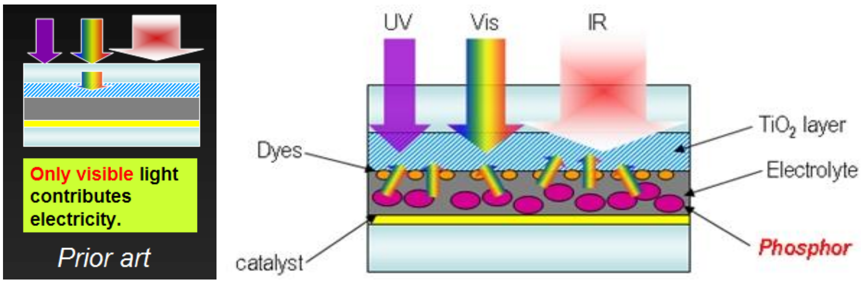
Enhancing efficiency of dye sensitized solar cell

Abstract

<Low efficiency of light to electric energy conversion>(problem) of <dye sensitized solar cell> with minimizing structure/manufacture complexity, was resolved by <utilizing broad range of light by light converting phosphor technique> is presented. If multiple dye or very advanced dye is introduced into the DSSC cell, photon-to-electricity converting efficiency will increase, but dye cost and manufacturing procedure and developing activity will be very complicated. One of root cause of current low efficiency is identified as DSSC cell uses only visible light to produce electricity. A simple idea to make the 'unused part of solar ray' useful without introducing very complicated dye or multiple dyes has been proved to enhance up to 15% of efficiency and patented in Korea and US.



PART 1. ANALYZING THE PROBLEM

1.1. Formulate the mini-problem

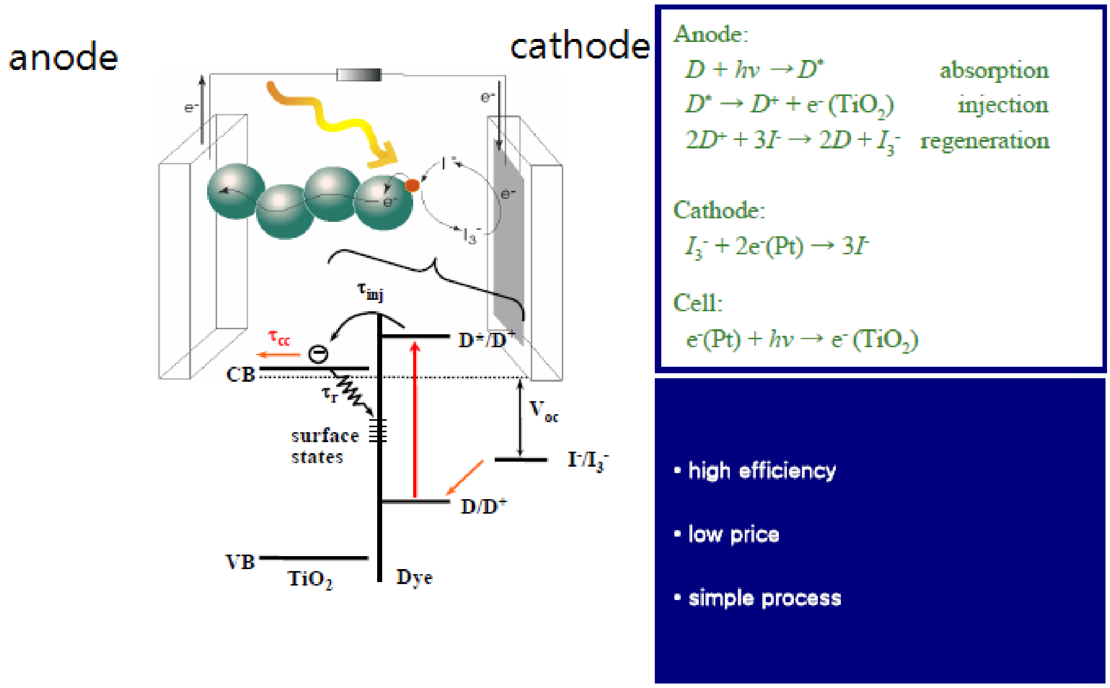


Figure 1 Dye sensitized solar cell operating scheme

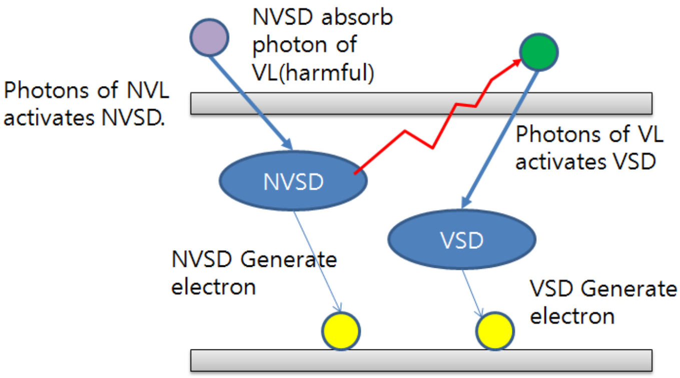


Figure 2 schematic diagram of problem in dye sensitized solar cell

The technical system<DSSC> for <converting photon of visible light to electron> includes < VSD (visible sensitive dye, main element to produce electron), NVSD(non-visible sensitive dye), electron(generated by NVSD or VSD), photon of VL(visible light), photon of NVL(non-visible light), electrodes, semiconductor particle, electrolyte, substrate, etc.>

TC-1: if there is big amount of non-visible sensitive dye(NVSD), then it convert photon of non-visible light(NVL) to electron, but absorb photon of visible light(VL).

TC-2: if there is small amount of NVSD, then it does not absorb remarkable amount of photon of visible light(VL), but photon of NVL is not converted to electron.

It is necessary with minimum changes to the system, to <convert photon of NVL to electron without absorption of VL photon>.

1.2. Define the conflicting elements

Tool A: NVSD

Condition 1: big amount

Condition 2: small amount

Product

B: photon of NVL

C: photon of VL

1.3. Describe graphic models for technical contradictions

Tool A: NVSD

A1: big amount

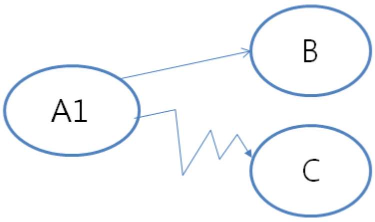
A2: small amount

Product

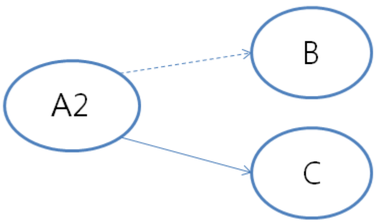
B: photon of NVL

C: photon of VL

TC1



TC2



1.4. Select a graphic model for further analysis

The main operating scheme of the DSSC is based on the VSD because visible light contains most part of the solar energy. NVSD utilize photon in NVL(non-visible light) to generate electron but, it hinder the functioning of the VSD. So TC 2 situation was chosen as starting point of the problem solving.

Tool A: NVSD

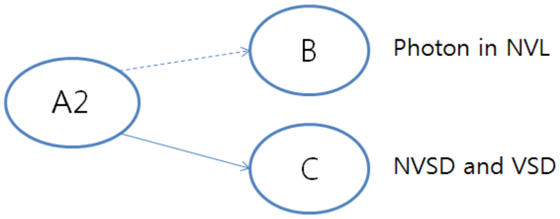
A2: low concentration

Product

B: photon of NVL

C: photon of VL

TC2



1.5. Intensify the conflict

Tool A: NVSD

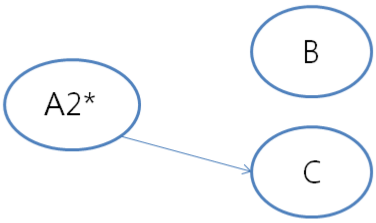
A2*: absent

The extreme case of concentration of NVSD is large → small →absent

Product

B: photon of NVL

C: photon of VL



1.6. Summarize the problem model

It is given an absent NVSD and a photon of NVL and photon of VL.

The absent NVSD does not provide to absorb photon of VL
and does not provide converting photon of NVL to electron.

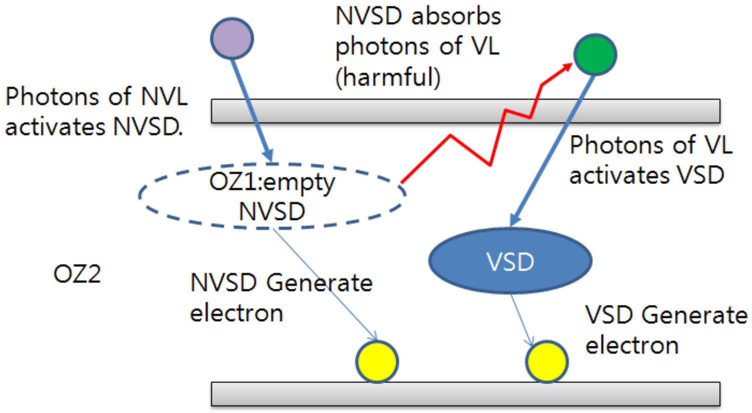
It is required to find an X-element that
will keep ability of the absent NVSD to absorb photon of VL
and will provide converting photon of NVL to electron.

1.7. Apply the inventive standards

NA

PART 2. ANALYZING THE PROBLEM MODEL

2.1. Define the operational zone (OZ)



- The OZ1 is the space previously occupied by the NVSD where absent NVSD exists.
- The OZ2 is the space where all around space except the space previously occupied by the empty NVSD

2.2. Define the operational time (OT)

- The T1' is the period that photon of NVL meets the NVSD.
- The T1" is the period that photon of VL meets the VSD.
- The T2 is the period before that photon of NVL and photon of VL meet the NVSD and/or VSD.

2.3. Define the substance-field resources (sfr)

	substance	Field	etc
internal	● tool: NVSD ● product : VSD, photon of NVL		
external	● Electron ● hole ● Photon of solar light ● anode substrate ● anode electrode ● semiconductor nanoparticle layer (TiO_2) ● electrolyte ● reducing agent (I) ● cathode electrode ● cathode substrate ● ion	● electric field ● electromagnetic field	● Manufacturing period ● Storage period ● Transport period
supersystem	● circuit ● moisture in the air ● rain ● air ● dust in the air ● bubble ● spacer ● glue	● heat generated by solar cell itself ● mechanical stress ● mechanical vibration ● gravity ● wind	● other energy system (ex. 2ndary battery) ● electric device which utilize energy of the DSSC

PART 3. DEFINING IDEAL FINAL RESULT (IFR) AND PHYSICAL CONTRADICTION (PhC)

3.1. Formulate IFR-1

1.6.

It is given an absent NVSD and a photon of NVL and photon of VL.

The absent NVSD does not provide to absorb photon of VL
and does not provide converting photon of NVL to electron.

It is required to find an X-element that
will keep ability of the absent NVSD to absorb photon of VL
and will provide converting photon of NVL to electron.

IFR-1

The <X-element>
without complication of a system and without harmful side effects, eliminates

the harmful function of absent NVSD <not to convert photon of NVL to electron >
During the <operation time>
Inside the <operation zone>

With keeping ability of the absent NVSD provide < not to absorb photon of VL>

3.2. Intensify definition of IFR-1

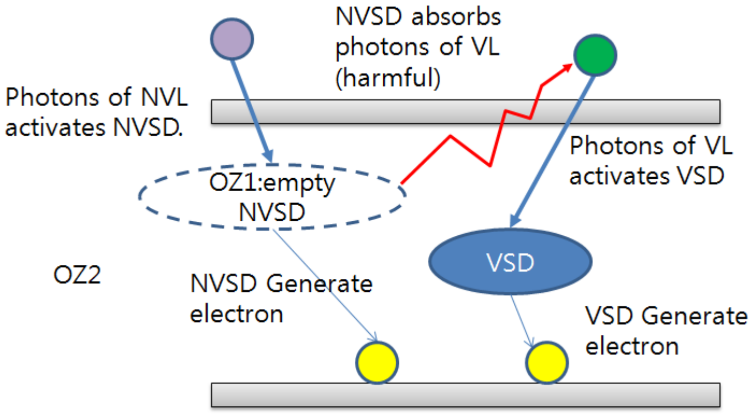
	substance	Field	etc
internal	● tool: space of absent NVSD ● product : photon of VL, photon of NVL		
external	● Electron ● hole ● Photon of solar light ● anode substrate ● anode electrode ● semiconductor nanoparticle layer (TiO2) ● electrolyte ● reducing agent (I) ● cathode electrode ● cathode substrate ● ion	● electric field ● electromagnetic field	● Manufacturing period ● Storage period ● Transport period
supersystem	● circuit ● moisture in the air ● rain ● air ● dust in the air ● bubble ● spacer ● glue	● heat generated by solar cell itself ● mechanical stress ● mechanical vibration ● gravity ● wind	● other energy system (ex. 2ndary battery) ● electric device which utilize energy of the DSSC

Selected X-element: space of absent NVSD(OZ1 itself)

IFR-1:X element is < space of absent NVSD >
The <space of absent NVSD> During the <operation time> Inside the <operation zone> without complication of a system and without harmful side effects, eliminates the harmful function of absent NVSD <not to convert photon of NVL to electron > With keeping ability of the absent NVSD provide < not to absorb photon of VL>

3.3. identify the physical contradiction for the macro-level

X-element: space of absent NVSD



Macro PhC: X element is < space of absent NVSD >
< space of absent NVSD(OZ1 by itself) > during the <Operational time>, should be < non-transparent > in order to perform <converting photon of NVL to electron> and should be <transparent> to perform <non-absorbing photon of VL>.

3.4. identify the physical contradiction for the micro-level

X-element: space of absent NVSD

Micro PhC: X element is < space of absent NVSD >
In the space of absent NVSD there should be < light keeping particles> in case of NVL illumination to provide <converting photon of NVL to electron> and there should be < light non-keeping particles> in case of VL illumination to provide <preventing absorption of photon of VL>.

3.5. Formulate IFR-2

X-element: space of absent NVSD

Micro PhC: X element is < space of absent NVSD >
<The molecules in the space of absent NVSD> Should <transform themselves into light keeping particles > in case of NVL illumination to provide <converting photon of NVL to electron> and should < transform themselves into light non-keeping particles > in case of VL illumination to provide <preventing absorption of photon of VL>.

3.6. Apply the inventive standards to resolve physical contradiction

Skipped

PART 4. MOBILIZING AND UTILIZING OF SUBSTANCE-FIELD RESOURCES (SFR)

4.1. Simulation with little creatures

X-element: space of absent NVSD (ref. step 3.5)

Micro PhC: X element is < space of absent NVSD >
<The molecules in the space of absent NVSD> Should <transform themselves into light keeping particles > in case of NVL illumination to provide <converting photon of NVL to electron> and should < transform themselves into light non-keeping particles > in case of VL illumination to provide <preventing absorption of photon of VL>.

Skipped

4.2. to take a "step back" from IFR

IFR-2

Micro PhC: X element is < space of absent NVSD >

<The molecules in the space of absent NVSD>

Should <transform themselves into light keeping particles > in case of NVL illumination to provide <converting photon of NVL to electron> and

should < transform themselves into light non-keeping particles > in case of VL illumination
to provide <preventing absorption of photon of VL>.

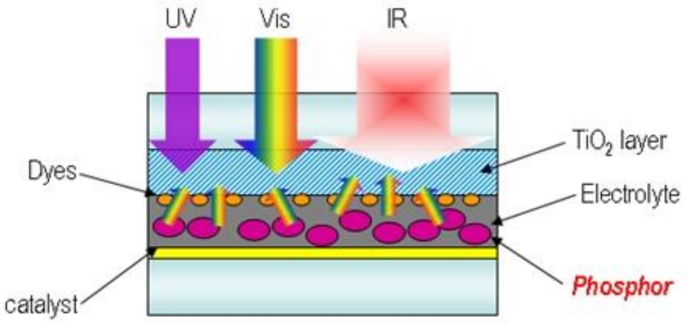
1 step back from IFR-2

The molecules in the space of the absent NVSD
Transforms themselves into photon of NVL keeping particles in case of NVL illumination to provide converting photon of NVL to electron and
Transforms themselves into photon of VL non-keeping particles in case of VL illumination to provide <preventing absorption of photon of VL>

There is a particle which keeps photon of NVL with releasing(=non-keeping) photon of VL, moreover this particle transform photon of NVL to photon of VL without absorbing photon of VL. This particle is called as ‘wavelength converting’ particle.

Imagining ‘a single imaginary particles’ which provides two different conflicting functions, the author could reduce the volume of patent search keywords(physical contradiction solving by transition to supersystem and micro-level su-field evolution)

Solution Idea. Adding light wavelength converting particles



Special particle which convert long wavelength light (i.e. infra red) to shorter one(i.e. visible light) is called as up-converting phosphor. Down-converting phosphor means special material which convert short wavelength light(i.e. UV) to longer one(i.e. visible light). Down-converting phosphor is very famous material in PDP and fluorescent lamp. By converting inappropriate range of light to visible light enhances light-to-energy conversion efficiency.

4.3. Using combination of substance resources

Skipped

4.4. Using "void"

Skipped

4.5. Using derived resources

Skipped

4.6. Using an electrical field

Skipped

4.7. Using a field and field-sensitive substance

Skipped but the solution idea has a strong relationship with this step.

PART 5. APPLYING THE KNOWLEDGE BASE

In many cases, Part 4 of ARIZ helps to achieve a solution concept, so it is possible to go to Part 7 of ARIZ. If no solution is achieved after step 4.7, Part 5 is recommended.

5.1. Applying the system of standard solutions for inventive problems

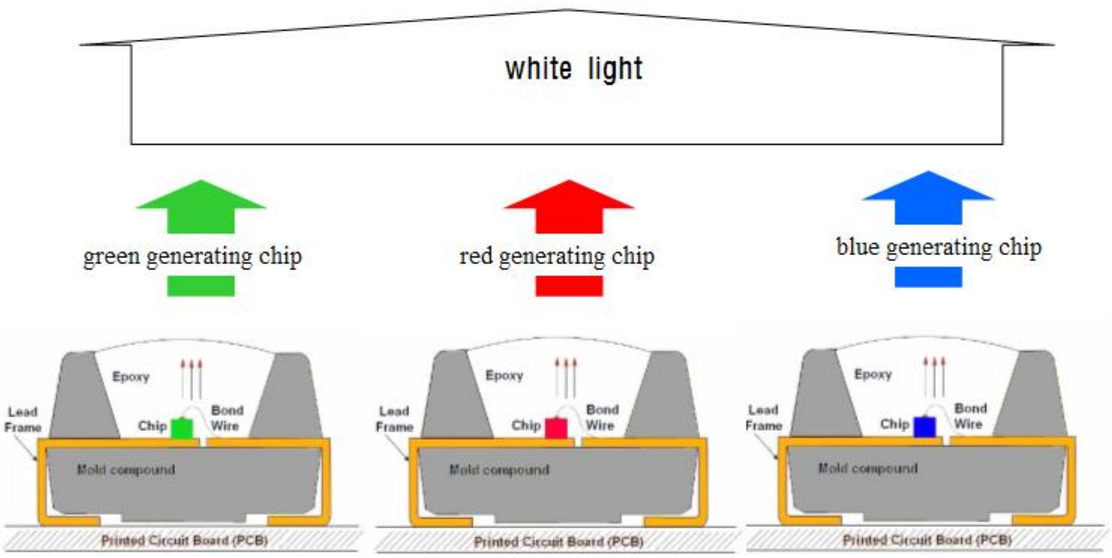
Consider possibility to solve problem (formulated as IFR-2, keeping in mind the SFRs considered in Part 4) by applying Inventive Standards.

NA

5.2. Applying the problems-analogous

Consider possibility to solve problem (formulated as IFR-2, keeping in mind the SFRs considered in Part 4) by applying solution concepts to non-standard problems, that have already been solved using ARIZ.

Analoguous problem: white color generation in LED system

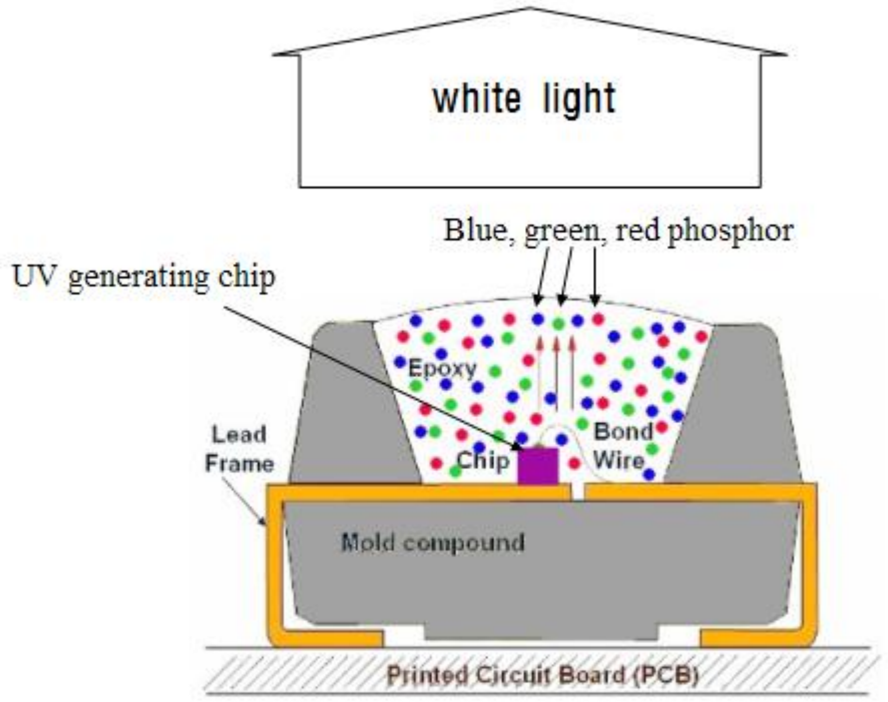


If three different LED semiconductor chip is prepared,

three colors can be generated to provide white light (good),

but manufacturing becomes very complex (bad).

Solution: UV chip + multi color phosphor



New art

A solution for above conflict is as following: instead of preparing three different color chips, single chip is prepared. This single chip generates UV or blue light. By adding multi-color phosphor in the epoxy cladding, each color phosphor generates three different colors. Mixing colors from phosphor, white color can be formulated.

Insight

LED system (electricity→light) has anti-function of DSSC system(light→electricity). The solution for the same type problem can be applied as anti-form: convert multi-color to single color by the help of phosphor. The Same conclusion of idea 3.

5.3. Applying the principles for resolving the physical contradictions

Consider possibility to resolve Physical contradiction using the typical transformations (see Table 2. Principles for resolving the Physical Contradictions)

5.4. Applying the pointer to physical effects and phenomena

skipped

PART 6. CHANGING OR SUBSTITUTING THE PROBLEM

6.1. Transition to the technical solution

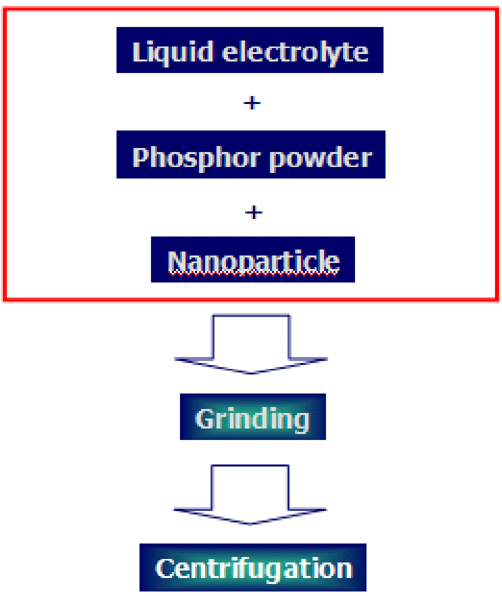
Idea.-03-1. Adding light wavelength converting particles-technical solution

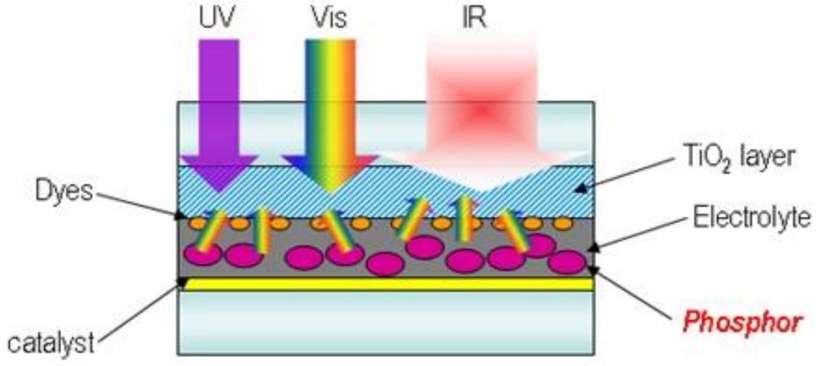
There are two types of phosphor in the world. One is increasing wavelength of the light, so called as down-converting phosphor. The other is decreasing wavelength of the light, which is called as up-converting phosphor. Both of them are well-known material in LED, PDP industry. There are lots of relavent patents of up-converting and/or down-converting phosphor for LED, PDP applications as following:

Knowledge 1) US Patent 6555958 - Phosphor for down converting ultraviolet light of LEDs to blue-green light ➔ $Ba_2 SiO_4 :Eu^{2+}$ phosphor, a $Ba_2 (Mg,Zn)Si_2O_7 :Eu^{2+}$ phosphor and/or a $Ba_2 Al_2 O_4 :Eu^{2+}$ phosphor etc.

Knowledge 2) US Patent 5541012 - Infrared-to-visible up-conversion material ➔ the infrared-to-visible up-conversion material of the present invention consists of Er and halogens, and optionally at least one element of Y, Pb, K, Ba, Na and Ag, or compounds thereof free from oxygen and thus can be prepared by mixing these materials in a predetermined proportion and then calcining the mixture.

Technical Solution mix up-conversion phosphor and down-conversion phosphor with electrolyte material and light scattering element(metal oxide particle) and introduce the mixture in the DSSC prepared by following procedure.





By confirm the effectiveness of above concept, preliminary experiment was executed. Experimental result is summarized in the following table.

	Efficiency (%)	impact
Neat electrolyte	5.40	NA
Phosphor only	6.19	14% up
Phosphor:metal oxide (5:5)	7.10	30% up

Comparing the neat electrolyte (light to electricity transition efficiency = 5.4% in experimental setup), phosphor contaied electrolytes showed enhanced value, 6.19%. Mixture of 50% Phosphor and 50% metal oxide particle (total weight ratio is the same as that of phosphor only electrolyte) showed more enhanced value 7.10%. Comparing to neat electrolyte, efficiency increased more than 15% withouth changing dye molecules. (it takes more than 3-5 research period to deliver new dye molecules,

6.2. Checking the problem formulation for combination of several problems

If the problem is not solved, check to see whether the description in Step 1.1 represents a combination of several problems. In this case, it is necessary to reformulate the step 1.1, by extracting separated problems. Those problems have to be solved one after another (often it is enough to solve just a main problem).

NA

6.3. Changing the problem

If the problem is not solved, change the problem by selecting another Technical Contradiction in step 1.4.

NA

6.4. Reformulation of mini-problem

If the problem is not solved, return to step 1.1 and reformulate the Mini-Problem with respect to the super-system. If necessary, repeat this reformulation process with the next several successive super-systems.

NA

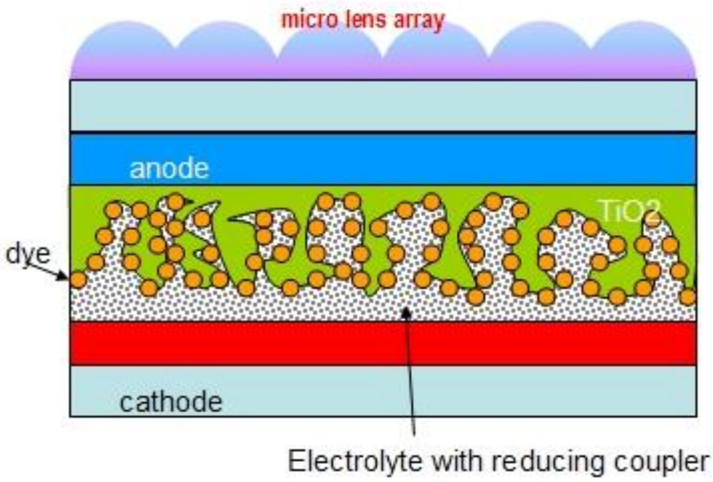
PART 7. ANALYZING THE METHOD OF RESOLVING THE PHYSICAL CONTRADICTION

7.1. Checking the concept of solution

Check the solution concept. Consider each introduced substance and field. Is it possible to apply available or derived SFRs instead of introducing the substances/fields? Can self-controlled substances be applied? Correct obtained technical solution accordingly

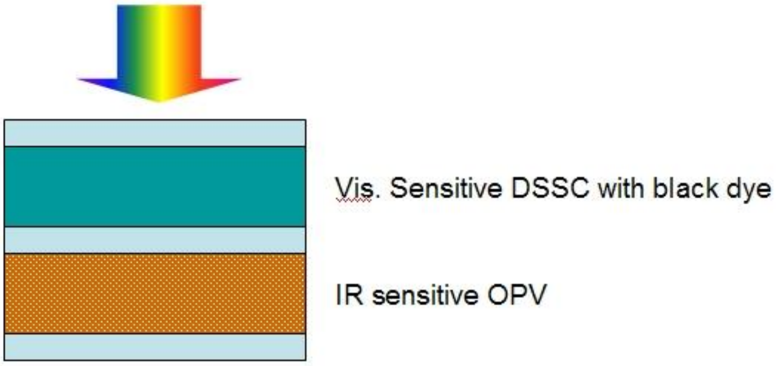
Control question (through 7.1)	Idea 1	Idea 2	Idea 3
Is it possible to apply available or derived SFRs instead of introducing the substances/fields?	yes	no	Yes
Can self-controlled substances be applied?	no	no	No

Idea-01. Micro lens array



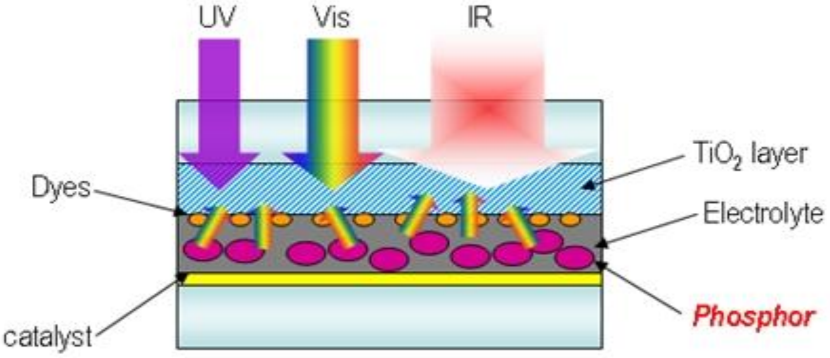
Add micro lens array outside of the cell. Micro lens array focuses sunlight more intensively. If light intensity increases, dye can convert borader wavelngth of light to electricity.

Idea-02. DSSC-OPV dueal photovoltaic cell



Combine conventional DSSC with organic polymer solar cell up and down. We can choose organic polymers with high responsibility to longer wavelength of sunlight (i.e. IR), which can penegrate the upper solar cell compose of black dye.

Idea-03. Adding light wavelength converting particles



Speical particle which convert long wavelength light(i.e. infra red) to shorter one(i.e. visible light) is called as up-converting phosphor. Down-converting phosphor means specail material which convert short wavelength light(i.e. UV) to longer one(i.e. visible light). Down-converting phosphor is very famous material in PDP and fluorescent lamp. By converting inappropriate range of light to visible light enhances light-to-energy conversion efficiency.

7.2. Preliminary estimation of the solution concept

Check the solution concept preliminary. If the solution concept does not comply with all of the above, return to step 1.1.

Control question (through 7.2.~7.4)	Idea 1	Idea 2	Idea 3
7.2.1. Does the solution concept provide the main requirement of IFR- 1 (the element without complication of a system...)?	no	No	no
7.2.2. Which Physical Contradiction (if any) is resolved by the solution concept?	no	no	yes
7.2.3. Does the new system contain	yes	No	Yes

at least one easily controlled element? Which element? How is it controlled?			
7.2.4. Does the solution concept found for "single-cycle" Problem Model fit the real conditions, multi-cycle conditions?	multi	multi	multi

7.3. Checking the priority of the solution concept through patent funds

Check the novelty of the solution concept via patent search.

Control question (through 7.2.~7.4)	Idea 1	Idea 2	Idea 3
7.3. Does the solution have novelty? (via patent search)	Neutral	Yes	Yes
Korean Patent Number			KP2008-0002336
US Patent Number	Under preparing filing		USP filing no. 12/201,582(2008.08.29)

7.4. Estimation of sub-problems to implement obtained solution concept

What sub-problems might appear during embodiment design of the new technical system?

Write down those possible sub-problems that might require invention, design, calculation, the overcoming of organizational challenges, etc.

Control question (through 7.2.~7.4)	Idea 1	Idea 2	Idea 3
7.4. What kind of sub-problems exist that might require invention, design, calculation, the overcoming of organizational challenges?	Attaching microlens array is well-known concept in photovoltaic industry. It is necessary to consider special structure/mfg process for microlens array.	New study is necessary for organic photo-voltaic material. It takes long time more than 3-4 years.	No more serious problems in realization

PART 8. APPLYING THE OBTAINED SOLUTION

8.1. Estimate of changes for super-system

Define how the super-system that includes the changed system should be changed.

Control question	Idea 1	Idea 2	Idea 3
8.1. How the super-system (that includes the changed system) should be changed?	Introduce micro lens array layer on the top of the DSSC. (out of the DSSC)	Stack new organic photovoltaic cell layer by layer	1) introduce phosphor in the electrolyte or apply phosphor out of the electrode or 2) Mfg process: phosphor should be mixed with electrolyte before electrolyte pouring into the space between two electrodes.

8.2. Find new application for obtained solution

Check whether the changed system or super-system can be applied in a new fashion.

Control question	Idea 1	Idea 2	Idea 3
8.2. Can the changed system or super-system be applied in a new fashion?	yes	Not now	Yes

8.3. Apply solution concept for other problems

Apply the solution concept to solving other problems:

- Formulate a general Solution Principle.

Corresponding Solution Principles: Inventive principle #13. Inversion, #12. Equipotentiality, #24. Intermediary

The backbone of solutions is "eliminate difference of incident light wavelenght with that of dye service wavelenght". Usual approach is insert two/multi dye to serve broad range of light, the solution of this project has changed 'light'.

- Change light instead of dye. → this concept can be classified as 'inversion'
- Change light wavelenght to fit that of dye → this concept can be classified as

'equipotentiality'

- Insert special agent to convert light wavelenght → this concept can be classivied as 'intermediary'.

- Consider direct application of the Solution Principle to other problem solving. : NA
- Consider applying the opposite Principle to other problems. : NA
- Create a morphological matrix (e.g. "parts location" versus "phase states of the product" or "applied fields" versus "phase states of the environment", etc.) that includes all possible modification of the solution concept, and consider every combination produced by the matrix. Consider the modifications to the Solution Principle that would result from changing the dimensions of the system or its main parts, imaging the result if dimensions were to approach zero or stretch toward infinity.

Solution Modification by Morphological box

Composition of the material → parts location	Neat phosphor	Phosphor + metal oxide	Phosphor + metal	Phosphor + other dye
Out of the cathode	Speical waveguide to convert broad wavelength range of light to visible range	NA	NA	NA
Inner part of the cathode	Speical waveguide to convert broad wavelength range of light to visible range + light scattering agent	Light scattering agent	NA	NA
Inside of the electrolyte (done)	done	done	Light recycle efficiency can be enhanced (to be considered)	NA
Inner side of the anode	Speical waveguide to convert broad wavelength range of light	Light scattering agent	NA	NA

	to visible range + light scattering agent			
Outer side of the anode	Speical waveguide to convert broad wavelength range of light to visible range	NA	NA	NA
Out of the whole cell	Speical mirror to convert broad wavelength range of light to visible range	NA	NA	NA

PART 9. ANALYZING THE PROBLEM SOLVING PROCESS

9.1. Compare proposed process and real

Compare the real process of problem solving with the theoretical one (that is, according to ARIZ). Write down all, if any, differences.

Resource analysis for analoguous system/problem was critical step of solution finding. SAIT TRIZ consultants have broad range of portfolio of project item and type. This resource comes from ealirer consulting report on LED system.

Critical hint for solution comes from conflict resolving example in anti system but from that of analoguous system. Referring problem solving result of analogous system and/or anti-system has many merits. Especially resource analysis and hard words on realization step can be minimized.

9.2. Compare obtained solution concept and knowledge from TRIZ

Compare the obtained solution concept to the information in the TRIZ knowledge base (Inventive Principles, Inventive Standards, and Pointer to Physical effects and phenomena).

If the knowledge base does not include a principle that applies to obtained solution concept, document this principle into preliminary knowledge base.

Corresponding Principles: Inventive principle #13. Inversion, #12. Equipotentiality, #24. Intermediary

The backbone of solutions is “eliminate difference of incident light wavelenght with that of dye service wavelenght”. Usual approach is insert two/multi dye to serve broad range of light, the solution of this project has changed ‘light’.

- Change light instead of dye. → this concept can be classified as ‘inversion’
- Change light wavelenght to fit that of dye → this concept can be classified as ‘equipotentiality’
    - Insert special agent to convert light wavelenght → this concept can be classivied as ‘intermediary’.

Supplementary

Related patent

KP2008-0002336 Gel type electrolyte for dye sensitized solar cell, preparing method for the same and solar cell employing the gel type electrolyte

➔Inventors: KANG MOONSUNG, LEE JIWON, Song MiJeong, SHIN BYONGCHEOL, KIM TAE GON

➔ USP filing no. 12/201,582(2008.08.29)

➔ UPS title: GEL TYPE ELECTROLYTE FOR DYE SENSITIZED SOLAR CELL, METHOD OF PREPARING THE SAME, AND SOLAR CELL INCLUDING THE GEL TYPE ELECTROLYTE

Bibliography

Image intensifier tube with IR up-conversion phosphor on the input side

(United States Patent 6624414)

The present invention comprises an enhanced vision device having an image intensifier tube (16) with an input end (17a) and an output end (17b) with an IR phosphor (19) deposited on the input end (17a) of the image intensifier tube (16). The IR phosphor (19) produces photons in response to light of wavelengths that would be undetectable by the image intensifier tube (16).

오류! 참조 원본을 찾을 수 없습니다.

UP-AND DOWN-CONVERSION AS NEW MEANS TO IMPROVE SOLAR CELL EFFICIENCIES

Thorsten Trupke1, Peter Würfel2 and Martin A. Green1

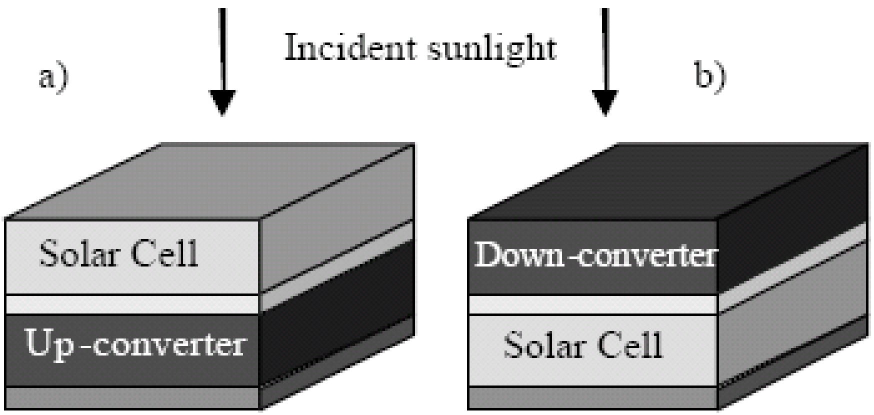


Figure 1. Device schematic of a) a solar cell in combination with an up-converter. b) a solar cell in combination with a down-converter. In both cases a reflector is located at the rear surface and the converter and the solar cell are electronically isolated from each other (possibly, but not necessarily by a separate insulating layer, as shown).

http://www.rmst.co.il/UP-AND%20DOWN-

CONVERSION%20AS%20NEW%20MEANS.pdf

APPLIED PHYSICS LETTERS **86**, 013505 (2005)

Application of $NaYF_4:Er^{3+}$ up-converting phosphors for enhanced near-infrared silicon solar cell response

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Erbium-doped sodium yttrium fluoride ($NaYF_4:Er^{3+}$) up-conversion phosphors were attached to the rear of a bifacial silicon solar cell to enhance its reponsivity in the near-infrared. The incident wavelength and light intensity were varied and the resulting short circuit current of the solar cell was measured. A close match between the spectral features of the external quantum efficiency and the phosphor absorption is consistent with the energy transfer up-conversion process. The peak external quantum efficiency of the silicon solar cell was measured to be $(2.5\pm0.2)\%$ under 5.1 mW laser excitation at 1523 nm, corresponding to an internal quantum efficiency of 3.8%. © *2005 American Institute of Physics*. [DOI: 10.1063/1.1844592]

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오류! 참조 원본을 찾을 수 없습니다.

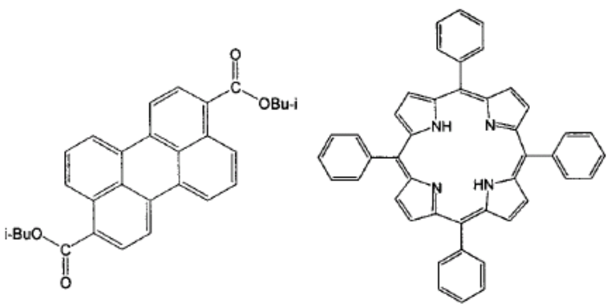

FIG. 2. Structures for 3,9-perylenedicarboxylic acid bis(2-methylpropyl) ester (PE) and tetraphenylporphyrin (TPP) phosphors.

Nanoporous TiO2 Coatings for Infrared Detectors

학술저널Journal of Sol-Gel Science and Technology출판사Springer NetherlandsISSN0928-0707 (Print) 1573-4846 (Online)권호정보Volume 26, Numbers 1-3 / 2003년 1월DOI10.1023/A:1020781901791페이지1029-1032Subject Collection화학, 재료공학SpringerLink Date2004년 10월 31일 일요일

Jun Shen, Tianhe Yang, Qinyuan Zhang, Jue Wang and Qinyao Zhang

In GaAs based infrared detectors, a considerable part of the incident light will be reflected at the surface, thus it decreases the detectors sensitivity considerably. In this paper, a TiO2 nanoporous coating was prepared successfully on the GaAs substrate by sol-gel method. The optical parameters of the coating were also controlled successfully.

It was proved that the coating could greatly improve the transmittance of the incident light, which agrees with the theoretical results quite well. In the 2.5–6.0 m waveband, the maximum transmittance of GaAs substrate is 56%, while the transmittance of the GaAs substrate coated with a nanostructured TiO2 coating is about 94%.
TiO2 coating - sol-gel process - infrared detector

Phosphor particle with antireflection coating
United States Patent 5910333 http://www.freepatentsonline.com/5910333.html
http://www.freepatentsonline.com/5910333.html

Improved luminous efficiency in plasma displays has been achieved by coating phosphor particles with a dielectric layer having a refractive index, for the ultraviolet light emitted by the plasma, that is intermediate between that of the phosphor and vacuum. When deposited in a thickness range between 0.5 and 5 microns, the layer causes the particle's reflectivity to be reduced because of reduced reflection at the vacuum-coating interface as well as internal reflection at the coating-vacuum interface. For coating thicknesses in the range of 0.1 to 0.5 microns, reflectivity is reduced because of interference between rays reflected at the vacuum-coating interface and the coating-phosphor interface. Several methods for forming these antireflection coatings are described. These include CVD, PVD, and suspension in molten dielectric followed by decanting onto either sticky or non-stick surfaces.

- Inventors:Lin, Chie-Ching (Taichung, TW); Tsai, Kuang-Lung (Hsinchu, TW); Ozawa, Lyuji (Hopewell Junction, NY, US) Application Number:090355
- Filing Date:06/04/1998
- Publication Date:06/08/1999
- Assignee:Industrial Technology Research Institute (Hsin-Chu, TW)

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JJAP Express Letter

Dye-Sensitized Solar Cells with Conversion Efficiency of 11.1%

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Dye-sensitized solar cells (DSCs) using titanium dioxide (TiO_2) electrodes with different haze were investigated. It was found that the incident photon to current efficiency (*IPCE*) of DSCs increases with increase in the haze of the TiO_2 electrodes, especially in the near infrared wavelength region. Conversion efficiency of 11.1%, measured by a public test center, was achieved using high haze TiO_2 electrodes. This indicates that raising the haze of TiO_2 electrodes is an effective technique for improvement of conversion efficiency. [DOI: 10.1143/JJAP.45.L638]

KEYWORDS: dye-sensitized solar cells, haze, internal resistance, TiO_2 electrode, IPCE

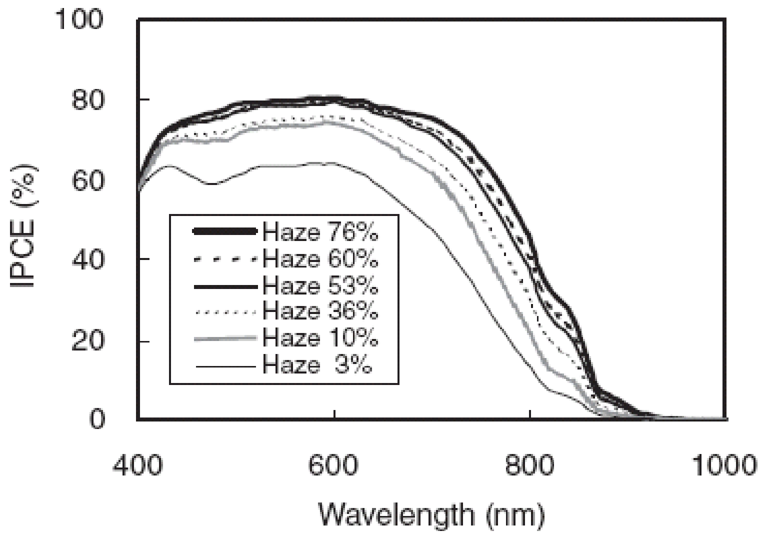

Fig. 1. Dependence of *IPCE* spectra on haze of TiO_2 electrodes. Haze in the figure was measured at 800 nm.

Haze was controlled by the addition of submicron particles (400 nm diameter) to the TiO2 electrodes. Haze, defined as the ratio of diffused transmittance to total optical transmittance, was measured at the wavelength of 800 nm using an integral sphere.

Acknowledgement

Special thanks to

Mr. KANG, Moon Sung

Dr. LEE, Ji Won

Mr.SHIN, Byong Cheol

AL: Final conclusion – I have impression, that the problem was solved without ARIZ and retroactively presented in form of ARIZ session. There are number of incorrect steps; developed ideas do not correlate with problem solving tools… I would recommend to present another problem really solved using ARIZ.