Fiber Optic SPR Sensor Modified With Copper Oxide Nanoparticles for Highly Sensitive and Selective Detection of Dopamine

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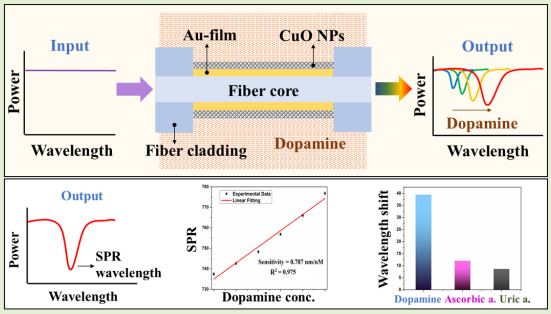
***Abstract*—In modern biomedical technology, the fabrication of high-performance sensors for dopamine detection is an important issue because dopamine is a major neurotransmitter and abnormal level of its concentration in the human body is accountable for several neurological diseases. Here, we report a highly sensitive and selective surface plasmon resonance (SPR) sensor modified with small copper oxide nanoparticles (CuO NPs) for experimentally detecting dopamine. Fiber optic sensing probes were fabricated by depositing a 50-nm-thick gold film over the unclad portion of a multimode optical fiber using magnetron sputtering and then further modified with synthesized CuO NPs (~7 nm). Detection of dopamine with the designed SPR sensor was achieved for a wide range of concentrations from very low concentrations with a limit of detection at 1.11 nM and up to 50 nM. The maximum sensitivity was achieved as 0.787 nm/nM and the limit of quantification was at 1.43 nM. To evaluate the selectivity of the studied sensor, experiments were also performed with ascorbic acid and uric acid, which usually coexist with dopamine in the biological fluids. Moreover, sensing characteristics, such as repeatability, linearity, and response time, were studied in detail. Taken together, these findings show that CuO NPs are excellent candidates as SPR sensitizer effectively improving the sensing performance of dopamine.**



***Index Terms*—Copper oxide nanoparticles (CuO NPs), dopamine, fiber optic sensors, selectivity, sensitivity, surface plasmon resonance (SPR).**

I. Introduction

DOPAMINE (3,4-dihydroxyphenethylamine) is a catecholamine neurotransmitter that plays a significant role in maintaining the functional activities of the cardiovascular, rental, central nervous, and hormonal systems in the human body as it carries brain messages in the form of nerve impulses [1], [2]. Therefore, dopamine is crucial in the regulation of cognitive functions such as stress, behavior, inspiration, emotions, and attention [3]. The typical concentration of dopamine in human cerebrospinal samples and urine is around 5 nM although its concentration in blood is less than 0.13 nM [4]. Abnormal concentration of dopamine is associated with several neurological diseases such as Parkinson's disease, Alzheimer's disease, Schizophrenia, and Huntington's disease [5]. Moreover, dopamine keeps the human heart from racing and dilates blood vessels in the intestine, being helpful in treating cardiogenic shock and kidney failure [6]. Thus, an accurate, sensitive, and rapid detection of dopamine in bodily fluids and biological systems is critical in the clinical diagnosis of neurological diseases. Over the years, various strategies and methods have been employed for dopamine detection such as high-performance liquid chromatography (HPLC) [7], chemiluminescence [8], colorimetric [3], electrochemical [9], fluorescence [10], mass spectrometry [11], and capillary electrophoresis [12]. Most of these techniques do not meet the growing requirements and have the drawbacks of bulky, prior chemical treatment of the sample, difficulties in surface-functionalization, expensive, and overlapping in the oxidation potential of interfering species such as ascorbic acid and uric acid that

Manuscript received 4 November 2023; revised 9 December 2023; accepted 10 December 2023. Date of publication 9 January 2024; date of current version 29 February 2024. This work was supported by Fondazione Cariplo under Grant 2017-2075. The associate editor coordinating the review of this article and approving it for publication was Prof. Carlos Marques. *(Corresponding author: Paola Saccomandi.)*

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This article has supplementary downloadable material available at https://doi.org/10.1109/JSEN.2023.3343600, provided by the authors.

Digital Object Identifier 10.1109/JSEN.2023.3343600

coexist with dopamine in biological fluids. Citing these limitations, it is essential to develop a new analytical method for dopamine detection having low cost, high sensitivity, biocompatibility, easy fabrication, high efficiency, and good selectivity.

Compared with various types of sensors, optical sensors based on surface plasmon resonance (SPR) technique have shown excellent performance due to their fast response, reusability, flexibility, label-free detection, and immunity to electromagnetic interference [13]. However, conventional SPR sensors require complex alignment and coupling processes, which increase the sensor size and reduce stability [14]. Optical fiber sensing technology not only obtains the benefits of optical sensors, but also has good merits of miniaturization, high sensitivity, easy integration, and no need for alignment and coupling [15]. Fiber optic SPR sensor is a new generation of high-precision optical sensor, which can remotely monitor the sample and take on significant importance for point-of-care clinical assessment [16]. In the past few years, several kinds of fiber optic sensors have been developed with different conduction modes such as multimode [17], few modes [18], and single mode [19], and different geometries such as D-shaped fiber [20], tapered fiber [21], and U-shaped fiber [22]. The basic mechanism of SPR sensing is the excitation of charge density oscillations (i.e., surface plasmons) at the metal–dielectric interface, and the electric field associated with surface plasmons is very sensitive to the change in refractive index (RI) or concentration of the layer adjacent to the modification layer [24]. To date, fiber optic SPR sensing technology is under investigation for the detection of biomolecules such cortisol, alanine aminotransferase [27], [28], and dopamine. However, the use of SPR sensors for monitoring dopamine and other small biomolecules is very limited and the reported results are very promising for developing a new generation of sensors [26]. For example, Sun et al. [27] experimentally developed an SPR sensor using a gold-supported graphene composite film on a D-shaped optical fiber. The results demonstrated a selective SPR response of the designed dopamine sensor in the concentration range from 10^{-10} to 10^{-6} M with a maximum RI sensitivity of 1539 nm/refractive index unit (RIU). In another experimental work, a rapid and accurate detection of nonenzymatic glucose was performed at low concentration by SPR sensor modified with $MoSe_2$/ZnO composite film [28]. Recently, another SPR sensor was reported with a bilayer structure of chitosan and gold film to sense dopamine [29]. The developed sensor showed a good stability in the linear range of 0.1 nM–1 μM and an RI sensitivity of 8.85°/RIU with a limit of detection (LOD) as 0.007 nM and an affinity constant of 1.383×10^8 M^{-1}. Thus, fiber optic SPR sensing technology has become an efficient alternative tool for the detection of small biomolecules like dopamine. However, more efforts are still needed to enhance the sensor's sensitivity and selectivity for the detection of very small concentrations.

Recent research has suggested that metal oxide nanoparticles (NPs) as sensitization and surface modification layers in traditional fiber optic sensors can achieve unprecedented enhancement in sensing performance [30], [31]. As a result, metal oxide NPs have received significant consideration for their promising applications in optoelectronics, nanodevices, nanoelectronics, information storage, and biosensors [32]. Among them, copper oxide (CuO) NPs prove to be excellent candidates for dopamine detection due to their useful properties such as better thermal conductivity, high-temperature superconductivity, low toxicity, chemical stability, good catalytic behavior, small bandgap, spin dynamics, and simplicity in synthesis process [33]. So far, many chemical and physical methods with different morphologies, particle sizes, and surface areas have been practiced for the synthesis of CuO NPs and their further utilization in the field of dopamine sensors [34], [35], [36]. For instance, a bioelectrochemical sensing approach was employed using CuO NPs-decorated graphene oxide sheets to detect dopamine [34]. The fabricated dopamine sensor reported a high sensitivity of 0.806 μA/μM over a broad linear range of 0.25–17 μM with an LOD as 2.6 nM. Recently, Azharudeen et al. [35] reported an ultrasensitive and selective electrochemical detection of dopamine based on CuO NPs and polyvinyl alcohol (PVA) nanocomposite-modified electrode. CuO NPs were modified with PVA as a capping agent to sense dopamine with a maximum sensitivity of 183.12 $\mu A \cdot mM^{-1} \cdot cm^{-2}$ and a detection limit of 0.017 μM. In addition, a fluorescent sensor based on green-synthesized CuO NPs and tyrosinase showed a selective response of dopamine with a detection limit of 5 μM [36]. Thus, it can be concluded that the electric field intensity can be effectively enhanced by applying CuO NPs in the sensitive layer and thus improve the performance of the designed SPR sensor.

Inspired by recent publications, we experimentally propose a highly sensitive and selective fiber optic SPR sensor modified with CuO NPs to detect dopamine in the concentration range from 0 to 50 nM. For this purpose, the CuO NPs synthesized by a simple solution technique were deposited over gold-coated fiber optic sensing probes. A detailed evaluation of the sensor in terms of sensitivity, linearity, selectivity, LOD, limit of quantification (LOQ), repeatability, stability, and response time is demonstrated. The fiber optic SPR sensor fabricated in this study showed high scalability and broad prospects, thus revealing that CuO NPs have promising applications in clinical diagnosis and biosensors. To the best of authors' knowledge, this is the first report on CuO NPs-modified fiber optic SPR sensor for dopamine detection.

II. Experimental Section

A. Materials and Sample Preparation

Dopamine hydrochloride, L-ascorbic acid (99%), and uric acid (≥99%) were provided by Sigma-Aldrich Chemicals, Milan, Italy. The gold target (99.99%) having a diameter of 50 mm was supplied by Nanovision S.r.l., Brugherio (MB), Italy, Copper acetate, HPLC plus grade water, and polyethyleneimine (PEI, Mw 25 kDa, branched) were purchased from Sigma-Aldrich Chemicals, Rehovot, Israel. Sodium hydroxide was purchased from Bio-Lab Ltd., Jerusalem, Israel, and glacial acetic acid from Carlo Erba, Barcelona, Spain. To detect low concentrations of dopamine, different samples of dopamine (10, 20, 30, 40, and 50 nM) were prepared in deionized water. The refractive indices of all the samples were measured with the help of an Abbes

Refractometer with a measurement accuracy of 0.0005 in white light, and the values were found to be the same for each sample.

B. Synthesis and Characterization of CuO NPs

CuO NPs stabilized with acetate ligands were synthesized by a simple solution technique [37]. Briefly, a 150 mL aqueous solution of 0.02 M copper acetate and 0.5 mL glacial acetic acid was refluxed while vigorously stirring. Once refluxing of the solution was achieved, a 0.550 g NaOH was immediately added, and the reaction was allowed to continue to reflux for 1 min. Then, the solution was cooled to room temperature and centrifuged at 4000 r/min for 10 min to separate CuO NPs from the reaction mixture. The resulting pellet was redispersed in water and the colloidal solution of CuO NPs was kept at room temperature for further use. The copper concentration of the samples was determined by a previously described PEI colorimetric method using UV–visible spectrophotometric measurement at 275 nm (Ultrospec 2100 pro UV/vis spectrophotometer, Biochrom Ltd., Cambridge, U.K.) [38], [39]. The morphology of the particles was assessed by transmission electron microscopy (Tecnai T12 G2 TEM, FEI Technologies Inc., Hillsboro, OR, USA), and size distribution was determined by dynamic light scattering (DLS) (ZetaSizer Nano ZS, Malvern Panalytical, Malvern, U.K.) (Fig. S1).

C. Design and Fabrication of Fiber Optic SPR Sensors

For the sensor fabrication, a step-index multimode optical fiber with a length of 8 cm, core diameter of 600 μm, and numerical aperture of 0.22 (Thor Labs, Bergkirchen, Germany) was considered with the cleaved ends. The refractive indices of the core and cladding are 1.457 and 1.439, respectively. Initially, a 1 cm length of fiber cladding from the middle portion and 0.5 cm from the end faces were carefully removed using a sharp stainless-steel blade. After this, the cladding removed central fiber was cleaned with acetone, followed by distilled water to remove any ionic impurities. After cleaning the fiber, the unclad portion of the fiber was coated with a 50 nm Au film under the Au target of direct current magnetron sputtering (Korvus Technology Hex system) in an argon atmosphere at 0.4 Pa, discharge current of 50 mA, and power of 21 W. Before coating the optical fiber, the deposition chamber was evacuated down to 6×10^{-3} Pa, and the target was presputtered for 10 min. After Au deposition, the sensing surface was modified with CuO NPs by immersing the Au-coated fiber in a beaker containing an aqueous colloidal solution of CuO NPs (3.82 mg/mL). The fiber was kept in the solution for at least 20 min and then dried with the help of a dryer. This process was repeated three times. Finally, the fibers were rinsed with distilled water and then kept at room temperature for 24 h before use. The coating of Au layer and CuO NPs over optical fiber was examined by the SEM (Zeiss Sigma 500) and EDS (Oxford Instruments Ultimax 65), as shown in Fig. S2.

D. Experimental SPR Sensing Setup

The experimental sensing setup used for the detection of dopamine is depicted in Fig. 1. A tungsten-halogen light source with spectral emission between 200 and 1200 nm (Avantes, Apeldoorn, The Netherlands) and an optical spectrometer (Avantes) of detection range from 200 to 1200 nm were used. Both the light source and the spectrometer were placed at stages to get the efficient coupling of the light into the fiber. Thereafter, the fabricated fiber optic sensing probe was mounted on a flowcell with the help of two rubber corks fit at both ends. To record the SPR spectra of different dopamine concentrations, the light was launched from the input end of the fiber and spectrally interrogated using the spectrometer from the other end. The spectrometer was further interfaced with a computer to record the spectra. For this, a preliminary test was performed by injecting deionized water (i.e., 0 nM dopamine solution) into the flowcell with the help of a surgical syringe, and the SPR response was measured. Similarly, other dopamine solutions (i.e., 10, 20, 30, 40, and 50 nM) were sequentially injected from low to high concentration and the corresponding SPR spectra were recorded. With a surgical syringe, the sample solutions can be injected and easily taken out of the flowcell. Further, the sensing probe and flowcell were rinsed with distilled water before starting of each measurement. All the experiments were performed at room temperature and repeated over three times with the same sensing probe over a period of different days.

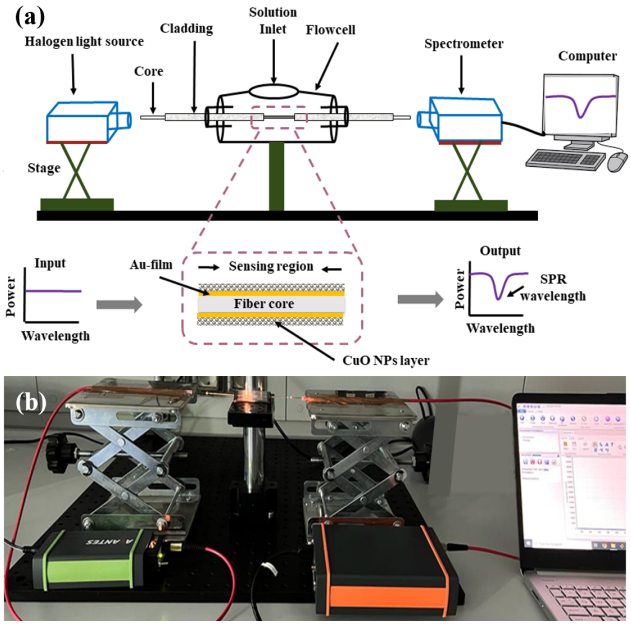

Fig. 1. (a) Schematic representation. (b) Practical view of the studied SPR sensing setup for dopamine detection.

III. Results and Discussion

A. Dopamine Detection Using Au-Coated Fiber Optic SPR Sensor

The most established technique for the excitation of surface plasmons is the Kretschmann–Raether configuration [23] and has been employed in this study for the detection of dopamine. To evaluate the performance of all the materials employed in the sensor fabrication (i.e., Au layer and CuO NPs), initially, the experiments were carried out using an Au-coated fiber optic SPR sensing probe without CuO NPs deposition.

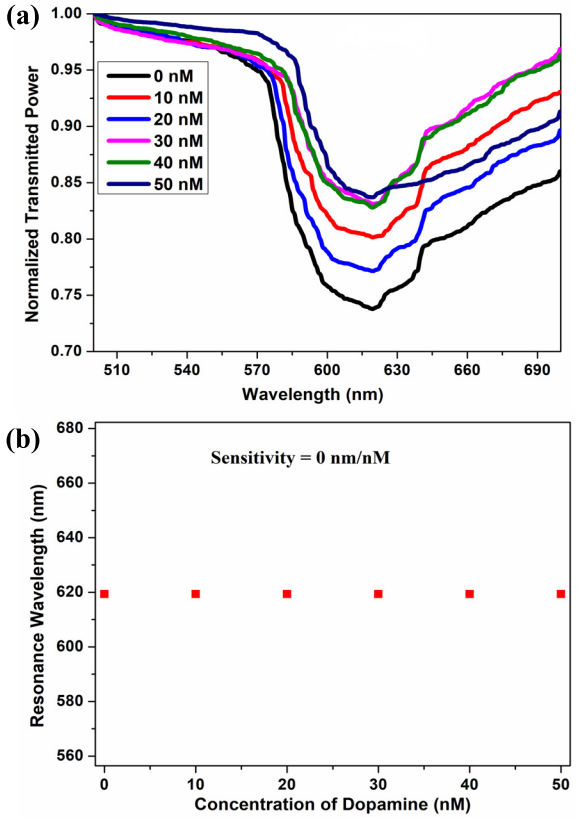

Fig. 2. SPR sensor coated with Au-film only. (a) Transmitted SPR curves for the dopamine detection. (b) Variation in resonance wavelength with various concentrations of dopamine.

To record the SPR spectra, a dopamine solution with 0 nM concentration was injected into the flowcell and the SPR response was recorded as a function of wavelength. A sharp drop in the transmitted power was detected due to the complete transfer of energy from the evanescent wave to the surface plasmon wave at a particular wavelength (i.e., resonance wavelength) of 619.35 nm. Subsequently, dopamine solutions with concentrations ranging from 10 to 50 nM were poured into flowcell, and the corresponding SPR spectra were recorded. After each measurement, the fiber optic sensing probe and flowcell were washed with distilled water and dried completely to remove any effect of the prior solution. Fig. 2(a) shows the transmitted SPR curves for different dopamine concentrations to specify their resonance wavelength. The position of resonance wavelength is the same for each concentration of dopamine, i.e., 619.35 nm [Fig. 2(b)] The experimental results clearly indicate that, regardless of the increase in dopamine concentration from 10 to 50 nM, there is no binding of dopamine molecules with Au film. As a result, there was no change in the effective index of the sensing layer, and thus, no shift in the resonance wavelength of the transmission curves was noticed.

B. Dopamine Detection Using CuO NPs-Modified Fiber Optic SPR Sensor

After the Au-coated SPR sensor showed insensitivity and incapability to detect dopamine at this concentration range, dopamine detection was continued by the CuO NPs-modified

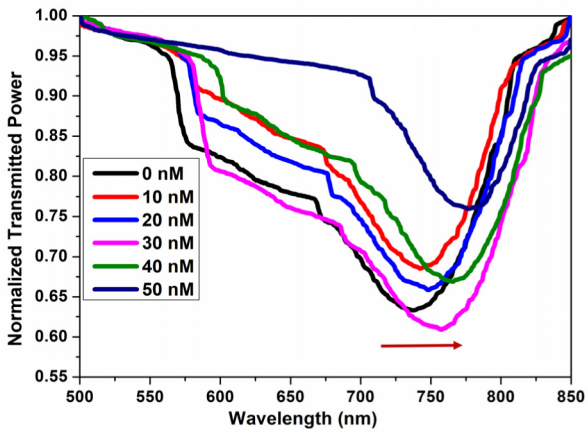

Fig. 3. Transmitted SPR curves for the CuO NPs-modified fiber optic sensing probe toward dopamine detection.

fiber optic SPR sensor, in the range of 0–50 nM. At 0 nM concentration, the resonance wavelength measured by the CuO NPs-modified sensing probe was 737.45 nm, which is located at a much higher wavelength when compared with the Au-layer only. The refractive indices of all these samples were measured with Abbes Refractometer, and their values were found to be similar. It means that the designed SPR sensor is not an RI sensor, but a concentration sensor. Afterward, a dopamine solution with a concentration of 10 nM was injected into the flowcell, and the resonance wavelength was observed as 742.59 nm, indicating a redshift of 5.14 nm. Similarly, the SPR spectra were measured for higher concentrations of dopamine (Fig. 3). It was found that with an increase in the concentration of dopamine, there is a red shift in the resonance wavelength. For dopamine samples with concentrations of 20 nM, 30 nM, 40 nM, and 50 nM, the resonance wavelengths were noticed as 748.31, 756.87, 765.99, and 776.82 nm, respectively. The higher wavelength shift can be explained with the strong electromagnetic coupling between the propagating surface plasmon waves caused by the Au layer and localized surface plasmon waves caused by the CuO NPs.

Second, the used CuO NPs act as bio-recognition materials for the adsorption of dopamine molecules and raise the light absorption to supply maximum excitation energy for effective charge transfer. This might be due to the presence of catechol groups of the dopamine molecules, which have a strong chelating character and can bind to the surface of CuO NPs [40]. This process produces a larger electric field at the sensing interface, which in turn causes the effective resonance wavelength shift. Furthermore, when the fiber optic sensing probe was immersed in the CuO NPs concentration, the effective fractional volume ratio of CuO NPs on the Au-layer surface is increased significantly. During this process, the CuO NPs come nearer to each other until a saturation value is achieved, and thus, a shift in the resonance wavelength for dopamine detection was monitored.

C. Evaluation of Performance Parameters for Dopamine Detection

The performance of the developed sensor is measured in terms of its various performance parameters such as sensitivity,

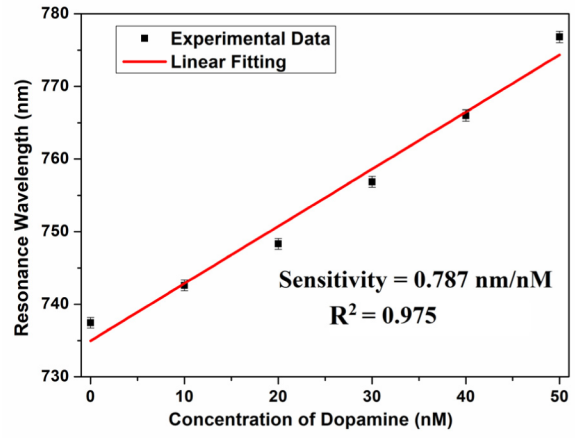

Fig. 4. Variation in resonance wavelength with various concentrations of dopamine for CuO NPs-modified SPR sensor.

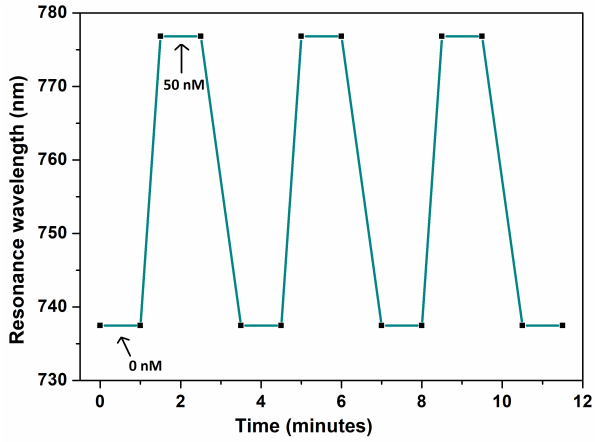

Fig. 5. Stability in time of CuO NPs-modified fiber optic sensing probe for dopamine detection.

linearity, repeatability, LOD, LOQ, stability in time, and selectivity. These critical parameters decide the application and sustainability of the designed sensor and have been discussed in detail.

1) Sensitivity, Linearity, and Repeatability: Sensitivity is defined as the shift in resonance wavelength per unit change in the concentration of the sensing analyte.

To calculate this, the variation in resonance wavelength with dopamine concentration for the CuO NPs-modified fiber optic sensing probe is plotted in Fig. 4. The results confirmed the linear correlation between the concentrations of dopamine and the resonance wavelength, with a sensitivity 0.787 nm/nM. Sensor repeatability describes the ability of a sensor to deliver consistent results under well-sustained operating and environmental conditions. To check the repeatability of the fabricated sensing probes, the experiments were repeated over three times with the same sensing probe over a period of different days and a standard variation of about 0.1% was detected in the resonance wavelengths (error bars in Fig. 4).

2) LOD and LOQ: The LOD is defined as the detectable concentration of analyte near zero concentration considering the spectral resolution of the spectrometer [41] and can be written numerically as

$$\mathrm{LOD} = \Delta\lambda / S_0 \tag{1}$$

where $\Delta\lambda$ denotes the spectral resolution of the spectrometer (0.575 nm in our case) and S_0 corresponds to the sensitivity near zero concentration (i.e., 0.514 nm/nM). On the other side, the LOQ measures the lowest quantity of the analyte present in a solution [41], which is given by

$$\mathrm{LOQ} = \delta\lambda / S_0 \tag{2}$$

where $\delta\lambda$ is the standard deviation in the resonance wavelength near zero concentration of analyte. The experiments were performed over three times and its value near zero concentration was detected as 0.737 nm for sensing dopamine. After calculation, the corresponding values of LOD and LOQ for sensing dopamine were found to be 1.11 and 1.43 nM, respectively, which pointed toward an ability to detect a lower concentration of dopamine efficiently. The LOD for the proposed sensor (i.e., 1.11 nM) is better than other sensing approaches using CuO NPs as coated material for dopamine detection. For example, LOD for bio-electrochemical sensing with CuO NPs-decorated graphene oxide sheets was 2.6 nM [34]. Similarly, for CuO NPs and PVA nanocomposite modified electrode, LOD was observed as 17 nM [35]. Moreover, a fluorescent sensor based on CuO NPs and tyrosinase resulted LOD of 5000 nM [36].

3) Stability in Time: To observe the stability in time of the CuO NPs-modified fiber optic sensing probe, two dopamine solutions having concentrations of 0 and 50 nM were considered. Initially, 0 nM dopamine solution was inserted into the flowcell, and the corresponding SPR spectrum was recorded for which the resonance wavelength turned out to be 737.45 nm. After 1 min, the SPR spectrum was again measured for the same solution to check the stability of the sensor, and a very small change in the resonance wavelength was detected.

Then, the initial dopamine solution was taken out and filled with a 50 nM solution. The difference in time between inserting the dopamine solution into the flowcell and obtaining the SPR spectrum for that solution takes approximately 30 s, as represented by the increasing slope in Fig. 5.

The resonance wavelength for the 50 nM dopamine solution was around 776.82 nm, and it gave a slight variation after 1 min of saturation. However, when the dopamine solution is evacuating from the flowcell, it takes about 1 min to wash and dry the sensing probe, and this is illustrated by the decreasing slope in Fig. 5. This completed one cycle of the experiment, and this cycle was repeated more than three times. The time responses were nearly identical during each cycle, confirming the good repeatability of the fabricated SPR sensor.

4) Selectivity Test: Selectivity is an important parameter in biological and analytical sensing applications. It is defined as the ability of a sensor to specifically detect desired analytes in comparison to other analytes of the same group or that are likely to interrupt the detection. The experiments for selectivity test were performed with respect to some other potentially interfering analytes, i.e., ascorbic acid and uric acid which co-exist with dopamine in the biological fluid of the central nervous system.

TABLE I
PERFORMANCE COMPARISON OF VARIOUS SENSORS FOR DOPAMINE DETECTION

Detection method	Materials used	Sensitivity	LOD	Linear range	Ref.
SERS	Au-NPs/graphene/epoxy resin	-	3.3 μM	5 - 90 μM	[42]
Electrochemical	Au/SiO_2	-	1.98 μM	10 - 500 μM	[43]
Colorimetric	Au-NPs/PET	-	0.5 μM	0.5 - 500 μM	[44]
Colorimetric	Graphene nanoribbons	-	0.035 μM	0.1 - 50 μM	[45]
Photoelectrochemical	BSA/$AgInS_2$/Au-NRs/GO	4.5 nA/μM	66.8 nM	0.3 - 10 μM	[46]
Electrochemical	Au-NPs/GO	-	10 nM	0.02 - 1 μM	[47]
DPV	ZnO	2.3681 μA μM^{-1} cm^{-2}	4 nM	0.1 - 374 μM	[48]
Electrochemical	Cu/Cu_2O/reduced GO	0.806 μA/ μM	2.6 nM	0.25 - 17 μM	[34]
DPV and Amperometry	Fe_3O_4	0.053 nA/ nM	0.8 nM	0.002 - 0.6 μM	[49]
Electrochemiluminescence	ZnSe/GO	-	0.6 nM	1 - 10^4 nM	[50]
SPR	Chitosan/Au	8.850 ^{0}/RIU	0.007 nM	0 - 1000 nM	[29]
SPR	Oxygen-deficient cerium oxide NPs	-	0.045 pM	10^{-7} - 0.1 μM	[51]
SPR	Au/CuO NPs	0.787 nm/nM	1.11 nM	0 - 50 nM	This work

Abbreviations: Au-NPs: gold nanoparticles; GO: graphene oxide; PET: poly(ethylene) terephthalate; SERS: surface-enhanced Raman spectroscopy; ZnSe: zinc selenide; BSA: Bovine Serum Albumin; NRs: nanorods; DPV: Differential Pulse Voltammetry

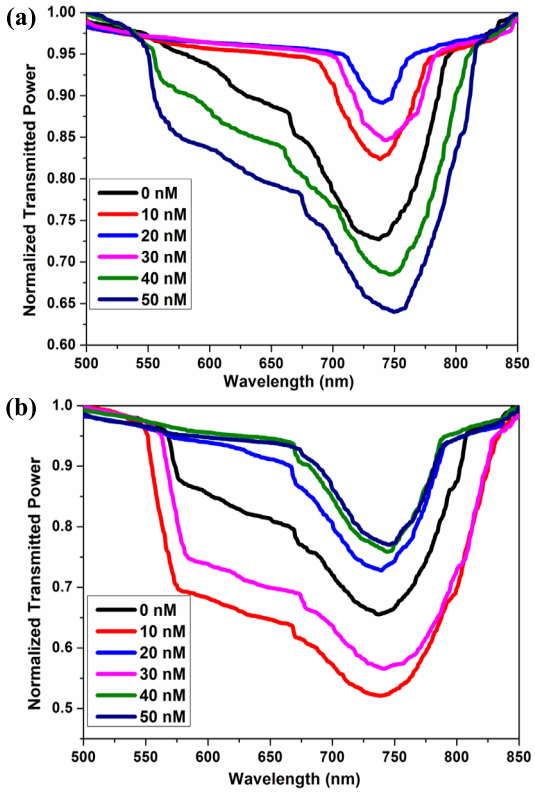

Fig. 6. SPR sensor modified with CuO NPs. (a) Transmitted SPR curves for the detection of ascorbic acid. (b) Transmitted SPR curves for the detection of uric acid.

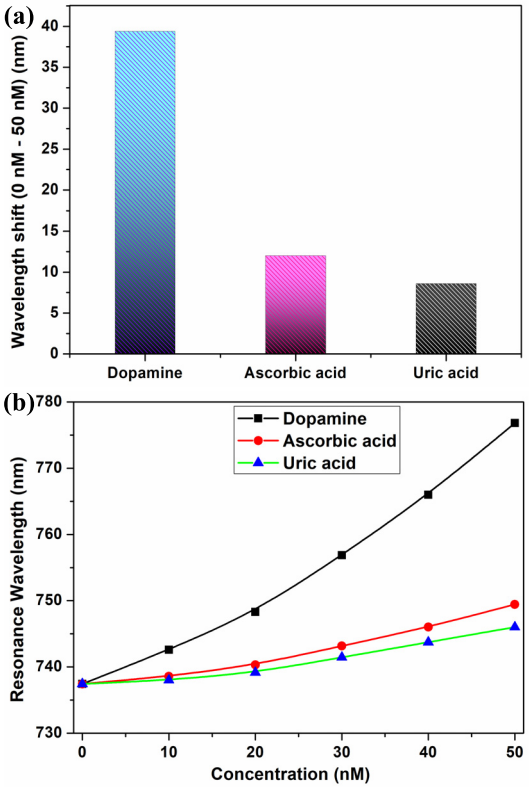

Fig. 7. (a) Selectivity bar diagram. (b) Variation in resonance wavelength of the fabricated SPR sensor exposed to various analytes.

The solutions of ascorbic acid and uric acid having concentrations equal to that of dopamine (i.e., 0–50 nM) were prepared and injected into the flowcell. Fig. 6(a) and (b) shows the SPR spectra of the SPR sensor for the detection of ascorbic acid and uric acid, respectively. It can be clearly seen that the sensor shows a very small shift in resonance wavelength for these analytes when compared to dopamine. For ascorbic acid and uric acid, the maximum resonance wavelength shift from 0 to 50 nM concentrations was observed as 12.00 and 8.57 nm, respectively, while the corresponding shift for dopamine detection was 39.37 nm.

Fig. 7(a) shows a bar diagram of the shift in resonance wavelength for changes in different analytes concentration from 0 to 50 nM, and Fig. 7(b) depicts the corresponding variation in resonance wavelength with concentration for these analytes. Therefore, the fabricated sensor demonstrated the highest selectivity toward dopamine detection among the selected analytes, which speaks about the specific nature of the SPR sensor for dopamine only. The high selectivity of dopamine toward CuO NPs is due to the catechol groups that can interact with transition metals such as copper by forming strong coordination bonds to give catechol-metal complexes.

It means that the dopamine molecules bind strongly to the CuO NPs surface and result in higher resonance wavelength shift compared to ascorbic and uric acids. Table I shows the performance comparison of the proposed sensor with previously reported sensors toward dopamine detection,

including surface-enhanced raman spectroscopy (SERS), electrochemical, electrochemiluminescence, and colorimetric sensors having different coating materials. Although these techniques are sensitive and stable, they still have some shortcomings. For example, the SERS method requires close contact between the enhancing surface and the sensing analyte and has limited selectivity and reusability of the substrates [42]. For electrochemical sensors, the biggest challenges encountered are low detection limit and suppressing the nonspecific adsorption of interfering species [34], [43], [47]. Electrochemiluminescence technique is time-consuming, having poor precision, and troublesome to realize automation [50]. For the colorimetric method, analysis of colorless compounds is not possible and does not work in IR and UV regions [44], [45]. On the other hand, SPR sensors based on glass chips [29], [51] show better detection limits than these techniques. The proposed work utilizes optical fiber as a substrate, which offers several advantages such as electromagnetic interference immunity and remote detection, which are not possible for glass chip-based sensors. Although LOD and linear range in the proposed work are comparable to those reported in existing literature, it shows much higher sensitivity toward dopamine detection. Thus, the fiber optic SPR sensor here presented is well-suited for accurate, selective, and highly sensitive dopamine measurement.

IV. Conclusion

This work presents a newly designed CuO NPs-modified fiber optic SPR sensor for the detection of very low dopamine concentration (0–50 nM). The sensor demonstrated high sensitivity toward dopamine detection up to 0.787 nm/nM with a detection limit of 1.11 nM and the selective detection toward dopamine in the presence of ascorbic and uric acids. Moreover, the sensor had excellent linearity, repeatability, time response, and stability. The advantages of simplicity and proficiency in real-time target detection by this sensor make it superior to other sensing techniques.

Acknowledgment

The authors acknowledge Shaked Ashkenazi, who helped with the synthesis and characterization of copper oxide nanoparticles (CuO NPs) as a part of her research project (Department of Biotechnology Engineering, Braude College of Engineering, Karmiel, Israel).

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Open Access funding provided by 'Politecnico di Milano' within the CRUI CARE Agreement