

## Natural and environment favourable Dye Used as Light Sensitizer in Dye Sensitized Solar Cell: A Critical Review

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### ABSTRACT

The flourishing of human culture to a great extent depends on safe vitality supply, and petroleum derivative has been filling in as the most solid vitality source. Be that as it may, as a non-sustainable power source, the depletion of petroleum derivative is normal and pending in this century. To talk, this risky, sustainable power source especially sun oriented vitality has intrigued much consideration since it straightforwardly remodels sun based vitality into electrical power leaving no natural impact. Previously, different photovoltaic gadgets like natural, inorganic, sun oriented cells were developed in grouping. Regardless of high change rate of silicon based sunlight based cells, the high module cost and complex generation process limited their application exclusively to astronautic and aerodynamic innovation. For household and other business applications, examine has been centred around natural sunlight based cells for their characteristic low module cost and simple manufacture. What's more, natural sun oriented cells have their lightweight and adaptability advantage over regular silicon based crystalline sun powered cells. Among all the natural sun based cells, colour sharpened sun based cells (DSSCs) are the most effective and effortlessly executed innovation. Here, this examination looks at the working rule, show improvement and future prospects for this novel innovation.

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### ARTICLE HISTORY

Received 10-09-2017

Revised 21-09-2017

Accepted 28-09-2017

Published 16-11-2017

### KEYWORDS

Dye sensitized solar cell,  
Sensitizer,  
Natural dye, Electrolytes,  
Performance

### Introduction

The petroleum products, for example, oil, flammable gas and coal are the fundamental wellsprings of vitality utilized everywhere throughout the creation. These foundations will be drained in future because of their simplicity of utilization in transport (aside from coal). In addition, the consuming of the petroleum derivatives produces a huge amount of CO<sub>2</sub> that contaminate the earth and furthermore change the climatic conditions. The advancement of sustainable wellsprings of vitality may lead in the direction of unspoiled green innovation aimed at a sound domain. Sun oriented, wind, hydro, biomass and geothermal are primary wellsprings of the sustainable power source, respectively of them has their benefits and faults additionally [1]. The sun powered vitality is the most key sustainable power foundation open today as it gives vitality to every living animal on earth through the procedure of photosynthesis for development and improvement. Be that as it may, it additionally changes geologically on the earth. A key favorable position of sunlight based vitality is that it canister be effectively saddled at local and business side by side. Sun powered vitality benefits singular proprietors as well as nature also. Sun powered radiation can be straightforwardly changed over into valuable warmth or power. Power is a type of vitality that can be made most effectively accessible. Consequently, researchers and architects today try to use sun powered radiation straightforwardly in creating power through financial gadgets [2].

A photovoltaic cell changes over sun powered radiations straightforwardly into electrical vitality. The original of the sunlight based cell comprises of monocrystalline silicon

sun powered cell as appeared in Fig. 1 [3]. Silicon is the best substantial utilized for manufacture of the crystalline sun based cells. It is bounteous material and safe for the ecological. These crystalline suns powered cells are created by Czochralski strategy. These sun oriented cells are comprised of silicon crackers and the proficiency of these suns powered cells is higher than other sunlight based cells. Be that as it may, their creation cost is high which styles the high general cost of the financially accessible crystalline sun based cell. The execution of the crystalline sun powered cell is influenced by the temperature and in this way influences the proficiency of this device [4].

The thin film sun based cells are alluded to the subsequent era of the sun oriented cell. These are fundamentally formless silicon sun oriented cell. The sun powered materials utilized as a part of thin movies are in the powder shape that influences (CdTe), To copper indium gallium selenide (CIGS) and formless silicon (a-Si) are the different classifications of thin film sun based cells [5].

The cell more adaptable and lighter in weight. The construction of the thin film sunlight based cell is appeared in Fig. 2. The fundamental snag before the thin film sun powered cell is the less effectiveness. Cadmium telluride The era of color sharpened sunlight based cell (DSSC) is measured as the third era of the sun oriented cell. The effectiveness of these sunlight based cells is more than thin movies while less when contrasted with the crystalline sun based cells. The principal color sharpened sun oriented cell was created by O'Regan and Gratzel in 1991 [6]. The construction of the DSSC comprises of a TiO<sub>2</sub> layer (semiconductor) covered photograph anode terminal, a

counter terminal utilized as a cathode, a sensitizer and an electrolyte as appeared in Fig. 3 [7- 8].

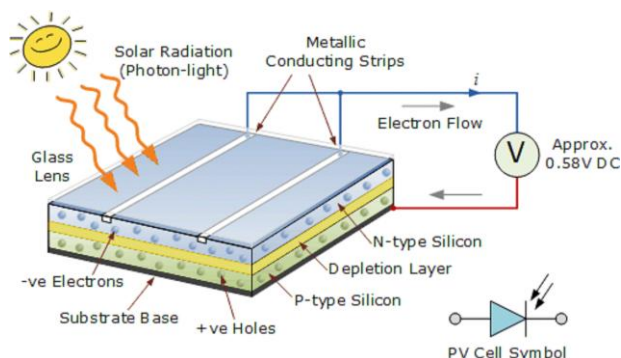


Figure 1: The construction of monocrystalline solar cell

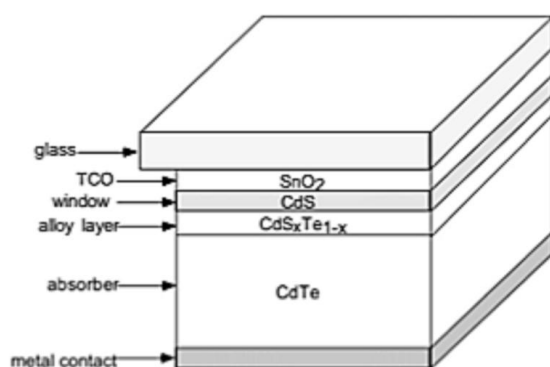


Figure 2: The assembly of thin film solar cell

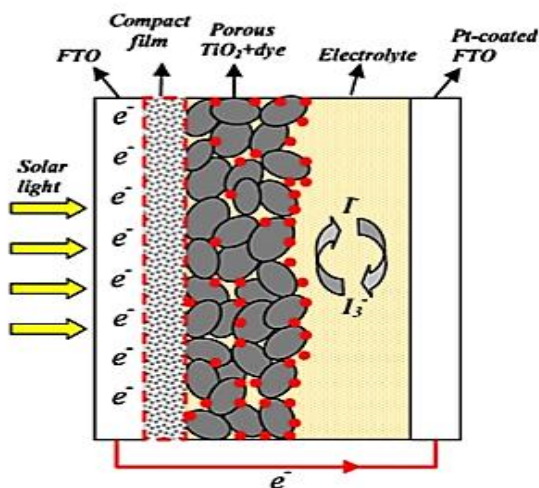


Figure 3: Assembly of DSSC

Escalated look into has been done in the advancement of manufactured/regular colors for a sunlight based cell in most recent two decades yet there is an absence of aggregated data in this field. In this correspondence, the progression in the third era of the sunlight based cell is talked about with the point by point correlation of engineered and characteristic color sun powered cells. An assortment of sensitizer is talked about being a key parameter that influences the execution of DSSC. This article additionally secured the progression of innovation in characteristic colors. Different parameters have been proposed to improve cell proficiency in this audit. At last,

the possible investigation zone of DSSC is additionally prearranged for upcoming improvement. This survey would be exceptionally productive to the specialist, investigator and academican of this region. Late advancements in NDSSC and their execution with the upcoming extension are examined in this composition.

### Performance parameters of DSSCs

The presentation of dye solar cell is commonly appraised by the altered limitations of the cell such as open circuit voltage, short circuit current, fill factor, maximum voltage and maximum current of the cell. Respectively parameter is deliberated in detail as follows [9].

#### Open circuit voltage ( $V_{oc}$ )

The open-circuit voltage,  $V_{oc}$ , is the maximum voltage available from a solar cell, and this occurs at zero current. The open-circuit voltage resembles to the quantity of forward bias on the solar cell due to the bias of the solar cell junction with the light-produced current [10].

#### Short circuit current ( $I_{sc}$ )

The short-circuit current is the current concluded the solar cell when the voltage crosswise the solar cell is zero (i.e., when the solar cell is short circuited).

#### Fill factor ( $FF$ )

The fill factor ( $FF$ ) as clear from equation iii is the ratio of the maximum power output ( $P_{max}$ ) to the product of short circuit photocurrent ( $I_{sc}$ ) and open circuit voltage ( $V_{oc}$ )

$$FF = \frac{P_{max}}{I_{sc} \cdot V_{oc}} = \frac{I_{mpp} \cdot V_{mpp}}{I_{sc} \cdot V_{oc}}$$

#### Power conversion efficiency ( $\eta$ )

The energy conversion efficiency ( $\eta$ ) is the ratio of  $P_{max}$  to the incident radiation power ( $P_{in}$ ) on the solar cell superficial

$$\eta = \frac{P_{max}}{P_{in}} = \frac{I_{sc} \cdot V_{oc} \cdot FF}{P_{in}}$$

where,

$V_{oc}$ – Open-circuit voltage,

$I_{sc}$ – Short-circuit current,

$V_{mpp}$ – Maximum value of voltage,

$I_{mpp}$ – Maximum value of current,

$FF$ – Fill factor

$P_{max}$ – Maximum Power

$P_{in}$ – Input Power

$\eta$  – Efficiency of the cell

### Comparison between synthetic and natural dye

Manufactured and regular sensitizer can be looked at in view of different parameters, for example, cost of cell, condition issues, strength issue, most extreme absorbance, proficiency of the DSSC, accessibility of the assets and creation technique the cell as talked about in Table 1.

The metal compound sensitizer integrated from compound manufacture strategy although regular sensitizers are set up from blossoms, leaves and roots and so forth utilizing straightforward ethanol, methanol or water extraction procedure hence less expensive when contrasted with engineered colors.

**Table 1:** Comparisons between synthetic and natural dye

S.No.	Parameter	Sensitizer	
		Synthetic dye	Natural dye
1	Cost	Complex material formed by different chemical reaction therefore results in high cost	Locally available resource, extracted from plants, flowers, fruits and roots. This results low cost
2	Environmental Effects	Bad effects on the environmental due to its chemical nature	Less effects on the environmental due being its natural occurrence
3	Stability	Slowly degrade in the presence of sunlight therefore long life of DSSC	Degradation of natural dye in the presence of sunlight radiation results stability problems in DSSC
4	Absorption on Solar Spectrum	N3 dye has absorption up to 800 nm	The dyes have shown absorption in broad range of the visible region (400–700 nm) of the solar spectrum
5	Efficiency	DSSC based on synthetic dyes have shown higher efficiency as compared to NDSSC	The efficiency of NDSSC is low due to degradation of natural dye
6	Availability	Noble material thus no long-term availability	Natural thus 100% availability
7	Fabrication Process	Requires multi procedures, which involves a variety of solvents and time-consuming purification processes, making synthetic dye production very expensive	Requires simple and direct chemical procedures, making natural dye production less expensive

The common colors are natural neighborly. Notwithstanding, dependability issue comes about less proficiency. The ruthenium buildings have demonstrated most extreme absorbance in unmistakable area. In this manner, these sensitizers give incredible electrical yield than normal colors. Then again, characteristic event and nontoxic impact are the advantages of regular colors [11–20].

### Working of DSSC

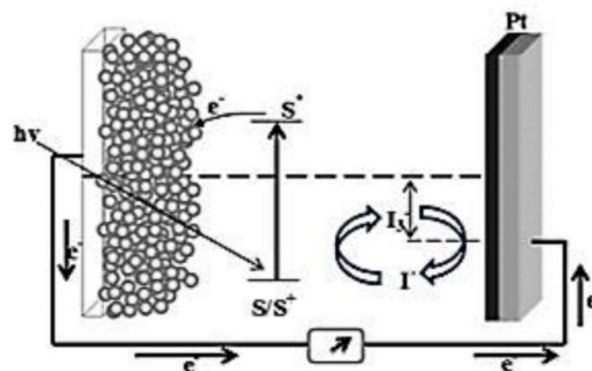
At the point when the daylight assaults on the exterior of the DSSC, the color particles gather photons and deliver the energized electrons. The sensitizer infuses energized electron into the conduction band of nanoporous semiconductor film. The color atoms that lost electrons are then oxidized. The infused electron goes through the Nano-permeable  $\text{TiO}_2$  thin film toward the straightforward conductive anode (working terminal), and compasses to a heap where work is performed and conveyed as electrical vitality. The electrons now go back through an outside load and achieve the counter cathode and in this way total the entire circuit [21].

A color sharpened sun oriented cell comprises of two terminals, an anode or photograph or working anode and a cathode or counter terminal, for the most part made up of uncommonly planned straightforward conductive glass covered with straightforward conductive oxide i.e. indium or fluorine doped tin oxide. The transmittance of the indium doped tin oxide (ITO) is higher than that of the fluorine doped tin oxide (FTO) while the sheet resistance of the FTO is not as much as that of the ITO. The sheet resistance of the ITO increments radically on raising the temperature amid the sintering procedure then again, the sheet resistance of the FTO is staying identical amid the sintering procedure [22].

The working cathode is covered with the  $\text{TiO}_2$  layer encompassing by a sharpening color. The covering of titanium dioxide layer on working cathode make it permeable subsequently more daylight can infiltrate the semiconductor layer. Fundamentally, the  $\text{TiO}_2$  semiconductor substantial is not delicate for noticeable light thusly, a sharpening material is obligatory to upgrade

its unmistakable light absorbance [23]. The  $\text{ZnO}$  has comparable band hole, transport properties and electron infusion productivity, is an option of the titanium dioxide. Be that as it may, by utilizing diverse colors and electrolytes, it is hard to watch the conduct of  $\text{ZnO}$  [24].

The capacity of the counter cathode is to finished the inside electrical circuit by infusing electrons into the electrolyte as appeared in Fig. 4. The working anode and counter terminal are isolated from an electrolyte arrangement. The electrolyte encourages the charge transportation among these terminals [25].

**Figure 4:** Working of dye solar cell

### Constructional parameters of the DSSC

The substrate, semiconductor, sensitizer, electrolyte and counter cathode are the numerous constructional parameters that implementation the presentation of the dye solar cell. These are deliberated as follows:

#### Substrate

The maximum widely recognized substrate utilized for color sun powered cell is straightforward conductive oxide (TCO). The high effectiveness and high straightforwardness of the TCO settles on it a typical decision for the analysts. The metal sheets and plastic thwart are the options of the TCOs those are good for move to move strategy hence can make adaptable sunlight based cells fig.5. The metal substrates are not straightforward [26–27] hence

influences the execution of the cell. Likewise, the plastic thwart demonstrates the soundness issues. Be that as it may, TCO covered glass substrates are best for sun oriented cells.

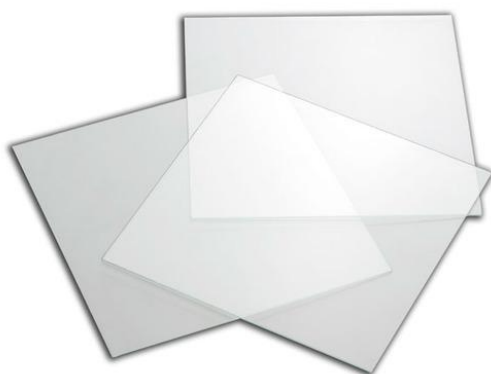


Figure 5: FTO glass substrate

### Semiconductor

A semiconductor ought to have high surface range, high permeable and its trademark should coordinate the sensitizer subsequently expands the efficiency of the DSSC [28,29].  $\text{TiO}_2$  is the principle decision for the creation of color sunlight based cell as examined beforehand fig.6. The zinc oxide, tin oxide,  $\text{MgO}$ ,  $\text{Al}_2\text{O}_3$  is likewise appropriate semiconductors for color sunlight.

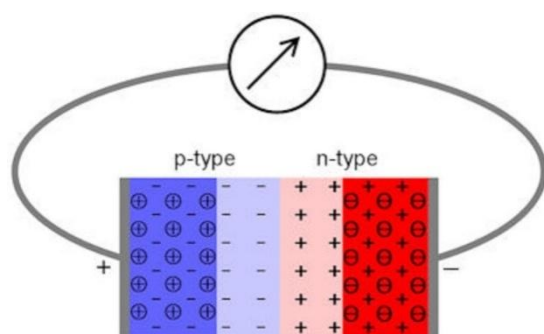


Figure 6: Semiconductor for solar cell

### Sensitizer

The sensitizer retains sun powered radiations consequently improves the conductivity of the cell. A sensitizer ought to have carboxyl and hydroxyl gather that is required for good authoritative with the semiconductor, demonstrates most extreme absorbance from obvious to close infra-red district of sun powered radiations and not debase quick [31]. The metal complex sensitizer, metal free natural sensitizer and normal sensitizer are the three sorts of sensitizers. The metal complex sensitizers are exorbitant, uncommon and harmful in nature [32]. In spite of the fact that, indicated most noteworthy efficiency of the cell [33]. The metal free natural sensitizers have indicated less efficiency and confounded manufactured course are the essential issues related with these colors. The regular colors separated from flowers, organic products, plants, leaves and roots in the shape betalains, carotenoids, anthocyanins and chlorophyll shades [34,35]. The efficiency of regular color sharpened sunlight based cell (NDSSC) is less when contrasted with the metal intricate

and metal free natural sensitizer however utilizes straightforward extraction procedure and more ecological amicable and hence winds up plainly most recent research in the area of DSSC.



Figure 7: Natural dye for solar cell

### Electrolyte

The fundamental capacity of the electrolyte is to recovers the color. The electrolyte ought to have low consistency, insignificant vapor weight, high breaking point and high dielectric possessions [36]. For the most part three sorts of electrolytes are utilized specifically,  $\text{I}^-/\text{I}_3^-$  inorganic solvents, inorganic ionic fluids and strong electrolyte.  $\text{I}^-/\text{I}_3^-$  (iodine) electrolyte is the most widely recognized electrolyte that give high efficiency of DSSC which is appeared in Fig.6 [37]. In any case, it has constrained long haul soundness. Same issue emerges if there should arise an occurrence of inorganic ionic electrolyte, its efficiency diminishes after quite a while. Spillage free nature of strong electrolyte gives a great trademark among every one of the electrolytes [38]. Copper iodide is the finest p-sort strong material obligating high band hole, straightforward and more affordable fig.8 [38]. In spite of the fact that causes shakiness issues.

### Electrolyte



Figure 8: Electrolyte for solar cell

### Counter Electrode

The counter anode recovers the electrolyte. The platinum is unsurpassed impetus material for counter terminal outcomes high efficiency of the cell albeit high cost expands general cost of the cell. Then again, carbon is less expensive and plentiful material utilized as synergist [39-41].

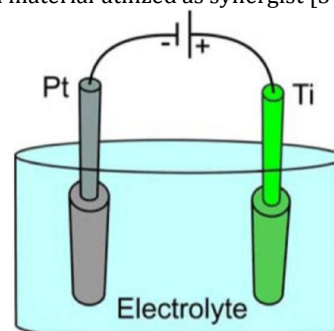


Figure 9: Counter electrode



## Background of natural resources for NDSSC

Kashyout et al. created zinc films utilizing colloidal strategy from zinc oxide. It has been watched that the grain measure was conversely corresponding to the diffusive speed. It diminished from 150 nm to 50 nm by expanding radial speed from 6,000 to 15,000 rpm. The cell was sharpened from manufactured and common color both. Regular color has indicated high open circuit voltage of 0.6 V [42].

Iha and Polo extricate blue anthocyanin from different organic products for making normal sensitizer for a color sun powered cell. The jaboticaba demonstrated a present thickness, fill factor, open circuit voltage and greatest energy of 9.0 mA/cm<sup>2</sup>, 0.54, 0.59 and 1.9 mW/cm<sup>2</sup>, separately. While Calafate utilized as a sensitizer, the present thickness, fill factor (FF), open circuit voltage and greatest power were watched not as much as that of jaboticaba and these were 6.2 mA/cm<sup>2</sup>, 0.36, 0.47 and 1.1 mW/cm<sup>2</sup> individually [43]. Wu et al. created color sun oriented cell utilizing normal colors as sensitizer. The regular colors removed from dark rice, capsicum, Erythrina variegata blossom, Rosa xanthina, and kelp. The blue rice separates and gives best outcomes among all colors. The present thickness, open circuit voltage, fill factor and energy of DSSC utilizing blue rice removes were found as 1.142 mA, 551 mV, 0.52 and 327  $\mu$ W separately [44]. Sirimanne et al. removed juice from pomegranate organic products containing cyanine (flavylum) used as regular color sensitizer. The strong state TiO<sub>2</sub> (n sort semiconductor)/pomegranate piment (regular color)/CuI (p sort) sun based cell has indicated greatest absorbance at the wavelength of 570 nm that made most astounding proficiency of the cell as looked at other normal shades (cyanidin, tannin, santalin and vitamin C) [45].

Kumara et al. utilized shisonin, chlorophyll and blender of the two colors extricated from shiso leaves utilized as the color for a strong state DSSC utilizing p-CuI as opening conductor. The most noteworthy productivity accomplished by mixed drink color (shisonin and chlorophyll) was 1.31%. The shisonin and chlorophyll based DSSC demonstrated effectiveness of 1.01% and 0.59% separately. The open circuit voltage (mV), current thickness (mA/cm<sup>2</sup>), FF and proficiency (%) utilizing shisonin are 550, 0.59, 0.51 and 1.01 while with chlorophyll are 432, 3.52, 0.39 and 0.59. also, the blended color sun oriented cell indicated most noteworthy effectiveness as 1.31% [46].

Yamazaki et al. utilized carotenoid, crocetin and crocin as common sensitizer. It was watched that carotenoid and crocetin that contain carboxylic gathering could adsorb adequately on semiconductor accordingly coming about best execution of the phone. While crocin indicated less productivity because of the nonattendance of carboxylic group [47]. Wongcharee et al. removed color from rosella, blue pea and blended concentrate in water utilized as a dissolvable at 100 °C. The most elevated effectiveness of 0.37% was accomplished by rosella separate. The color sunlight based cell in light of blue pea and blended colors demonstrated 0.05% and 0.15% productivity separately. It has been discovered that while removing temperature was diminished to 50 °C and pH of the color was changed from 3.2 to 1.0 the effectiveness utilizing rosella has been enhanced and recorded as 0.70%. In this way, the

temperature and pH estimation of dissolvable influences cell execution [48].

Senadeera et al. extricated distinctive characteristic shades from tropical blossoms (*Sesbania grandiflora* red, *hibiscus rosainensis*, *hibiscus surattensis*, *Nerium oleander*, *Ixoramacrothyrsa* and *rhododendron arboretum zeylanicum*). The general proficiency differed from 0.2% to 1.1% with current densities running from 1.1 to 5.4 mA/cm<sup>2</sup>. *Hibiscus surattensis* demonstrated most elevated productivity of 1.14% [49]. Teoh et al. utilized gold nano-particles on working anode (TiO<sub>2</sub>), where water based electrolyte with Ce<sup>4+</sup>/3<sup>+</sup> was utilized and sharpened with concentrates of *rhoeospathacea* stream. [50]. McHale et al. manufactured characteristic color sun oriented cells utilizing betalain shades from red beet roots. The present thickness and open circuit voltage saw as 2.42 mA/cm<sup>2</sup> and 0.44 V separately. The betanin (I), betanidin (II), indicaxanthin and betalamin subordinates of betanin shades demonstrated greatest absorbance at wavelength of 535 nm, 542 nm, 482 nm and 424 nm respectively [51-56].

## Conclusions

This article outlines execution affecting parameters of the DSSC with basic audit. The high cost, complex union, honorable material and ecological threatening are different deterrents for metal complex sensitizers for color sun based cell. Then again, less expensive, straightforward extractable, bounteous and ecological well-disposed are the key purposes of normal color sensitizers. The efficiency and dependability of DSSC utilizing metal buildings is impressively higher than regular colors. This supports additionally examine on common colors to upgrade strength and efficiency of DSSC. Different regular colors can be joined in suitable extents to shape "mixed drink color sensitizer". This may be another option to build the band ingestion and accordingly to enhance efficiency of the DSSC. In this manner, financially practical choice is mixed drink regular colour. The blending of different colors display in the normal colors can likewise give better outcomes. The sensitizer is the core of color sunlight based cell and ought not debase quick which leads in expanding the life of the cell. It ought to have high annihilation coefficient. This audit would be exceptionally useful to the analysts and researchers who are chipping away at expanding the efficiency of DSSC.

## Acknowledgement

The authors would like to thank Nanotechnology and Renewable Energy Research Laboratory, Jamia Millia Islamia, Central University, New Delhi, India and Material Research Laboratory, Sharda University, Greater Noida (U.P.), India.

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