windows during aging of a material or in changing environmental conditions, by using two approaches, first, deposit a semiconducting material, such as TiO_2, on the glass window, and second, use the Ferro-fluid to fill the spacer between the double-sides of glass. The study here is made in order to enhance the heat insulation for windows by measuring the reflectance of the sunlight.

2. Theoretical part:

2.1 Insulating Glass of building:

Insulating glass is manufactured glass made for installation to retard or restrict heat transfer into or out of a home or building. It is composed of several layers separated by spacers, which can be made of metal (such as aluminum) or structural foam. The gap between the glass is sometimes filled with a noble gas, argon or krypton. The technical term for this kind of glass is Insulating glass (IG) and may also be known as double-glazed, or double-pane. As technology advances, triple-glazed or quadruple-glazed options also exist [8].

Insulated glass consists of the following components: Several layers of glass, which include materials and gases to help maintain a vacuum, or a gas-filled space between the glasses. All these pieces are put together into one sealed unit that keeps the system together and prevent changes particular in the air (or gas) between the glasses. These are known as insulating glass units (IGUs).

2.2 Low-Emissivity Glass

The IG unit windows can normally be fabricated with low-Emissivity glass, which has a coating that cuts down the amount of ultraviolet and infrared light that can travel through a window. It can help regulate the temperature (and heat energy) in a building by sending heat back to where it came from. Low-Emissivity coatings are constructed from ultra-thin layers of materials that reflect heat significantly better than they absorb or radiate it [9].

The building equipment is in the winter to keep the cold out, and in summer, it's used to keep the heat out. The big factor in each of those cases is the solar heat gain coefficient and U-factor [10]. U-factor is essentially the rate of heat transfer, and an indication of how well the window insulates. They tend to be in the range of 0.25–1.25. The SHGC (solar heat gain coefficient) measures how much solar radiation is allowed to enter through a window. It ranges between 0 and 1. The smaller the value, the less heat it transmits [11].

There exists a number of indices for quantifiably describing the performance of Low-Emissivity coated glasses [12]:

1-Solar Heat Gain Coefficient (SHGC): The fraction of the solar radiation that is admitted through the window. This may either be directly transmitted and absorbed or radiate inwards.

2-U-Value: The rating that is assigned to a window according to how much the loss of heat it enables.

3-Visible Light Transmittance (VLT): The amount of visible light that passes through glass.

4-Light to Solar Gain: The relationship of the window's ability to transmit sunlight in relation to its insulating value.

The low Emissivity glass is good to reduce a certain amount of ultraviolet light [wavelengths between 310-380 nm], and heat near infrared light that has a wavelength of about 780 nanometers [13], which penetrates into the home. The infrared that comes from the sun is referred to as short-wave infrared, whilst the one produced by other warm objects is called long-wave infrared. [14] Blocking these kinds of light prevents heat from reaching where you want it to, as shown in fig. 1.

Fig.1 shows the Emissivity-coating glass window receives sunlight from the left, in winter and summer. In the summer its an insulating feature that keeps heat from entering the building, and when winter rolls around it keeps heat inside. The 10-50% of energy loss in a typical home happens through its windows and doors; and between 80-90% of those losses occur through the glass[14].

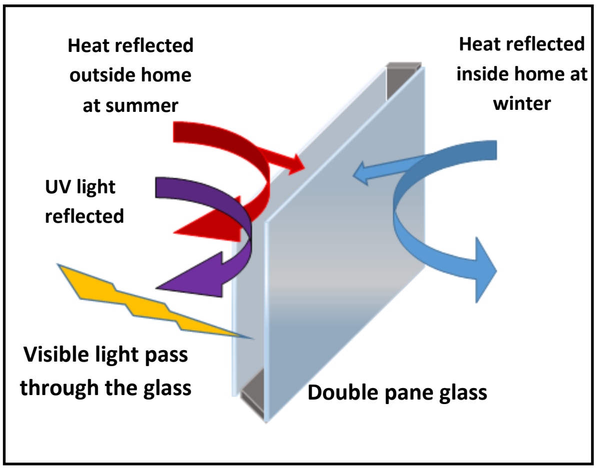


Figure (1). A schematic representation of how low-emissivity coatings prevent UV and IR wavelength some wavelengths of light but allow visible light to pass through the window [1].

The phenomenon of absorbing and re-radiating energy is called emissivity; that's why highly reflective materials usually have a pretty low emissivity. [15] Reducing the emissivity of the glass surfaces in a window will improve its insulating properties. The surface emissivity is the rate at which a surface emits energy relative to that emitted by a blackbody (a perfect emitter) at the same temperature. A substance has an emissivity from 0 to 1; a perfect reflector may have an effectiveness of zero (emissivity = 0), while an ideal absorber has an emissivity of one. Metallic materials such as Silver and Aluminium exhibit thermal emissivities as low as <0.05; whereas normal clear glass has a value of approximately 0.9 — one of the highest of all materials. To break this down, standard glass with a thermal emissivity of 0.9 lets 90% of heat flow through it and reflects back the remaining 10%. So it's obvious: window glass could use some help reflecting heat back into the building [16,17]. The two types of glass coating are: first, passive low-emissivity films, and solar low-emissivity. The passive low emissivity is produced by a pyrolytic method [18]. In such cases, indium tin oxide is coated onto the window[19] , which can be used in cold climates [20]. Because these glazing allow more solar energy through, they do not have a good U-value, but are preferable for building with passive solar heating because there is more light and heat transmitted into the homes [21]. Solar control low-emissivity coatings are made with a process called the MSVD (Magnetic Sputtering Vacuum Deposition) or sputtered method. Such a coating has reduced emissivity and, consequently, allows for less passage of solar energy through the window." On these types of coatings, a very thin layer of silver is usually the layer that is put on the window[19]. Solar control low-e coatings are commonly applied in warmer climates where the exclusion of heat from outside a building is more crucial [22].

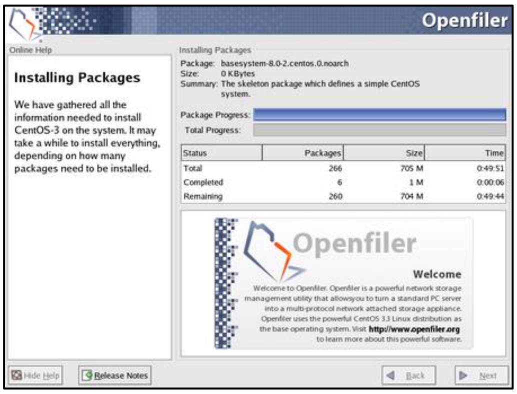
This work investigates the insulation property via the openfilter program to apply semiconductor thin film TiO_2 by varying the thickness of layer, and uses ferrofluid materials to fill the spacer between the slide's glass window.

3. Experimental part :

Window glass design can be made using the openfilter program. By using double-pane glass in two approaches, either coating with high reflection TiO_2, which has high thermal insulation. The other approach is fill the spacer between the two pane glass with ferrfluid material that has two refractive indices and can pass the sunlight depending on the value of the external magnetic field.

Software: The OpenFilter is an operating system providing capabilities for file-based network-attached storage and block-based intersystem storage services. It's produced by Xint Systems and based on CentOS Linux.

The first page of the 'program' is shown in fig (2).



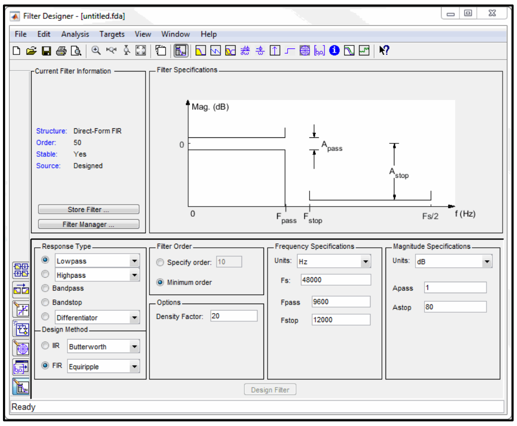


Figure (2) the front page of the open filter program

The program's capabilities can be summarized as a comprehensive set of tools for filter design and analysis. It allows users to design filters using an open filter design environment, as well as to quantize and analyse filters efficiently. Additionally, the program supports the modification of existing filter designs and the creation of multi-rate filters. It also enables the implementation of quantized, direct-form FIR filters as Simulink models, along with the re-evaluation of filter designs through digital frequency transformation.

4. Results and Discussions

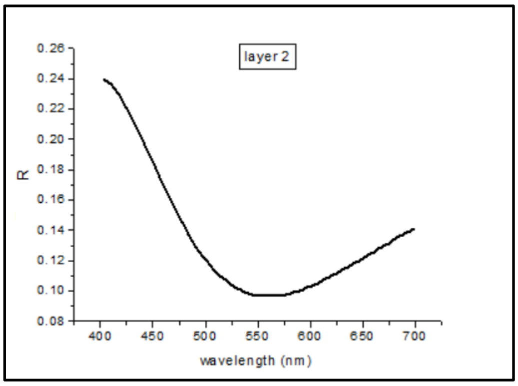
4.1The first approach :

The fabrication period of the TiO_2 thin film a uniform coating glass was achieved after 10, 15 and 30 layers up to a thickness of 2268nm ,since each layer is about 151 nm as listed in table(1). For an optical filter TiO_2 employed as a visible light 400-700 nm pass filter, the reflectance is calculated for each layers increased by even number of layers. The results of the reflectance curves shown in Table 2.

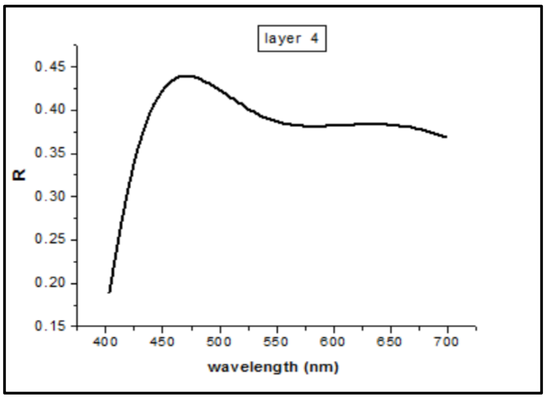
Table 1: The TiO_2 coating thickness and number of layers details.

Step of number of layers	Number of layers	Thickness of layers (nm)
1	2	151.22
2	4	302.45
3	6	453.67
4	8	604.90
5	10	756.12
6	12	907.34
7	14	1058.57
8	16	1209.79
9	18	1361.02
10	20	1512.24
11	22	1663.46
12	24	1814.69
13	26	1965.91
14	28	2117.14
15	30	2268.36

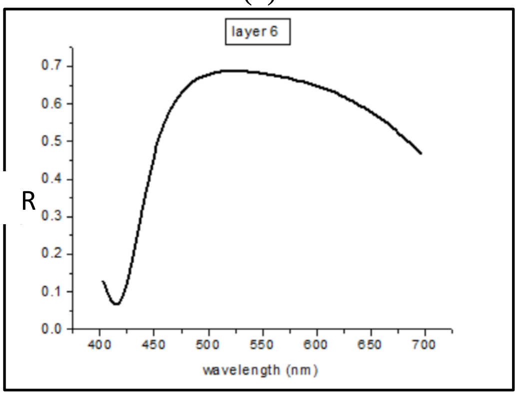
The fig (3 a-o) show how the reflectance changes for incident light rang 400-700nm for a) 2layers,b) 4 layers, c) 6 layers, d) 8 layers, e) 10 layers, f) 12 layers, g) 14 layers, h) 16 layers, i) 18 layres, j) 20 layers, k) 22 layers, l) 24 layers, m) 26 layers, n) 28 layers, o) 30 layers.



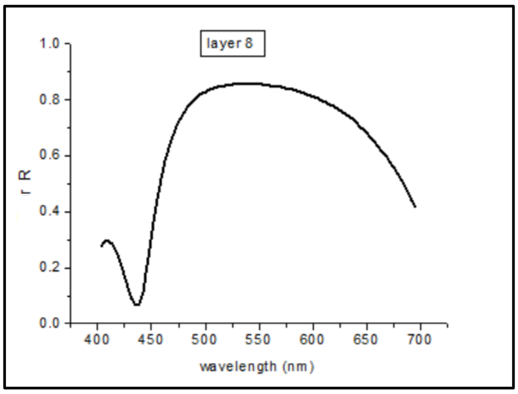
(a)

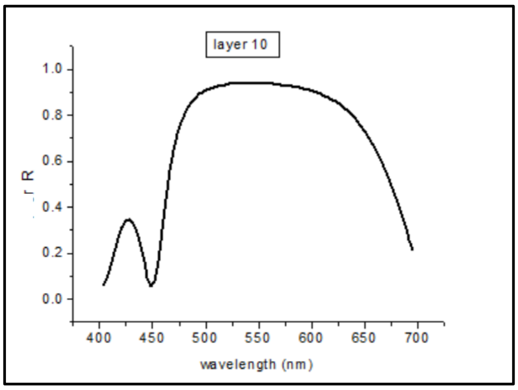


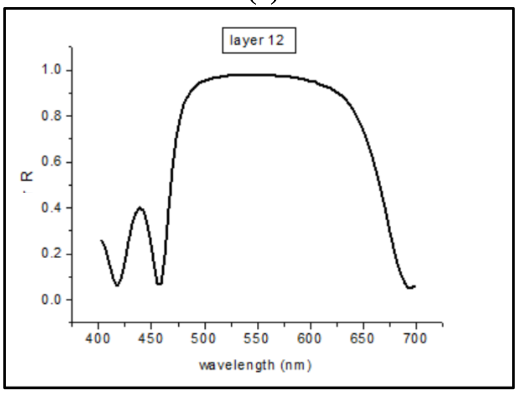
(b)

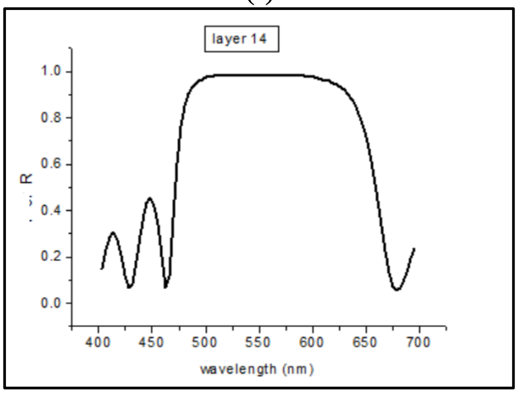


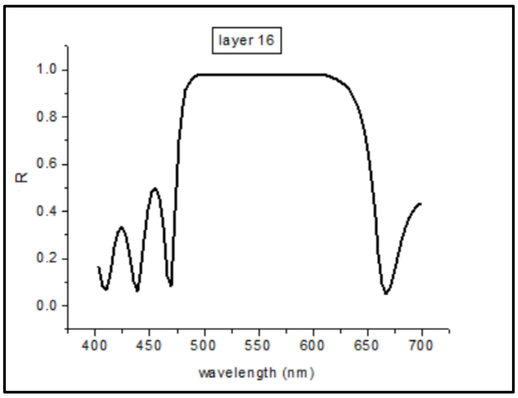
(c)

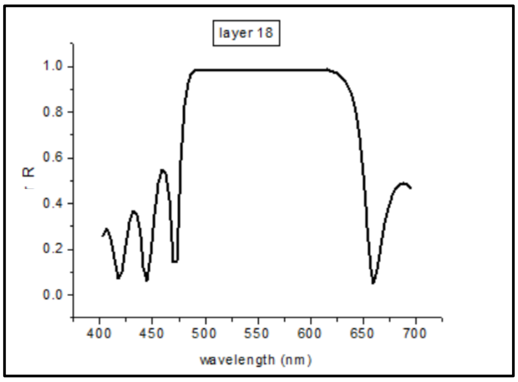

layer 8
R
1.0
0.8
0.6
0.4
0.2
0.0
400 450 500 550 600 650 700
wavelength (nm)
(d)

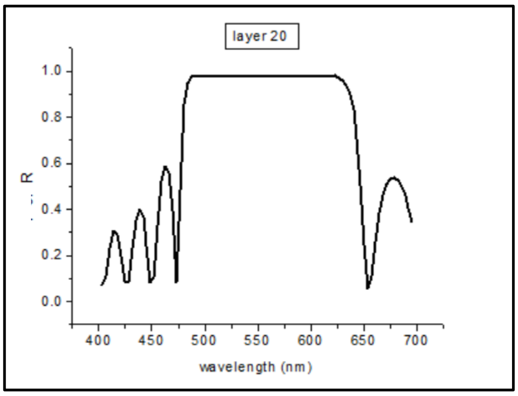

layer 10
R
1.0
0.8
0.6
0.4
0.2
0.0
400 450 500 550 600 650 700
wavelength (nm)
(e)

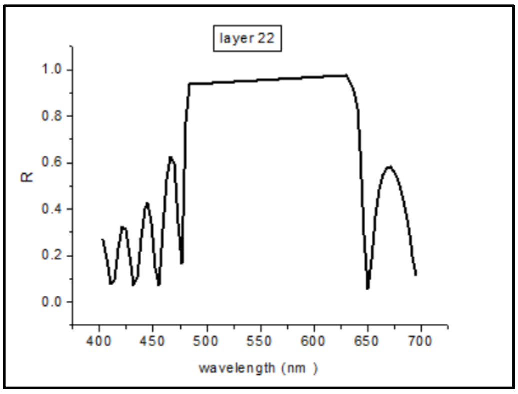

layer 12
R
1.0
0.8
0.6
0.4
0.2
0.0
400 450 500 550 600 650 700
wavelength (nm)
(f)

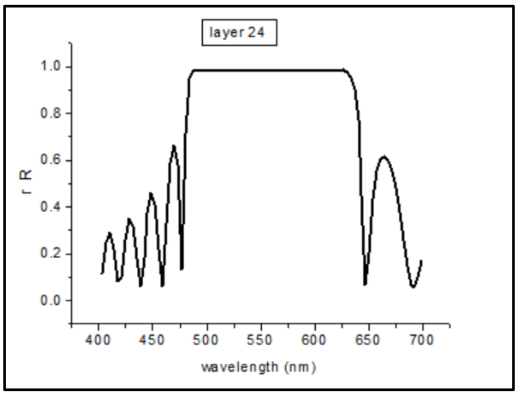

layer 14
R
1.0
0.8
0.6
0.4
0.2
0.0
400 450 500 550 600 650 700
wavelength (nm)
(g)


layer 16
R
1.0
0.8
0.6
0.4
0.2
0.0
400 450 500 550 600 650 700
wavelength (nm)
(h)

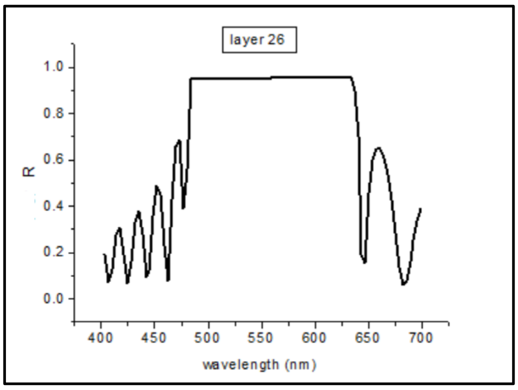

layer 18
R
1.0
0.8
0.6
0.4
0.2
0.0
400 450 500 550 600 650 700
wavelength (nm)
(i)


layer 20
R
1.0
0.8
0.6
0.4
0.2
0.0
400 450 500 550 600 650 700
wavelength (nm)
(j)

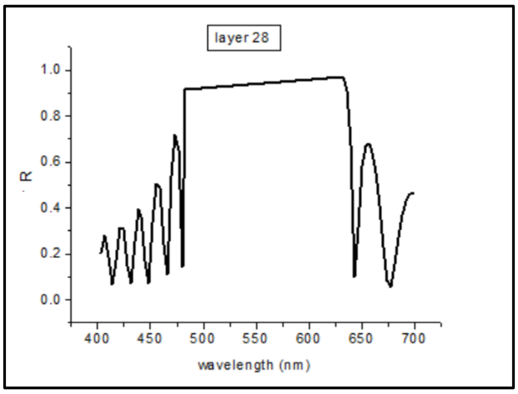

layer 22
R
1.0
0.8
0.6
0.4
0.2
0.0
400 450 500 550 600 650 700
wavelength (nm)
(k)



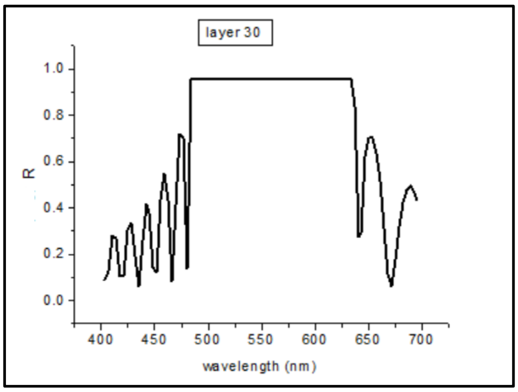
(l)



(m)



(n)



(o)

Figure (3): The reflectance of the TiO_2 thin film coated the glass pane window.

Table 2: The curves of Reflectance details

Curves no.	Observation notes
a	no peak appears
b	Two peaks appear at 475nm and 650nm with max intensity reach 43%,
c	broad band peak 575-700nmwith intensity 65%,
d	two peaks at 400nm and a broad band 475-650nm with intensity 80%
e	Two peaks at 425nm with 30% intensity, and 475-650nm with 90% intensity.
f	Two peaks at 430nm with 40% intensity, and 475-650nm with saturation intensity.
g	Three peaks at 410nm with 30% intensity , 450nm with 45%, and 475-650nm with saturation intensity.
h	Three peaks at 425nm with 30% intensity, 460nm with 50% intensity, and 475-650nm with saturation intensity.
i	Five peaks at 400nm with 30% intensity, 430nm with 35%, 460nm with 50%, 475-650nm with

	saturation, and 480nm with 50% intensity.
j	Five peaks at 410nm with 30% intensity, 430nm with 40%, 465nm with 60%, 480-650nm with saturation, 675nm with 50% intensity.
k	Five peaks at 415nm with 30% intensity, 4355nm with 40%, 475nm with 60%, 480-650nm with saturation, and 675nm with 60% intensity.
l	Six peaks at 405nm with 30% intensity, 425nm with 35%, 450nm with 45%, 470nm with 62%, 475-650nm with saturation, and 665nm with 60% intensity.
m	Six peaks at 415nm with 30% intensity, 430nm with 40%, 450nm with 50%, 475nm with 65%, 480-640nm with saturation, 660nm with 65%intensity.
n	Seven peaks at 405nm with 27% intensity, 425nm with 30%, 435nm with 40%, 450nm with 50%, 475nm with 70%, 500-650nm with saturation , 660nm with 70% intensity.
o	Eight peaks at 405nm with 27% intensity, 425nm with 30%, 440nm with 40 %, 460nm with 50%, 475nm with 70%, 480-630nm with saturation, 650nm with 70%, and 680nm with 50% intensity.

4.2The second approach:

Utilizing ferro-fluid Fe_3O_4-based water as an insulating material was put into the spacer between the double-pane glass window, then the flow of heat transfer from outside the heat source to the ferrofluid without a magnetic field was reduced from 85˚C to 20˚C, and the heat capacity was reduced by 90% due to the increase in the reflectance that matches the data in ref. [20,21].

The heat transfer rates increase with increasing of the concentration of the magnetic nanoparticles recorded more, thermal conductivity reached 70% for under a magnetic flux of 50 mT at room temperature for a concentration 5% that have match the data of ref. [22-24].

Conclusions

The developing in the building windows has very promising results in this work by using two methods to enhance the thermal insulation of the pane glass window of the building. The first approach is coat the inner side of the glass with TiO_2 thin films which give a range in reflectance the incident light between 400-700nm, the 30 layers show the biggest reflectance amount of the sunlight, while the second approach is using the ferro fluid (Fe_3O_4 based water) as filling materials of the space between the double panel of glass which can reduce the heat transform from the outside about 70%.

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