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Non-enzymatic electrochemical sensing of dopamine from COVID-19 quarantine person

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HIGHLIGHTS
• ZIF-67 integrated with PEDOT has been successfully synthesized through solvothermal approach.
• The fabricated ZIF-67/PEDOT electrode shows a significant sensing and selective performance towards DA detection.
• The developed electrode was successfully applied to monitor DA from COVID-19 quarantined person blood.
• The developed sensor also shows reliability in terms of reproducibility, reusability, and stability as well.

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ABSTRACT
The worldwide outbreak of COVID-19 pandemic, is not only a great threat to the victim life but it is leaving invisible devastating negative affect on mental health of quarantined individual because of isolation, depression, bereavement, and loss of income. Therefore, the precise monitoring catecholamine neurotransmitters specifically of dopamine (DA) is of great importance to assess the mental health. Thus, herein we have synthesized Co-based zeolitic imidazolate framework (ZIF-67) through solvothermal method for precise monitoring of DA. To facilitate the fast transportation of ions, highly conductive polymer, poly(3,4-ethylenedioxythiophene; PEDOT) has been integrated on the surface of ZIF-67 which not only provides the smooth pathway for ions/electrons transportation but also saves the electrode from pulverization. The fabricated ZIF-67/PEDOT electrode shows a significant sensing performance towards DA detection in terms of short diffusion pathways by exposing more active sites, over good linear range (15–240 μM) and a low detection limit of (0.04 μM) even in the coexistence of the potentially interfering molecules. The developed ZIF-67/PEDOT sensor was successfully employed for sensitive and selective monitoring of DA from COVID-19 quarantined person blood, thus suggesting reliability of the developed electrode.

1. Introduction
Good mental health is fundamental to overall health and well-being, but the emergence of COVID-19 pandemic has become an unprecedented threat to our population in terms of economic downturn and health. However, it not only affect the victim life but also disrupt or halt the mental abilities of the quarantined person and may lead to several neurological complications such as delirium, agitation, insomnia, depression, hypertension, anxiety and stroke [1]. According to a WHO survey (conducted in August 2020, on mental health of 130 countries) COVID-19 has left a devastating impact on mental health [2]. Therefore, the research on brain science specifically on neurotransmitters level...
have attracted great interest. Dopamine (DA) is a prevalent catecholamine neurotransmitter present in hypothalamus, adrenal glands, and ventral tegmental area [3] plays a vital role in motor control, cardiovascular, renal, human metabolism, motivation, cognitive function and hormonal systems [4]. The typical concentration of DA in human body is 10–1000 nM [3], and any fluctuation in this range may lead to several diseases such as Parkinson’s [6], hypertension, Schizophrenia, anxiety, depression and even attention deficit hyperactivity disorder [7]. Therefore, early identification and prevention of these neurological disorders at trace level from real biological sample is very important to maintain human health [8,9]. Thus, the development of DA sensor with excellent properties like high selectivity and sensitivity is highly demanded.

Several analytical methods have been used for the detection of DA such as chemiluminescence [3], spectrophotometry [10], high-performance liquid chromatography [11], capillary electrophoresis [12], calorimetry [13], mass spectrometry [14–17]. Although these techniques are highly sensitive, but these require expensive instrumentation, complicated pretreatment, require large volume of solvents and chemicals that possibly cause environmental pollution and are time-consuming [18,19]. Since DA is an electroactive compound, this makes it easily measurable by facile electrochemical technique. The electrochemical method has been widely explored for the monitoring of DA due to their outstanding properties such as excellent sensitivity, facile operation, high selectivity, quick detection, low-cost, environmentally friendly and miniaturization ability [5]. Using electrochemical methods, several materials including graphene based materials [15], carbon nanotubes [20] and metal oxides such as NiO, CoO, TiO, CuO [4,21,22] have been extensively applied in electrochemical sensing of DA with high accuracy. Even though these materials have various key properties such as large surface area with flexible pore size, higher thermal and electrical conductance, increased electron mobility, higher strength and elasticity, and excellent selectivity [15,20,23–26]. But still there is need to construct such materials that have much higher surface area, more surface stability and possess more exposed catalytic active sites with homogenous porosity.

Recently, metal organic frameworks (MOFs) emerged as the rising stars and formed by combination of metal ions with organic linker. MOFs have attracted great attention owing to their remarkable properties such as crystalline structure, chemical tenability, tunable pore size, ultra-high specific surface area, outstanding thermal stability, and increased porosity [27,28]. Until now, more than 20,000 types of MOFs have been established with potential applications [29]. However, MOFs utilization for electrode modification to identify biomolecules has not been studied widely and a few reports are accessible on analysis of electrochemical performance of MOFs owing to their low conductivity, instability in aqueous media and less catalytic activity [27,28]. To overcome this limitation, MOFs have been integrated with several other materials such as gold, silver nanoparticles, multiwall carbon nanotubes and conducting polymers to achieve fast transportation of ions and high stability [30–32]. Among various conducting polymers, Poly (3,4-ethylenedioxythiophene) (PEDOT) possess higher electrical conductivity and flexibility [33]. Thus, MOF composite with PEDOT, endowed with higher electrical conductivity, large surface area and redox activity can facilitate development of highly stable and efficient electrochemical sensor.

Herein, we fabricated novel PEDOT wrapped ZIF-67 (ZIF-67/PEDOT) electrode via a simple and eco-friendly approach for the electrochemical detection of DA. The fabricated ZIF-67/PEDOT was coated at the surface of low-cost lead pencil graphite electrode (LP). Addition of PEDOT not only enhance the conductivity or charge transportation at the surface of ZIF-67, whereas it also maintains its features including large surface area and stability. The designed ZIF-67/PEDOT composite shows remarkable electrochemical sensing and selective features, thus enabling it to apply for real time monitoring of DA from blood of COVID-19 quarantine person and to the best of our knowledge this research work is the first of its kind to report such application.

2. Experimental section

2.1. Chemicals and reagents

All the chemicals were of analytical grade. Dopamine hydrochloride, cobalt nitrate hexahydrate (Co(NO$_3$)$_2$·6H$_2$O), methanol, ethanol, 2-methylimidazole (2-MIm), ascorbic acid (AA), glucose (Glu), uric acid (UA), l-cysteine (L-Cys), salbutamol (Sal), Poly 3,4-ethylenedioxythiophene (PEDOT) and potassium ferrocyanide were purchased from Sigma Aldrich and used without further purification. Phosphate buffered saline tablets (PBS) were purchased from innovative chemical products. Distilled water was used for the preparation of all solutions in experiment. Details of instruments used has been provided in the supporting information.

2.2. Synthesis of ZIF-67

The ZIF-67 was prepared in an ambient condition according to earlier reported procedure [34]. First, 1.746 g of Co(NO$_3$)$_2$·6H$_2$O and 1.97 g of 2-methylimidazole were dissolved separately in mixed solution of 20 mL ethanol and 20 mL methanol, respectively. Both solutions were mixed and stirred at room temperature for 6 h, until homogeneous solution was formed. Then, it was kept at room temperature for 20 h. After the given time, purple precipitate was obtained through centrifugation and washed with water and ethanol several times. Finally, the precipitate was subjected to drying in an oven at 80 °C for 24 h.

2.3. Synthesis of ZIF-67/PEDOT composite

In a typical manner, 1 mL of PEDOT was dispersed in 20 mL of deionized (DI) water under vigorously sonication treatment for 30 min. After that 1.746 g of Co(NO$_3$)$_2$·6H$_2$O and 1.97 g of 2-methylimidazole were added separately in solution mixture of 20 mL ethanol and 20 mL methanol, respectively. Now these two separately prepared solutions (such as Co(NO$_3$)$_2$·6H$_2$O in ethanol and 2-methylimidazole in methanol) were added to the above PEDOT-linker mixture and these contents were stirred for 6 h at room temperature (RT, 25 ± 2 °C). Then, the resulting ZIF-67/PEDOT composite was collected by centrifuging (10,000 rpm, 20 min), washed with DI water and methanol subsequently for several times, and finally dried in vacuum-oven at 80 °C for 24 h.

2.4. Fabrication of ZIF-67/PEDOT coated LP electrode

Electrochemical studies were investigated using a three-electrode system which is consisted of Ag/AgCl electrode as reference electrode, a platinum wire as counter electrode and LP electrode (LP: 0.5 mm diameter and 40 mm length) modified with ZIF-67/PEDOT material as a working electrode [35]. The LP electrode was modified by simple dip-coating method. First, a slurry was prepared by mixing 2 mg of synthesized material (in 1 mL distilled water and subjected to sonication for 30 min then 1 mL of PEDOT was mixed in it and sonicated again to obtain a homogeneous mixture. LP electrode was dipped in this solution mixture for 24 h and dried at room temperature for 48 h (Scheme 1). Finally, the prepared ZIF-67/PEDOT electrode was used for electrochemical applications. Moreover, same method was applied for the fabrication of ZIF-67 electrode.

3. Results and discussion

3.1. Morphological and compositional analysis of synthesized materials

Morphological and compositional characteristics of ZIF-67 nanocomposite was assessed using Fourier transformation infrared spectroscopy (FTIR), Scanning electron microscope (SEM) and X-rays
diffraction (XRD) analysis. SEM analysis was performed for determining the morphology of ZIF-67 and ZIF-67/PEDOT nanocomposite. SEM images indicates the formations ZIF-67 with nano crystalline polyhedral shape (Fig. 1A). The average diameter of the nano polyhedral crystals was in the range of 300–450 nm. Similarly, ZIF-67/PEDOT nano-composite also shows polyhedral shape morphology with size in the range of 300–400 nm (Fig. 1B and C). However, some aggregation and distortion in shape is also observed in case of ZIF-67/PEDOT nano-composite, that could be due the incorporation of PEDOT.

X-ray diffraction (XRD) was next used to measure the phase purity and crystallinity of prepared ZIF-67 and ZIF-67/PEDOT nanocomposite (Fig. 1D). The more prominent reflections at 20 value of 7.02, 10.5, 13.0, 14.4, 16.9, 18.8 and 26.4° corresponds to (011), (002), (112), (022), (013), (222) and (002) planes of ZIF-67 and matching well with the reported literature [35]. Similarly, well-defined peaks matching well with the ZIF-67 pattern also appears in case of ZIF-67/PEDOT, however, an extra peak appears at 26. 3° confirming the presence of PEDOT.

FTIR analysis were performed to confirm the functional groups present in ZIF-67 and ZIF-67/PEDOT as shown in Fig. 2A. The peaks were mainly attributed to ligand 2-methylimidazole [35]. The peaks obtained in 600–1500 cm⁻¹ range were attributed to the bending and stretching of imidazole group. A minor peak at 1476 cm⁻¹ was due to stretching mode of C=N bonding in 2-methylimidazole. The peaks obtained at 2842.91 and 3026 cm⁻¹ were due to stretching of C–H from aromatic ring and aliphatic methyl group of 2-methylimidazole, thus confirming the formation of ZIF-67 [36]. In case of ZIF-67/PEDOT composite the intensity of the above-mentioned bands is reduced as a result of addition of PEDOT.

Scheme 1. Schematic illustration representing sequential construction of ZIF-67/PEDOT electrode.

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Fig. 1. (A) High magnified SEM micrograph of ZIF-67 showing clear formation of polyhedral shape nanoparticles. Panel (B) and (C) represent the low and high magnification images of ZIF-67/PEDOT with little distortion in polyhedral shape upon addition of PEDOT. (D) XRD results indicate the clear formation of ZIF-67 (black line) and ZIF-67/PEDOT (red line). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)
Raman studies are helpful in determining light scattering from C=C and C–C bonds. In ZIF-67/PEDOT, Raman peaks were observed at 1441 and 1511 cm$^{-1}$ due to symmetrical as well as asymmetrical vibrations of C=C bond (Fig. 2B) [35]. Moreover, some peaks were observed at 466, 510, 673, and 1144 cm$^{-1}$ in both samples. These peaks are linked with various vibrational modes and arise due to interaction of cobalt and nitrogen in ZIF-67. Additionally, these vibrations present in composite confirm the presence of PEDOT in ZIF-67/PEDOT [37].

### 3.2. Electrochemical performance of ZIF-67 and ZIF-67/PEDOT electrode

The electrochemical performances of ZIF-67 and PEDOT/ZIF-67 electrodes were evaluated through cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS). The electrochemical behavior of ZIF-67 and ZIF-67/PEDOT electrodes were tested using redox probe 2 mM K$_4$[Fe(CN)$_6$]$_{3-/4-}$ in 10 ml of 0.1 M PBS (pH: 7.5) electrolyte over a potential range of 0.6 to 0.6V (vs. Ag/AgCl) at a scan rate of 100 mV/s (Fig. 3A). Both, the CV plots shows redox peaks, however, ZIF-67/PEDOT electrode possesses higher peak current response compared to ZIF-67 electrode because of PEDOT integration, thus resulting in surface activation and increased electron transport capability at the surface of composite. Moreover, lower peak-to-peak separation value at the surface of ZIF-67/PEDOT (0.41 V) compared to ZIF-67 (0.47 V) electrode further confirm the enhanced ion transmission at electrode electrolyte interface and engaging more fractions of catalytic active sites on surface of electrode for faradaic redox reaction.

The electron transport capability of both electrodes was further studied by performing electrochemical impedance spectroscopy (EIS) in 2 mM solution of K$_4$[Fe(CN)$_6$]$_{3-/4-}$ in 10 ml of 0.1 M PBS (pH: 7.5) electrolyte (Fig. 3B). EIS data of both electrodes was plotted by using Randle’s circuit model (Fig. S1). In circuit Cdl, Zw, Rs and Rct represents double layer capacitance, Warburg impedance, solution resistance and charge transfer resistance respectively. From EIS plot (Fig. 3B), diameter of semicircle at higher frequency displays Rct between surface of electrode and redox probe while linear part at lower frequency exhibits diffusion process. Results clearly reveals that ZIF-67/PEDOT electrode showed small semicircle compared to ZIF-67 electrode, thus suggesting superior electron transport capability of the composite.

### 3.3. Electrochemical performance of ZIF-67/PEDOT electrode towards DA

Electrocatalytic activity of ZIF-67/PEDOT electrode was further studied against increasing concentration of DA (Fig. 4A) in 0.1 M PBS (pH: 7.5). Results indicate the quantitative determination, as CV current signal changes with increasing concentrations (10, 20, 50 and 100 μM) of DA (red to green line). Results clearly show that upon continual addition of DA, the anodic peak current increases with increase in DA concentration, whereas no peak appears in the absence of DA (black line). This is due to the excellent electrocatalytic oxidation activity of ZIF-67/PEDOT electrode towards DA oxidation, which is further supported by highly conductive PEDOT. Before performing any further experiment, the pH of the electrolyte (PBS) was optimized as it is very crucial in attaining the optimal sensing performance. The CV results indicate that the current response gradually increases from 4.5 to and 7.5 starts decreasing upon further increase in pH from 8.0 to 9.5 (Fig. S2). Thus, to achieve the optimal sensing performance the pH 7.5 was selected and applied through-out the experiment.

The current dependence on scan rate was further examined by performing CV at various scan rates (20–200 mV/s) towards fix concentration of DA (10 μM) as depicted in Fig. 4B to investigate the redox
properties and effective electrochemical surface area of modified electrode. Results clearly reveal the peak current increases with increase in scan rate. Also, oxidation peak current (Ipa) of DA increased with increasing scan rate and oxidation peak potential value (Epα) was shifted towards positive side and reduction peak potential value (Epс) towards negative side. The linear plots of Ipa and Ipс scaled with square root of scan rate with high correlation coefficient of 0.995 and 0.998, respectively, indicating the diffusion controlled electrochemical process (Fig. 4D).

Moreover, linear regression equations were obtained when graph is plotted between natural log of scan rate and natural log of anodic current Fig. 4E.

\[
I_p = -0.7462x + 2.4348 \quad R^2 = 0.9832 \quad \text{for anodic} \quad (1)
\]

\[
I_p = 0.4333x - 2.5198 \quad R^2 = 0.9939 \quad \text{for Cathodic} \quad (2)
\]

Furthermore, linear relation is also obtained by plotting a graph between potential and natural log of scan rate Fig. 4F.

\[
E_p = 0.0243x + 0.3357 \quad R^2 = 0.8584 \quad \text{for anodic} \quad (3)
\]

\[
E_p = -0.0177x + 0.0977 \quad R^2 = 0.9964 \quad \text{for cathodic} \quad (4)
\]
Based on these results, the number of electron transfer was calculated by applying Tafel slope Eq. (5) [38].

\[
\text{Slope} = 2.303\frac{RT}{nF}
\]  

(5)

Where T and R shows temperature in kelvin and general gas constant, F shows Faraday constant (96485 C mol\(^{-1}\)), \(n\) represents electron transfer coefficient and its value is 0.5 for reversible voltammograms [39] and \(n\) denotes electron transfer number. The value of \(n\) is calculated from slope as shown in Fig. 4F. The value of slope calculated for cathodic and anodic is \(-0.0177\) and \(0.0243\) respectively and the number of electrons involved in are \(1.992\) and \(1.998\), respectively.

The electrocatalytic oxidation of DA at the surface of ZIF-67/PEDOT electrodes is shown in Scheme 2. Briefly, Co\(^{3+}\) is oxidized to Co\(^{3+}\), thus resulting in fast oxidation of DA to dopaquinone (DAQ). There is an electrostatic interaction between Co of ZIF-67 and O of PEDOT; here PEDOT provides smooth conductive pathways for the fast ion transfer. Oxidized Co\(^{3+}\) further leads to the fast oxidation of DA to DAQ. Thus, ZIF-67/PEDOT electrode has exhibited excellent electrochemical response towards DA oxidation.

3.4. Functionality of ZIF-67/PEDOT electrode

3.4.1. Diffusion capability

The diffusion coefficients of DA at the surface of electrode were measured by chronoamperometry (Figs. S3–A) in the presence (red line) and absence (black line) of 1 mM of DA. Cottrell equation (Eq. (6)) was used for calculation of diffusion coefficient. A linear relationship was obtained between \(t^{-1/2}\) and \(I_1\) towards 1 mM of DA (Inset Figs. S3–A).

\[
I_1 = nFAD^{1/2}c^{-1/2}t^{-1/2}
\]  

(6)

Where \(I_1\) is the current in presence of 1 mM DA, A is geometric surface area of electrode (1 cm\(^2\)), \(F\) is faraday constant (96,485 C/mol), \(D\) is diffusion coefficient (cm\(^2\)/sec), \(c\) represents analyte concentration and \(t\) shows elapsed time (sec). The diffusion co-efficient of 1 mM at the surface of designed electrode was observed to be \(5.12 \times 10^{-6}\) cm\(^2\)/s, which is much higher compared to the similar kind of reported materials [39].

Similarly, electrocatalytic rate constant of the designed electrode was calculated by using Eq. (7) and deduced from chronoamperometric measurement (Figs. S3–A).

\[
\frac{I}{I_1} = \frac{x^{1/2}}{\gamma^{1/2}} = \frac{1}{\gamma^{1/2}(kct)^{1/2}}
\]  

(7)

\(I/I_1\) represents current in presence and absence of DA, \(\gamma = kct\), here \(k\) is catalytic rate constant, \(c\) is DA concentration and \(t\) represents duration of chronoamperometric measurement. \(K\) is obtained from slope of \(I/I_1\) curve (Figs. S3–B). The value of electrocatalytic rate constant of the developed electrode was calculated to be \(5.94 \times 10^{3}\) (M s\(^{-1}\)).

3.4.2. Sensing and selective capability of the designed electrode

Developing non-enzymatic sensor with high sensitivity and selectivity remains a big challenge. Thus, sensing, and selective capability of the designed electrode was evaluated. Amperometry was applied to demonstrate the sensing capability of designed ZIF-67/PEDOT electrode towards increasing concentrations of DA. Figs. S3–C shows the amperometric current response of ZIF-67/PEDOT electrode towards continuous addition of DA in 0.1 M PBS at a fixed potential of 0.24 V (vs. Ag/AgCl). A well-defined, stable and fast amperometric current response was observed with successive addition of DA. A calibration curve was drawn between current verses concentration to measure the sensitivity, linear range, and detection limit (LOD) of the designed electrode. The calibration curve shows a linear relation with regression equation and the linear regression was expressed as \([I(\mu A)] = 2.75 \mu M [DA] + 26.96; R^2 = 0.98; N = 5\]. The designed electrode shows the LOD of 0.04 \(\mu M\) and sensitivity of 2.75 mA/\(\mu M\) cm\(^2\) against linear range of 15–240 \(\mu M\) DA (Figs. S3–D), and these results are in good competition with the reported literature (Table S1).

A sensor capability can be drawn from its selective efficacy towards anlyte of interest. Thus, to study the selective ability of the ZIF-67/PEDOT electrode was investigated by determining the responses of the modified electrode towards low concentration of DA (0.025 mM) and high concentrations (1 mM) of other co-existing interferents such as AA, UA, L-Cyst, Glu and Sal in 0.1 M PBS at an applied potential of 0.24V. Interestingly, the amperometric selective current signal of the designed electrode shows insignificant interfering effect towards DA even in the presence of a several-folds higher concentration of major interfering molecules (Fig. 5A). These results suggest the reliable selective efficacy of the developed electrode, that could be attributed to fast transport capability of ion/electron involved in DA electro-oxidation at a specific oxidation potential.
3.4.3. Reproducibility, reusability and stability of the designed electrode

To construct a reliable sensor, it is very important to measure reproducibility and reusability of sensor. The reproducibility of ZIF-67/PEDOT electrode was evaluated using amperometry. Electrode to electrode reproducibility of 10 electrodes towards constant concentration of DA (10 μM) was evaluated under optimum sensing conditions (pH 7.5) in 0.1 M PBS and at applied potential of 0.24 V (Fig. 5B). Results reveals that the developed electrode maintained a reliable reproducibility, with a relative standard deviation (RSD) of 0.92%.

To evaluate the reusability, current response of same electrode was studied repeatedly for 10 days, and results shows that the electrode retained more than 98% of current response even after 10 days, thus indicating reliable reusability of the designed electrode (Fig. 5C). Similarly, stability of the electrode was evaluated by using chronoamperometry technique. Results indicate that the designed electrode retained more than 80% stability towards 10 μM of DA (Inset Fig. 5C).

3.4.4. Real time applicability of the designed electrode

Various neurological disorders such as anxiety, depression, agitation, and delirium has been increased due to severe lockdown after the COVID-19 outbreak. Thus, it is highly recommended to monitor the DA level from blood of COVID-19 quarantine person. The practical applicability of ZIF-67/PEDOT electrode was demonstrated in blood sample taken from person suffering from quarantine stress (Fig. 5D). Amperometric methods was used to investigate the real time applicability of the developed electrode. Briefly, first we spiked the standard concentration of DA (10 μM) in 10 mL of 0.1 M PBS and measured the current response of the designed electrode at an applied potential of 0.24 V. Amperometric signal shows an increase in current response of ~11.02 μA (red bar). However, in next step the current response is increased up to ~13.08 μA against the mixture of 10 μM of DA and 1 mL of real blood sample in 10 mL of 0.1 M PBS at the same applied potential. This increased in current response could be attributed to the addition of real sample along with standard solution, thus suggesting reliability of the developed sensor.

4. Conclusions

In summary, we introduced ZIF-67/PEDOT electrode for sensitive, selective, and non-enzymatic detection of DA. The designed electrode showed better conductivity, exceptional electron transfer ability and better electrocatalytic property with high sensitivity and fast response time towards DA monitoring. The developed electrode also shows wide linear range (15–240 μM), excellent selectivity and low limit of detection (0.04 μM). The developed sensor also exhibited good reusability, reproducibility, and stability. Moreover, real time application of sensor was tested in the blood sample of COVID-19 quarantine person with better accuracy. All these features suggest that ZIF-67/PEDOT based electrode exhibits great potential for application in electrochemical sensing.
CRediT authorship contribution statement

Tayyaba Masood: synthesized the material, characterized, and interpreted the material part. Muhammad Asad: perform the electrochemical application work and guided the Tayyaba in learning the electrochemical sensing application. Sara Riaz: helps in writing the whole manuscript, Whereas Miss Sara help in drawing the scheme and Figures. Naeem Akhtar: Writing – original draft, helps in writing the whole manuscript, Whereas Miss Sara help in drawing the scheme and Figures, developed the idea along with. Akhtar Hayat: Writing – original draft, both helps in deriving and writing the mechanism and application part. Mohammed A. Shenasheen: Writing – original draft, both helps in deriving and writing the mechanism and application part. Mohammed M. Rahman: helps in proof reading, finalizing and managing the whole project, Writing – original draft, helps in writing the whole manuscript, Whereas Miss Sara help in drawing the scheme and Figures.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found at https://doi.org/10.1016/j.matchemphys.2022.126451.

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