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## Original Article

# Pt-MWCNT modified carbon electrode strip for rapid and quantitative detection of H<sub>2</sub>O<sub>2</sub> in food



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## ABSTRACT

A single-use screen-printed carbon electrode strip was designed and fabricated. Nano-hybrids, prepared by deposition of platinum (Pt) nanoparticles on multi-wall carbon nanotube (MWCNT), was modified on the surface of screen-printed carbon electrode for the development of a fast, sensitive and cost-effective hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) detection amperometric sensor strip. With Pt-MWCNT nano-hybrids surface modification, current generated in response to H<sub>2</sub>O<sub>2</sub> by the screen-printed carbon electrode strip was enhanced 100 fold with an applied potential of 300 mV. Quality of as-prepared electrode strip was assured by the low coefficient of variation (CV) (<5%) of currents measured at 5 s. Three linear detection ranges with sensitivity of 75.2, 120.7, and 142.8  $\mu\text{A mM}^{-1} \text{cm}^{-2}$  were observed for H<sub>2</sub>O<sub>2</sub> concentration in the range of 1–15 mM, 0.1–1 mM, and 10–100  $\mu\text{M}$ , respectively. The lowest H<sub>2</sub>O<sub>2</sub> concentration could be measured by the as-prepared strip was 10  $\mu\text{M}$ . H<sub>2</sub>O<sub>2</sub> levels in green tea infusion and pressed Tofu could be rapidly detected with results comparable to that measured by ferrous oxidation xylenol orange (FOX) assay and peroxidase colorimetric method.

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## 1. Introduction

Hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) as a chemical compound is often used as an oxidizer, bleaching agent, and disinfectant. H<sub>2</sub>O<sub>2</sub> as a product generated from human body or enzymatic reaction is a valuable biomarker of inflammation [1,2], some chronic diseases [3–5], and an essential mediator in food [6], industry, medical, and environmental analysis [7,8]. Therefore, developing a reliable, sensitive, rapid and low-cost sensor for

detecting H<sub>2</sub>O<sub>2</sub> has become an area of increased importance in recent years [9–15]. There already have various colorimetric, fluorescence, and electrochemical methods been developed to detect the H<sub>2</sub>O<sub>2</sub> concentration. Among these methods, the electrochemical is the most preferred one due to its simplicity, high sensitivity, and rapid detection [16–18]. Most of electrochemical sensors developed for H<sub>2</sub>O<sub>2</sub> detection are amperometric in which the surface of electrodes are modified with redox enzymes to catalyze the redox reaction of H<sub>2</sub>O<sub>2</sub> to generate electron current when a potential is applied.

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However, the high cost and low stability of the employed enzymes usually limit their long-term applications. Thus, there is a critical need to develop high stability, low cost and high sensitivity electrochemical nonenzymatic sensors for the detection of  $H_2O_2$ .

It has been reported that platinum, rhodium, ruthenium, palladium and several other noble metals are very good catalysts for redox reaction with  $H_2O_2$  [19], among which platinum and palladium were considered as better catalysts than other metals [20]. In recent time single-wall, multi-wall carbon nanotube (MWCNT), and several carbon nanomaterials have been used as a support for catalysts to promote electron transfer reactions in the development of electrochemical sensors due to their superior electrical conductivity [21–25]. However, only few studies were reported on employing MWCNT in single-use screen-printed carbon-based electrodes for the development of low-cost disposable biosensor strips [26,27]. In this study, nanohybrid of MWCNT and Pt nanoparticles was prepared to modify the surface of a screen-printed disposable carbon electrode for the detection of  $H_2O_2$  by amperometric method. With significantly augmented conductivity and catalytic surface area, the Pt-MWCNT nanohybrid surface-modified carbon (Pt-MWCNT/C) electrode is expected to generate a higher current signal with a lower applied potential, as a consequence, a cost-effective and fast response electrochemical sensor with high sensitivity can be obtained [28–33]. This nanohybrid modified carbon electrode strip is also expected to find success to assay various biochemical compounds by detecting the  $H_2O_2$  produced by the corresponding oxidative enzymatic reactions, such as glucose oxidase, cholesterol oxidase, alcohol oxidase, and *L*-amino acid oxidase. In this work, the Pt-MWCNT nanohybrid was prepared and characterized by SEM, TEM and cyclic voltammetry. The optimal amount of Pt-MWCNT modified on screen-printed carbon electrode surface, applied potential, and detection time employed in the amperometric detection of  $H_2O_2$  were investigated. Besides, the quality of as-prepared disposable Pt-MWCNT/C electrode strip was also studied by measuring the coefficient of variation of currents detected at different time with fixed applied potential.

In addition,  $H_2O_2$  due to its ready availability and affordable price is often used as bleaching and antimicrobial agent in many processed products available in the local food markets of many developing countries. Consuming these  $H_2O_2$  containing processed food products can lead to headaches, nausea, and the potential risk of cancer, therefore, well-monitoring the residual level of  $H_2O_2$  in the processed food by an inexpensive and rapid method is an important task. Green tea is known to have rich content of polyphenols such as catechins and the presence of these polyphenols has already been proved will generate  $H_2O_2$  in green tea infusion [34–36]. In this work, as-prepared Pt-MWCNT/C electrode strip was employed to detect  $H_2O_2$  residual level in the pressed Tofu obtained from local market and  $H_2O_2$  level generated in green tea infusion. Two other colorimetric methods, ferrous oxidation xylenol orange (FOX) assay and peroxidase method were also employed to demonstrate the accuracy of the amperometric method developed based on this disposable  $H_2O_2$  electrochemical sensor strip.

## 2. Materials and methods

### 2.1. Materials

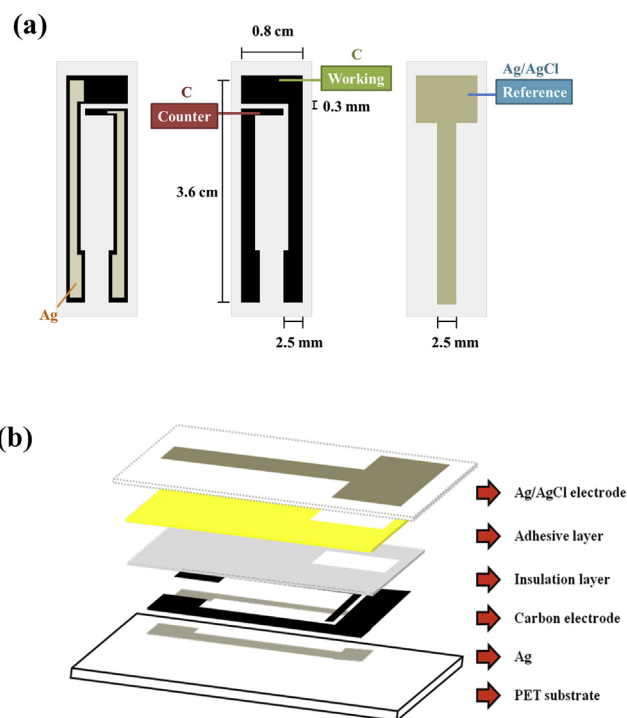
Hydrogen hexachloroplatinate hexahydrate  $H_2PtCl_6 \cdot 6H_2O$  (38–40% Pt) and hydrogen peroxide (35%) were obtained from ACROS. The MWCNTs (95% purity, 20–40 nm diameter) were purchased from Scientech Co. (Taiwan). Carbon ink (E3451) and Ag/AgCl ink (E2430) were obtained from Ercon Co. (MA, USA) for screen-printing the disposable electrodes. *o*-Dianisidine and horseradish peroxidase (HRP) were obtained from Sigma. The other chemicals employed were of analytic grade.

### 2.2. Fabrication of electrode sensor strip

The disposable sensor strip was prepared by screen-printing carbon black ink onto an Ag coated PET plastic film as working and counter electrodes. The Ag/AgCl reference electrode was screen-printed on the other side of PET film using Ag/AgCl ink. The dimension and assembly of the electrode strip is shown in Fig. 1. The reaction area of each electrode is 5.60 mm<sup>2</sup>, 1.60 mm<sup>2</sup> and 8.96 mm<sup>2</sup> for working, counter, and reference electrode, respectively. Approximately, 3  $\mu$ l of sample solution will be sucked into the reaction area by the capillary action.

### 2.3. Pt-MWCNT nanohybrid preparation

Pt-MWCNT nanohybrid with Pt:MWCNT weight ratio of 1:4 was prepared based on Watanabe method [37]. Briefly,



**Fig. 1** – Schematic design of single-use electrochemical  $H_2O_2$  sensor strip with carbon ink screen-printed on the front and Ag/AgCl ink screen-printed on the back of PET film. (a) 2-D design and dimension, (b) 3-D assembly of the strip.

MWCNT was first treated with a strong acid mixture containing 1:1 ratio of 65% HNO<sub>3</sub> and 98% H<sub>2</sub>SO<sub>4</sub> at 100 °C for 8 h. Chloroplatinic acid solution (5.13 mM) of 7 ml was adjusted to pH 7.0 by 0.1 M NaCO<sub>3</sub> solution then 0.15 g of NaHSO<sub>3</sub> powder was added. The Pt precursor solution was then well-mixed with 25 ml 0.64% (w/w) well-dispersed MWCNT solution. H<sub>2</sub>O<sub>2</sub> (35%) of 6 ml was then slowly added into the mixture and the pH was adjusted to 6.0 by using 1 M NaOH. After heated at 100 °C for 3 h, the precipitate collected by centrifugation was washed with ethanol and dried at 80 °C. The dried precipitate was ground into powder then reduced at 300 °C under 10% H<sub>2</sub>:90% Ar atmosphere.

#### 2.4. Electrode modification with Pt-MWCNT and characterization

Pt-MWCNT nanohybrid slurry with concentration of 2 mg/ml was prepared by dispersing the dried Pt-MWCNT nanohybrid in 0.1% (w/v) Triton X-100 under ultrasonication for 60 min. Various amount of Pt-MWCNT were deposited by spreading 0.5 μL of Pt-MWCNT slurry of different concentration onto the surface of electrode. After drying, 1.6 μL of 0.05% (w/v) Triton X-100 solution was again loaded onto the surface of Pt-MWCNT nanohybrid modified electrode. The electrocatalytic performance of bare carbon electrode and Pt-MWCNT modified electrode sensor strip in 0.1 M PBS buffer with and without 3 mM H<sub>2</sub>O<sub>2</sub> were studied by cyclic voltammetry (CV) with applied potential in the range of –0.8 to 0.8 V at a scan rate of 100 mV/s using a CHI 6600A electrochemical workstation (CH instrument, Austin, TX, USA). The quality of as-prepared disposable Pt-MWCNT/C electrode strip was assured by studying the coefficient of variation of currents measured from 10 randomly selected electrodes under same applied potential. The morphology of the Pt nanoparticles along with MWCNT was characterized using a Philips Tecnai F20 G2 FEI-TEM operated at 80 kV. The surface of carbon and Pt-MWCNT/C electrode were observed using JEOL JSM-6500 FE-SEM.

#### 2.5. Detection of H<sub>2</sub>O<sub>2</sub>

H<sub>2</sub>O<sub>2</sub> of various concentrations were prepared by diluting 35% H<sub>2</sub>O<sub>2</sub> solution obtained from ACROS in pH 7.4, 0.1 M PBS buffer. The proper diluted standard H<sub>2</sub>O<sub>2</sub> solution was employed to establish a linear calibration curve based on the currents generated at an applied potential of 300 mV using the as-prepared Pt-MWCNT/C electrode strip. For detecting H<sub>2</sub>O<sub>2</sub> level in green tea infusion and leaching solution of processed food products, green tea powder and pressed Tofu were employed as model compounds. Green tea powder from local market of 0.2 g was mixed in 20 ml distilled water at 50 °C for 10 min. After centrifugation (13,000 rpm, 5 min), the supernatant was diluted with equal volume of pH 7.4 0.1 M PBS buffer and considered as an infusion. The infusion solution was shaken for various time at 37 °C before polyvinylpyrrolidone (PVPP) powder was added to 5% (w/v) for polyphenolic compounds removal. After mixing with PVPP for 30 min at room temperature, the solution was subjected to centrifugation to obtain the clarified green tea infusion for H<sub>2</sub>O<sub>2</sub> detection. To measure residual H<sub>2</sub>O<sub>2</sub> level in pressed Tofu obtained from a local market in Taipei city (Taiwan),

pressed Tofu of 1 g was added into 10 ml pH 7.4, 0.1 M PBS buffer and stirred for 1 h at room temperature to leach H<sub>2</sub>O<sub>2</sub>. H<sub>2</sub>O<sub>2</sub> concentration in the leaching solution was then measured after proper dilution. In addition to the amperometric detection using Pt-MWCNT/C electrode strip, ferrous oxidation xylenol orange (FOX) method [38] and the enzymatic method using horseradish peroxidase (HRP) with o-dianisidine (ODA) dye [39] were also employed for H<sub>2</sub>O<sub>2</sub> detection as references. Briefly, sample solution of 20 μl was mixed with 180 μl of ferrous oxidation xylenol orange reagent (0.45 mM xylenol orange, 0.45 mM Fe(NH<sub>4</sub>)(SO<sub>4</sub>)<sub>2</sub> in 0.11 M HClO<sub>4</sub>) for 30 min at room temperature. The optical density of solution was measured at 550 nm using UV–Vis spectrometer. For enzymatic method, 150 μl sample solution was well-mixed with 720 μl ODA solution (66 μg/ml in 0.1 M pH 7.0 phosphate buffer) and 30 μl HRP solution (1 mg/ml) at room temperature then the optical density of the solution was measured at 727 nm.

### 3. Results and discussion

#### 3.1. Characterization of Pt-MWCNT/C electrode strip

TEM images shown in Fig. 2 show that most of the nano-sized Pt particles are spherical and highly dispersed on the MWCNTs with no significant particle aggregation. The average size of Pt particles was evaluated statistically by ImageJ software measuring the diameter of 50 nanoparticles in selected TEM images to be 3.37 ± 0.54 nm. The MWCNTs on the other hand, has a diameter approximately 30 nm with length much longer than 100 nm. More than 50% of MWCNTs are free of Pt nanoparticles probably because the ratio of Pt to MWCNTs was designed to be 20% in the preparation of Pt-MWCNTs nanohybrid. Fig. S1 (supplementary figure) shows the SEM image of Pt-MWCNTs modified carbon electrode (Pt-MWCNTs/C). In addition to the widely distributed carbon nanoparticles, the entrapped MWCNTs wires could also be observed. The electrochemical performances of bare carbon and Pt-MWCNTs/C electrodes toward H<sub>2</sub>O<sub>2</sub> (3 mM H<sub>2</sub>O<sub>2</sub> in pH 7.4, 0.1 M PBS containing 10 mM KCl) were investigated using cyclic voltammetry (CV, apply potential from –800 mV to 800 mV with scan rate of 100 mV/s). As shown in Fig. 3a, no obvious redox peaks and quite low currents were observed on the bare carbon electrode regardless of H<sub>2</sub>O<sub>2</sub> addition. In contrast, the presence of Pt-MWCNT resulted in a significantly enhanced current on Pt-MWCNTs/C electrode that could be ascribed to the large reactive surface provided by Pt-MWCNT and the catalytic activity of Pt nanoparticles. A redox peak between –0.2 and 0.0 V on Pt-MWCNTs/C electrode could be observed in 0.1 M PBS regardless of H<sub>2</sub>O<sub>2</sub> addition. It is not clear to us what is the exact redox process generated this peak. However, as the applied potential higher than 185 mV, it can be observed that H<sub>2</sub>O<sub>2</sub> started to be oxidized and generated a current exceed that obtained in PBS without H<sub>2</sub>O<sub>2</sub> (Fig. 3b). In comparison with Pt-MWCNT/C electrode, bare carbon electrode needs a much higher potential (>460 mV) to oxidize H<sub>2</sub>O<sub>2</sub> but generate a less sensible current. Evidently, Pt-MWCNT nanohybrid is a very effective nanocatalyst for amperometric detection of H<sub>2</sub>O<sub>2</sub> at a lower applied potential.

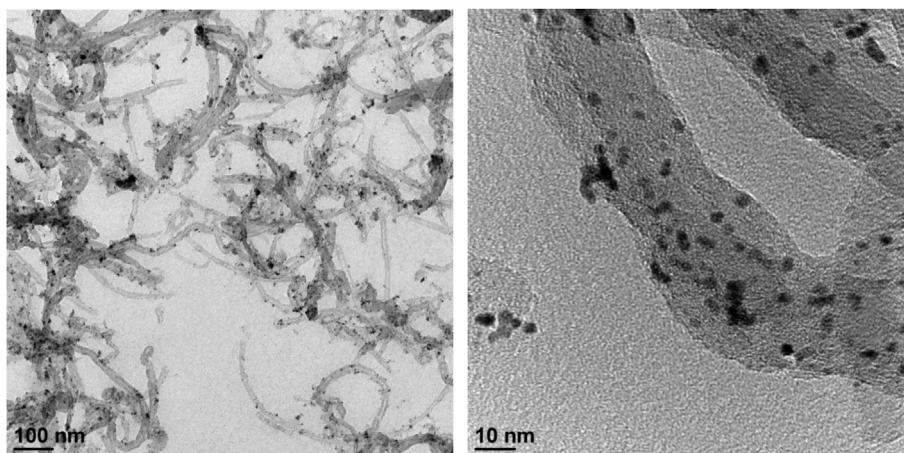


Fig. 2 – TEM images of as-prepared Pt-MWCNT catalytic nanohybrid.

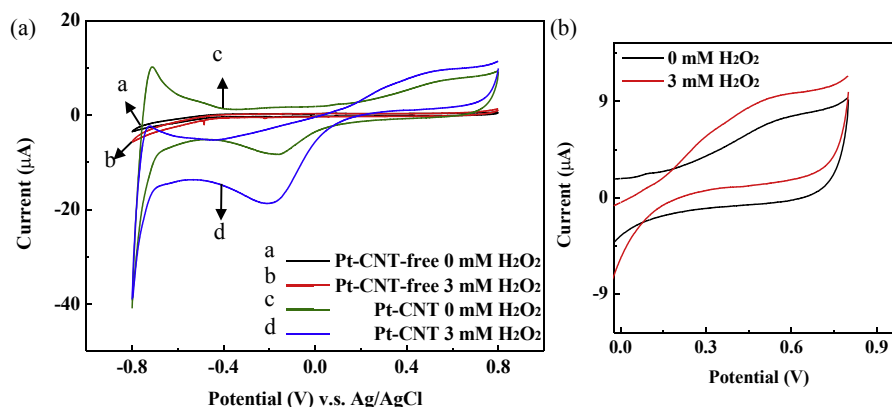


Fig. 3 – Effect of H<sub>2</sub>O<sub>2</sub> and Pt-MWCNT modification on cyclic voltammograms of single-use carbon electrode sensor strips. Pt-MWCNT of 0.179 ng/cm<sup>2</sup> was modified on the surface of carbon electrode sensor strip (Scan rate: 100 mV/s). (a) CV of bare carbon and Pt-MWCNT/C electrode; (b) Magnified CV of Pt-MWCNT/C electrode.

### 3.2. Optimization of Pt-MWCNT/carbon electrode

In developing an amperometric method, usually the applied potential employed to oxidize the target analyte should be kept at a low level to minimize the interference caused by the oxidation of interferences. As observed in the CV of H<sub>2</sub>O<sub>2</sub> using Pt-MWCNT/C electrode (Fig. 3b), apparent oxidation current could be detected at applied potential higher than 185 mV. As a consequence, the potential applied was increased from 200 mV to study the effect of applied potential on H<sub>2</sub>O<sub>2</sub> detection. Fig. S2 shows that the current obtained at 5 s increased linearly with the potential applied but leveled-off after 400 mV. Although the higher current generated at higher potential will benefit the H<sub>2</sub>O<sub>2</sub> detection sensitivity, but the higher potential will also result in more electric active compounds to be oxidized to generate interference current. Therefore, 300 mV was employed in the rest of experiments for H<sub>2</sub>O<sub>2</sub> detection using the as-prepared Pt-MWCNT/C electrode sensor strip.

The effect of Pt-MWCNT nanohybrid loading amount on the current generated from detecting H<sub>2</sub>O<sub>2</sub> concentration was

also studied. As shown in Fig. 4, the response current at 5 s increased with the concentration of H<sub>2</sub>O<sub>2</sub> at Pt-MWCNT concentration higher than 0.179 ng/cm<sup>2</sup>. No significant difference of response currents could be observed at concentration lower than 0.179 ng/cm<sup>2</sup> for H<sub>2</sub>O<sub>2</sub> concentration up to 500 μM. Evidently, nanohybrid concentration lower than 0.179 ng/cm<sup>2</sup> is not enough to catalyze the redox reaction involved with the H<sub>2</sub>O<sub>2</sub> concentration applied. The performance variation of the as-prepared Pt-MWCNT/carbon electrode strips was also studied by testing 10 randomly selected strips on the current generated at applied potential of 300 mV in 250 μM H<sub>2</sub>O<sub>2</sub> solution. As shown in Fig. 5a, all the strips demonstrated very similar behaviors that current decreased sharply within 10 s and leveled-off after 30 s. The current variations with respect to time are shown in Fig. 5b that coefficient of variation increased linearly with detection time after 20 s. However, at detection time less than 10 s the coefficient of variation was less than 5%. Due to the higher current and smaller current variation, the current detected at 5 s using Pt-MWCNT/C electrode strip was employed to establish a calibration curve for H<sub>2</sub>O<sub>2</sub> concentration determination.



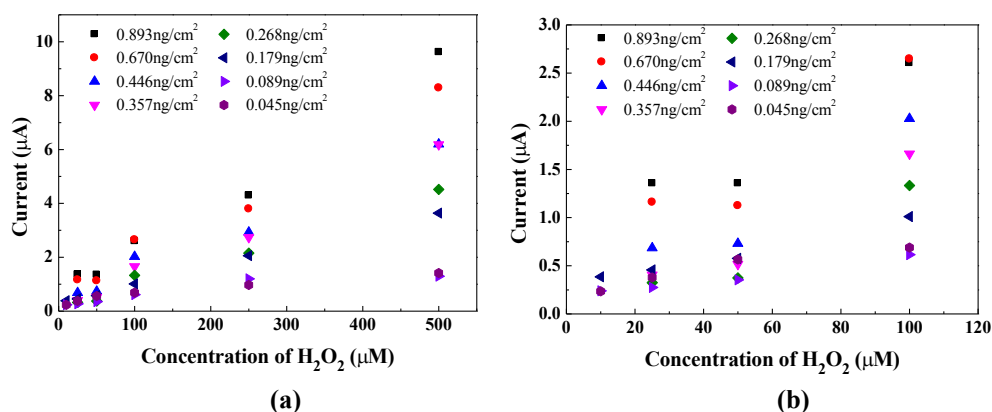


Fig. 4 – Effect of Pt-MWCNT amount on current generated at 5 s by the Pt-MWCNT/C electrode strip in H<sub>2</sub>O<sub>2</sub> concentration (a) 0–500 μM; (b) 0–100 μM.

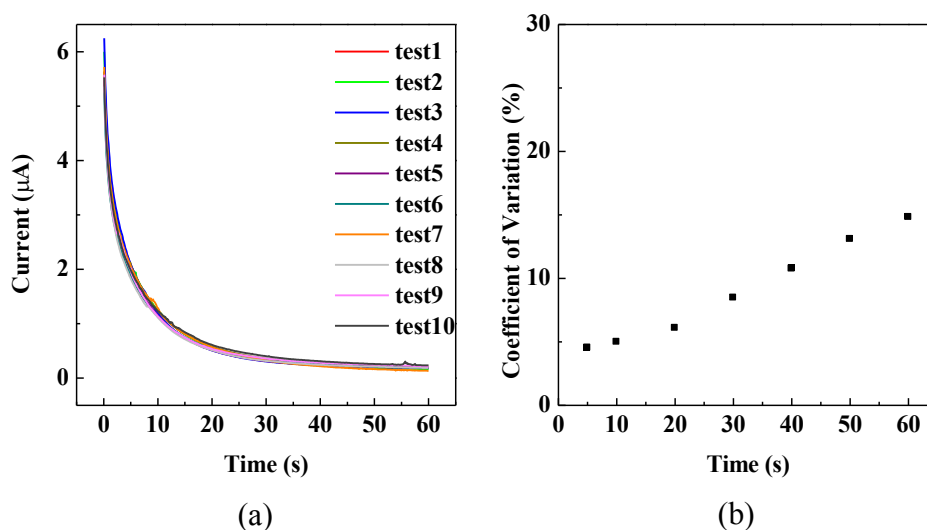


Fig. 5 – (a) *i*–*t* curves of 10 different Pt-MWCNT/C electrode strips measuring 250 μM H<sub>2</sub>O<sub>2</sub> at an applied potential of 300 mV. (b) Coefficient of variation of current measured at different time from 10 *i*–*t* curves.

### 3.3. H<sub>2</sub>O<sub>2</sub> detection

Amperometric method was employed to detect H<sub>2</sub>O<sub>2</sub> concentration with applied potential of 300 mV using Pt-MWCNT/C electrode strips. As shown in Fig. S3, a linear detection range could be established for H<sub>2</sub>O<sub>2</sub> concentration from 1 to 15 mM. The sensitivity was determined to be 75.2 μA mM<sup>-1</sup> cm<sup>-2</sup> with coefficient of variation of 2.24%. A more sensitive linear detection range with sensitivity of 120.7 μA mM<sup>-1</sup> cm<sup>-2</sup> could also be obtained for H<sub>2</sub>O<sub>2</sub> concentration lower than 1 mM. The limit of detection (LOD) of Pt-MWCNT/C electrode strip was studied by employing H<sub>2</sub>O<sub>2</sub> concentration in the range of 0–100 μM. As shown in Fig. 6, a more sensitive linear detection range with sensitivity of 142.8 μA mM<sup>-1</sup> cm<sup>-2</sup> could be obtained using currents measured at 5 s. H<sub>2</sub>O<sub>2</sub> concentration as low as 10 μM could be detected with a current of 0.2 μA.

Based on the established linear detection range, the as-prepared electrode strip was applied for measuring H<sub>2</sub>O<sub>2</sub> level in green tea and pressed Tofu samples. Green tea has been recognized as a healthy drink because of its rich

content of polyphenol chemical compounds, mainly the catechins. It has been reported that catechins will react with the dissolved oxygen to generate H<sub>2</sub>O<sub>2</sub> and its production increases with pH. The presence of H<sub>2</sub>O<sub>2</sub> also explains the observed bactericidal effect of green tea infusion [34]. Therefore, green tea was employed as a model solution for detecting its H<sub>2</sub>O<sub>2</sub> level by the as-prepared electrode strip. However, the presence of rich polyphenolic compounds in green tea will also participate the redox reaction between H<sub>2</sub>O<sub>2</sub> and Pt-MWCNT nanohybrid, as a consequence, significant interferences were observed in the obtained *i*–*t* curves (data not shown). Polyvinylpyrrolidone (PVPP) is well-known for its high polyphenolic compounds removal capacity [40]. Thus, all the green tea samples were pre-treated with PVPP powder to remove the polyphenolic compounds before H<sub>2</sub>O<sub>2</sub> detection were carried out by amperometric method. As observed in the *i*–*t* curves of green tea solutions (Fig. S4), the current increased significantly after 1 h incubation. The result is consistent with previous observation that H<sub>2</sub>O<sub>2</sub> will be generated with time in green tea solution

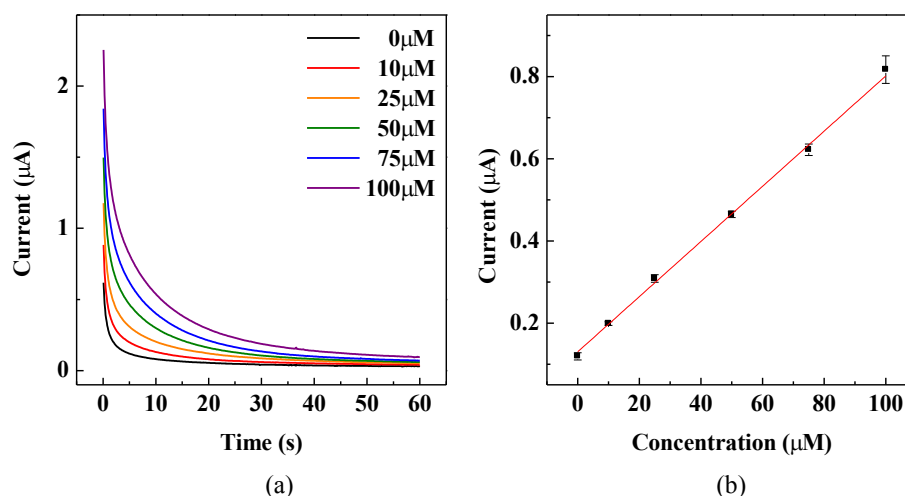


Fig. 6 –  $\text{H}_2\text{O}_2$  detection limit of Pt-MWCNT/C electrode strip. (a)  $i-t$  curve for concentration in the range of 0–100  $\mu\text{M}$ . (b) calibration curve of  $\text{H}_2\text{O}_2$  concentration 0–100  $\mu\text{M}$  based on currents measured at 5 s.

**Table 1 –  $\text{H}_2\text{O}_2$  concentration in green tea solution detected by amperometric single-use electrode sensor strip and colorimetric methods.**

	Test 1	Test 2	Test 3	Mean		
Methods	amperometric sensor strip				colorimetric methods	
					FOX	ODA/HRP
$\mu\text{M}$	724.2	700.1	687.6	703.9	530.2	749.1

[36]. As shown in Table 1,  $\text{H}_2\text{O}_2$  level in green tea solution after 1 h incubation was determined to be about 703  $\mu\text{M}$ . Two other colorimetric assay methods were also employed to assure the accuracy of  $\text{H}_2\text{O}_2$  level detected by the as-prepared single-use electrode strip.  $\text{H}_2\text{O}_2$  concentration of 530  $\mu\text{M}$  was determined by HRP enzymatic method, while 749  $\mu\text{M}$  was detected by FOX assay. These results show that the facile and fast amperometric method using as-prepared electrode strip can determine  $\text{H}_2\text{O}_2$  level in green tea infusion with acceptable accuracy. Finally, the fast amperometric  $\text{H}_2\text{O}_2$  detection method was also applied for detecting  $\text{H}_2\text{O}_2$  residual level in pressed Tofu obtained from a local market. As shown in Table 2, the colorimetric methods (HRP and FOX assay) generate approximately 10% higher  $\text{H}_2\text{O}_2$  level than our fast electrochemical method. The higher  $\text{H}_2\text{O}_2$  level detected by the colorimetric methods could be ascribed

**Table 2 –  $\text{H}_2\text{O}_2$  concentration detected in pressed Tofu sample in pH 7.4 PBS by amperometric single-use Pt-MWCNT/C electrode sensor strip and colorimetric methods.**

	Test 1 ( $\mu\text{M}$ )	Test 2 ( $\mu\text{M}$ )	Test 3 ( $\mu\text{M}$ )	Mean ( $\mu\text{M}$ )	CV (%)
Pt-MWCNT/C sensor strip	862.3	901.2	893.1	885.5	2.31
FOX method	1168.7	1208.7	1161.7	1179.7	2.15
ODA + HRP	1015.6	950	1005.5	990.4	3.57

to the fact that  $\text{H}_2\text{O}_2$  level in the leaching solution of pressed Tofu was too high to be directly detected by the sensitive colorimetric method, as a consequence, several folds of dilution was employed before colorimetric tests were carried out. In contrast, sample solution could be directly employed without dilution for amperometric Pt-MWCNT/C sensor detection because the amperometric sensor demonstrated a linear detection range from 1 to 15 mM of  $\text{H}_2\text{O}_2$  as shown in Fig. S3a. The sample dilution employed in colorimetric method may possibly resulted in overestimated  $\text{H}_2\text{O}_2$  level as compared with that detected from undiluted sample by amperometric method. In addition to the advantage of facile and fast  $\text{H}_2\text{O}_2$  detection, no tedious dilution is required for using the as-prepared disposable electrode strip for detection because a quite broad linear detection range could be established (up to 15 mM) as shown in Fig. S3.

#### 4. Conclusions

Pt-MWCNT nanohybrid was prepared to modify the surface of a disposable screen-printed carbon electrode for fast and sensitive detection of  $\text{H}_2\text{O}_2$  by amperometric method. Pt-MWCNT modification not only lowered the applied potential to 300 mV but also generated a current approximately 100 fold higher than that of bare carbon electrode. The quality of as-prepared electrode strips was assured by its low coefficient of variation (<5%) on current measured at 5 s. The fast current response to  $\text{H}_2\text{O}_2$  with applied 300 mV could generate 3 linear detection ranges with sensitivity decreased with  $\text{H}_2\text{O}_2$  concentration. The sensitivity of linear detection range was 75.2, 120.7, and 142.8  $\mu\text{A mM}^{-1} \text{cm}^{-2}$  for  $\text{H}_2\text{O}_2$  concentration in the range of 1–15 mM, 0.1–1 mM, and 10–100  $\mu\text{M}$ , respectively. The lowest  $\text{H}_2\text{O}_2$  concentration could be measured by the as-prepared strip was 10  $\mu\text{M}$ . This fast response, single-use  $\text{H}_2\text{O}_2$  electrode strip was successfully applied to detect the  $\text{H}_2\text{O}_2$  level in green tea infusion and pressed Tofu with results comparable to that obtained from FOX and HRP enzymatic colorimetric methods.

## Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jfda.2017.08.005>.

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