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Electrochemical Analysis of CuO NPs in Artificial Saliva at Different Concentrations, pH, and Scan Rates Using Cyclic Voltammetry

Maha Hussaien Al-Mhana[a], Hawraa Khalid Aziz[a], Muhammed Mizher Radhi[*b]

[a] Dental Techniques Department, Health and Medical Techniques, Middle Technical University, MTU – Iraq
[b] Radiology Techniques Department. Health and Medical Techniques, Middle Technical University, MTU – Iraq

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ABSTRACT

In this study, the effect of nanoparticles of copper oxide (CuO NPs) dissolved in heat polymerizing acrylic-based soft liner was studied in artificial saliva that was used in the total denture in the mouth was identified, using the electrochemical method, to characterize the extent of the effect of nanoparticles on the oral cavity. Different concentrations (0.3% and 0.5% CuO NPs), pH, scan rates, and reproducibility were studied. The study concluded that the low percentage of 0.3% CuO NPs has less effect than the percentage of 0.5% CuO NPs by redox reaction in the artificial saliva. Furthermore, the acidic pH of the medium has less affected in oxidant that shows reduction peak appeared in the range of pH 2-6, so the nanoparticles of CuO save the acidity of the mouth, while the alkaline pH causes the oxidative effect in the artificial saliva. It can be used the nano copper to improve the chemical properties in the mouth medium.

1. Introduction

Studies have recently expanded to the applications of nanomaterials in various fields, especially in the field of dentistry (Piedras, et al., 2021; Saleh, 2015; Brett, et al., 2004; Vázquez, et al., 2019; Radhi, et al., 2015). The chemical and physical properties of copper oxide nanoparticles (CuO NPs) have different from the microparticles with high accuracy in the solubility in polymers. With high surface area, small volume and synthesis material, low-cost production processing, and non-toxic nature, CuO NPs are an adsorbent effectively used to reduce various pollutants from the aqueous environment. Figure 1 (Ighalo, et al., 2021).

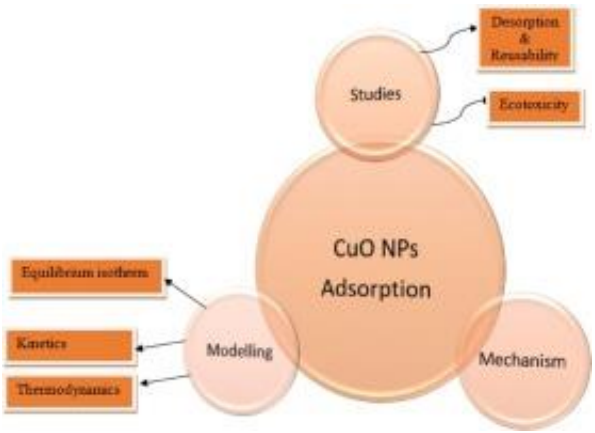

Fig. 1. Mechanism CuO NPs absorption in water

***Corresponding author:** Muhammed Mizher Radhi, Radiology Techniques Department of Health and Medical Techniques, Michigan Technological University - United States of America

E-mail: mmradhi@yahoo.com

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The electrochemical properties of copper oxide nanoparticles were studied both at the microparticle and at the group level in neutral solutions by the electrode impingement method and cyclic voltammeter, respectively (Zampardi, et al., 2018). Different forms of copper oxide nanoparticles were prepared by cetyl trimethyl ammonium bromide (CTAB) and sodium dodecyl sulfate (SDS) co-precipitation method. Synthesized copper nanoparticles were used to prepare modified carbon paste (MCPE) electrodes for the electrochemical detection of dopamine (DA) at pH 6.0 (Reddy, et al., 2012).

Electrochemically studied copper oxide nanoparticles (CuO NPs) with sulfonated poly(ether ether ketone) copolymer (SPEEK) and sulfonated polyether (SPEEK/CuO) nanoparticles on gold electrodes. The electrochemical performance of the fabricated electrodes examined that CuO NPs improved the electrochemical properties of SPEEK, and the effect of quantum size was observed for good adsorption by SPEEK/CuO nanocomposite compared to SPEEK polymer and CuO NPs alone (Fayemi, et al., 2022).

A new study of all Ag NPs, ZnO NPs, and ZnO with Ag NPs as mixtures showed significant instability and high destabilization within 24 hours of analysis. The reactions of NPs in the saliva of humans could be reversible. The mixtures have different antibacterial activities and destabilization kinetics, depending on the composition of the NPs and the types of fluids (Pokrowiecki, et al., 2019). CuO-NPs are increasingly being used in consumer-related products, which have been shown to increase with oral ingestion. Digestion of nanoparticles can alter their physicochemical behavior and toxicity (Büttner, et al., 2022).

The effective study of using cinnamon nanoparticles (Ci NPs), Zinc oxide nanoparticles (ZnO NPs), and Copper oxide nanoparticles (CuO NPs) as antibacterial treatment of a luting and lining glass ionomer cement (GIC) which was used for the cementation of orthodontic bands to the tooth . The in vivo study of using cinnamon nanoparticles (Ci NPs), zinc oxide nanoparticles (ZnO NPs), and copper oxide nanoparticles (CuO NPs) as antibacterial treatment of glass ionomer cement (GIC) that was used to cement orthodontic bands on teeth (Shafaee, et al., 2022). In this study, CuO NPs with heat polymerizing acrylic-based soft liner were used to find the electrochemical effect in artificial saliva (AS) at different concentrations and pH.

2. Materials and Methods

Materials

Artificial saliva (AS) was prepared by scientific lab of Shafeeq comp (Iraq), CuO NPs 99%, 40 nm was received from Skyspring nanomaterials, Inc. 2935 Westhollow Drive, Houston, TX 77082, USA, heat polymerizing acrylic-based soft liner manufacturer – Vertex Source - Netherland, 0.1M of HCl, 0.1M of NaOH used as a buffer solution, and deionized water.

Methods

Instrumentation

The cell of cyclic voltammetry (CV) cell technique was used by added of 10ml of artificial saliva in this cell and immersing the glassy carbon electrode (GCE) as the working electrode, Ag/AgCl as the reference electrode, and platinum wire as the counter electrode, then the three electrodes were connected with a potentiostat (potentiostat/galvanostat) NuVant System EZstat (U.S.A), to the calculation of the results by the cyclic voltammogram appeared in the screen of computer (Kilmartin, et al., 2001) as shown in Fig.2.

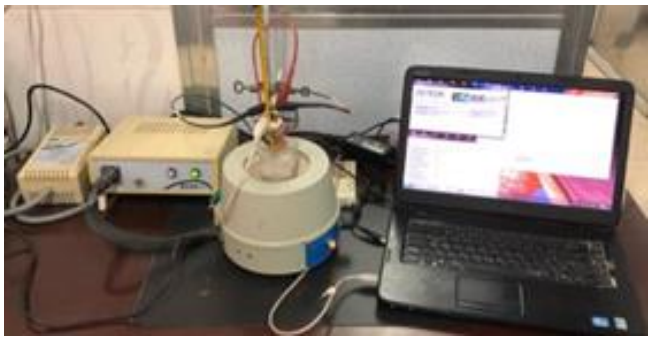
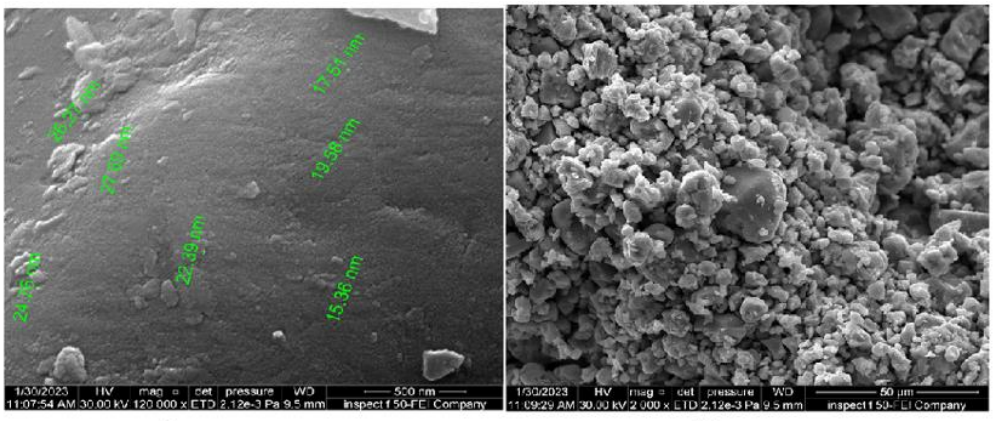


Fig. 2. Cyclic voltammetry set up

Scanning Electron Microscopy (SEM)

The range of the dimension of CuO NPs found from scanning electron microscopy (SEM) analysis is about 15.36-26.27 nm as shown in Fig. 3-A. The morphology of CuO NPs has spherical form in the nano dimension as shown in Fig.3-B.



A B

Fig. 3. A: SEM of CuO NPs for the dimension particles; B: SEM of CuO NPs for the morphology form of particles

3. Results and Discussion

Effect of Different Concentrations Study

The electrochemical behavior of the different concentrations of copper oxide nanoparticles (CuO NPs) dissolved in heat polymerizing acrylic-based soft liner at 0.5% and 0.3% in artificial saliva shown in the cyclic voltammogram in Fig. 4, which have oxidation–reduction peak current at a potential of +125 and -50 mV respectively. It was found that CuO NPs act as an electro-catalyst of the redox process in the artificial saliva medium (Radhi & Al-Mulla, 2015; Radhi, et al., 2018). The higher concentration of 0.5% CuO NPs with polymer in artificial saliva enhanced the redox peak current as in the low concentration of 0.3%. also, the oxidation–reduction peak current of 0.5% CuO NPs with polymer was enhanced after increasing the concentration as shown in Fig. 5.

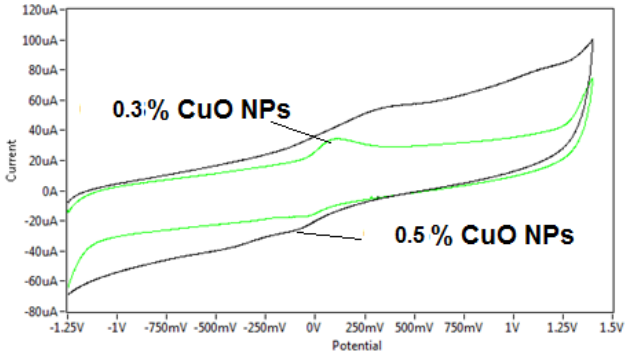


Fig. 4. Cyclic voltammogram of CuO NPs with heat polymerizing acrylic based soft liner on GCE at different concentration (0.3% and 0.5% CuO NPs) in artificial saliva at scan rate of 0.1 V sec-1.

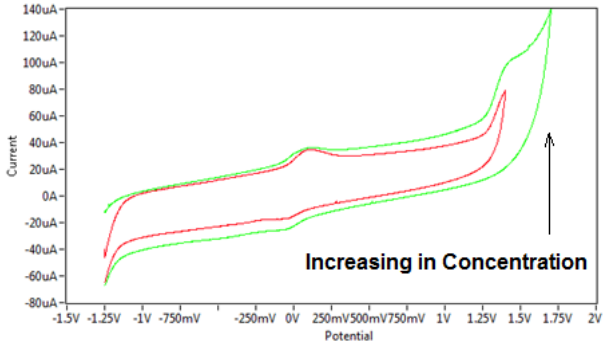


Fig. 5. Cyclic voltammogram of 0.5% CuO NPs with heat polymerizing acrylic based soft liner on GCE at different concentration in artificial saliva at scan rate of 0.1 V sec-1.

Effect Different Scan Rates Study

Other studies to confirm the redox reaction of 0.5% CuO NPs with polymer in artificial saliva have a good relationship of the current against the different scan rates as shown in Fig. 6. The relationship between the oxidation-reduction peak current against the scan rates illustrated in Fig. 7, with the straight line of the equations and high values of sensitivity as in the following equations (Radhi, et al., 2017):

Oxidation equation: Y = 230.3X + 7.333 with high sensitivity of R^2= 0.9724

Reduction equation: Y = -152.12X – 4.3333 with high sensitivity of R^2 = 0.9836

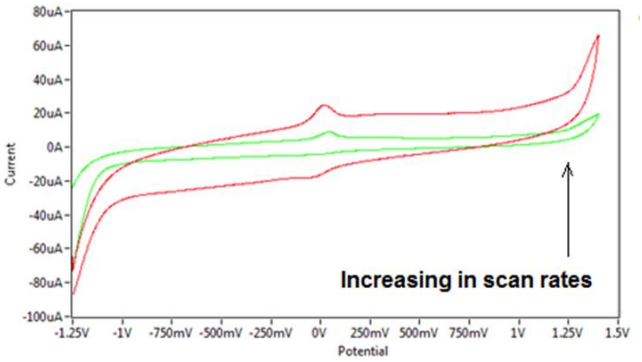


Fig. 6. Cyclic voltammogram of 0.5% CuO NPs with heat polymerizing acrylic based soft liner in artificial saliva at different scan rates of 0.01 - 0.1 V sec-1.

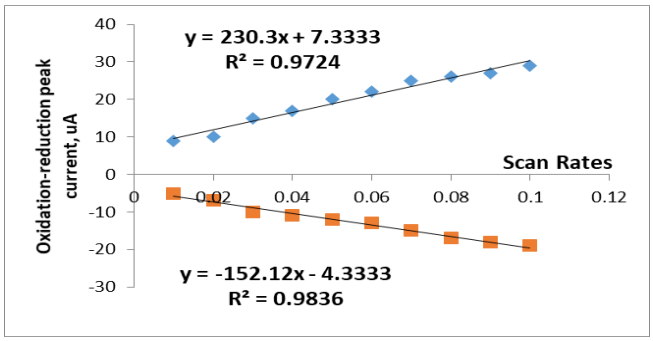


Fig. 7. Relationship between oxidation – reduction peak current of 0.5% CuO NPs with heat polymerizing acrylic based soft liner in artificial saliva against to different scan rates of 0.01-0.1 Vsec-1

Effect of Different pH Studies

The effect of different pH in the artificial saliva using CuO NPs mixed with heat polymerizing acrylic-based soft liner, which found the oxidation-reduction of CuO NPs has different peak current density against the pH values as in the following media:

In acidic pH: the study included the range of acidic pH from 2-6. Fig.8 and 9 illustrated the cyclic voltammogram of oxidation peak current for CuO NPs in these pH has gradually disappeared, so, the CuO NPs act as an antioxidant reagent in artificial saliva, that the behavior of nano copper in acidic pH appeared in Fig. 10 without oxidation peak current and enhanced the reduction peak current. The normal value of the pH in the mouth is acidic with a value about of 6.2 (Baliga, et al., 2013).

In alkaline pH: the study in an alkaline medium at the range from 7-12 and the cyclic voltammogram of CuO NPs was illustrated in Fig. 11, it appeared in the cyclic voltammogram that the current peak of CuO NPs was enhanced gradually in these pH as shown in Fig. 9, while the reduction current peak of the nanoparticles has been decreased in values of pH as shown in Fig. 10

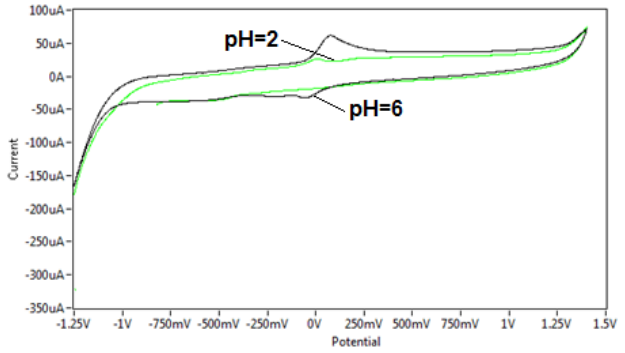


Fig. 8. Cyclic voltammogram of 0.5% CuO NPs with heat polymerizing acrylic based soft liner in artificial saliva in different pH (2-6) at scan rate of 0.1 V sec-1.

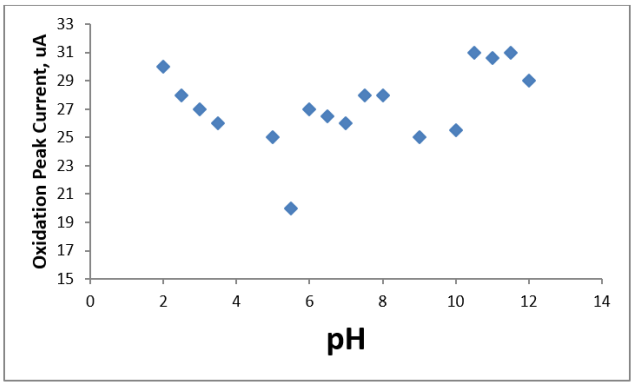


Fig. 9. Relationship between oxidation peak current of 0.5% CuO NPs with heat polymerizing acrylic based soft liner in artificial saliva against to different pH (2-12) at scan rates of 0.1 Vsec-1

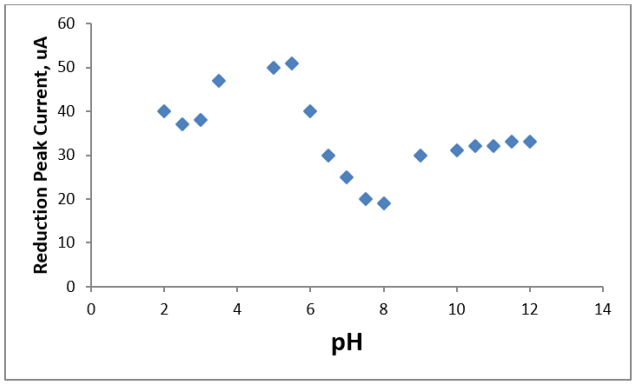


Fig. 10. Relationship between reduction peak current of 0.5% CuO NPs with heat polymerizing acrylic based soft liner in artificial saliva against to different pH (2-12) at scan rates of 0.1 Vsec-1

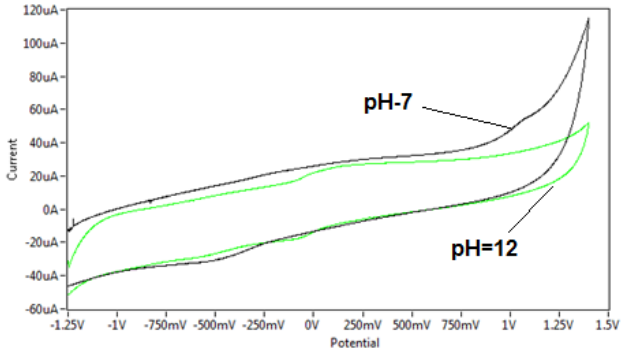


Fig. 11. Cyclic voltammogram of 0.5% CuO NPs with heat polymerizing acrylic based soft liner in artificial saliva in different pH (7-12) at scan rate of 0.1 V sec-1.

Reliability and Stability Study

In this study, a cyclic voltammogram can be evaluated by scanning the redox peaks of CuO NPs in artificial saliva ten times (Radhi, et al., 2019) as shown in Fig.12 to calculate the relative standard divination (RSD), this type of study gives the results of the research more reliability and increased the precision of the results. It was found the acceptance values of RSD of the oxidation peak current of CuO NPs has ±1.05% and reduction peak current has ±0.92%.

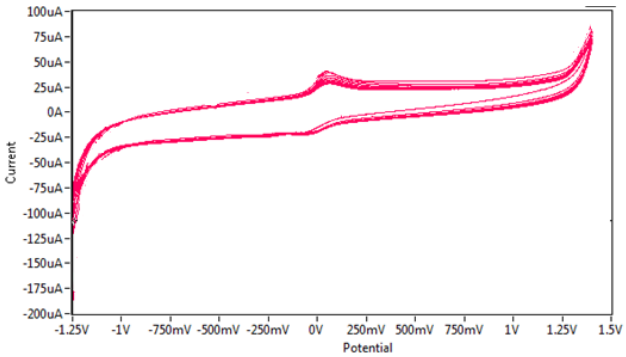


Fig. 12. Cyclic voltammogram of 0.5% CuO NPs with heat polymerizing acrylic based soft liner in artificial saliva at ten times scanning.

4. Conclusion

The electrochemical properties of copper nanoparticles were used to evaluate the reaction of nanoparticles in artificial saliva by changing the concentration and pH. It can be concluded that the low percentage of 0.3% CuO NPs in artificial saliva has less effect on oxidation reaction and the percentage of 0.5% CuO NPs has more oxidative stress. the acidic pH of the medium with the CuO NPs has less affected by oxidant that shows disappearing the oxidation peak current and appearing reduction peak in the range of pH 2-6, so the nanoparticles of CuO save the acidity of the mouth by the resistance to the pH, while the alkaline pH causes oxidative stress in the artificial saliva at the range of pH 7-12, so it can be used the CuO NPs in the complete denture to improve the properties of the mouth medium.

Competing Interests

The authors had no competing interests.

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