CoS2: Synthesis and Characterization Detection of Ascorbic Acid by Electrochemical Method

Rishita1 , B.Shantveer1,a)

1Rishi Health Centre, Delhi, India

**Corresponding Author:** a)[biradarshantveer5@gmail.com](mailto:biradarshantveer5@gmail.com)

**Abstract:** As the most abundant water-soluble vitamin ever dissolved, ascorbic acid is found mostly in biological systems and food, primarily fresh vegetables and fruits. Iron absorption, collagen formation, and immunological response are all aided by vitamin C. The metal is deposited electrochemically at the interface of an electrolyte solution containing the metal and an electrically conductive metal substrate. Using a drop coating approach, the Glassy Carbon Electrode (GCE) was modified with CoS2. Prior to coating, the GCE was manually polished with alumina pastes of varying diameters and ultrasonically cleaned. After dissolving 5 mg of CoS2 in ethanol, the suspension was applied to the GCE surface. This modification attempts to improve the electrochemical characteristics of the electrode, increasing sensitivity and selectivity in a variety of applications. Because of the drop coating method's homogeneous and regulated coating thickness, the modified GCE with CoS2 is ideal for accurate and reliable electrochemical experiments. XRD measurement confirmed the crystalline structure of the CoS2 synthesis. A flower-shaped morphology with constant size and form was also discovered by FE-SEM analysis. This CoS2 material was then used in electrochemical sensing applications, notably for ascorbic acid detection. The results confirmed its superior ascorbic acid detection capabilities, making it a suitable candidate for possible usage in various electrochemical sensing systems. CoS2 unusual crystalline structure and flower-shaped morphology likely contribute to its increased sensing properties, opening up new avenues for research and development in sensor creation and applications.

**Keywords:** Morphological analysis, XRD ANALYSIS, Scan rate effect

# INTRODUCTION

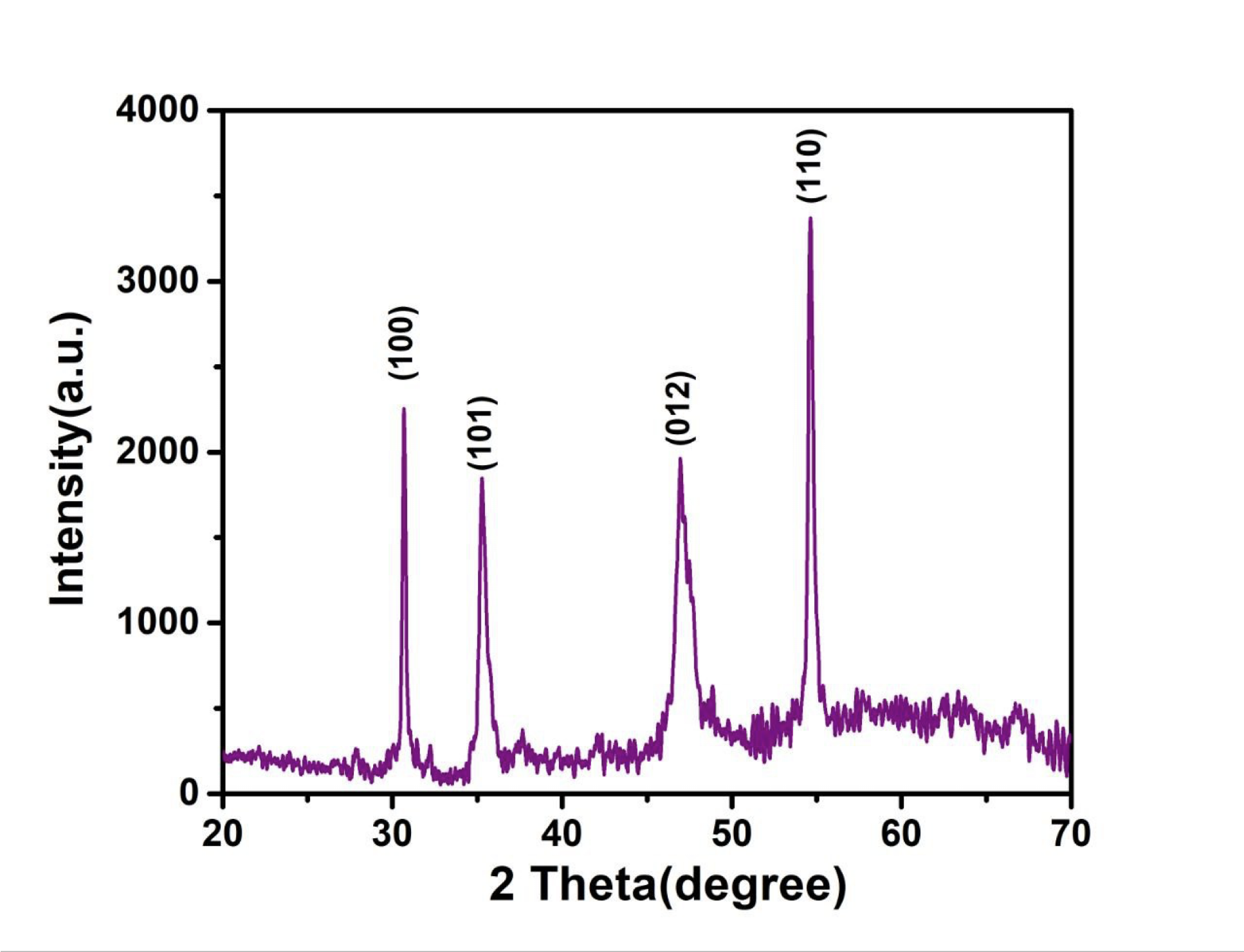
Small biomolecules like ascorbic acid (AA), dopamine (DA), uric acid (UA), and xanthine (XA) are required for a variety of physiological processes in the neurological, metabolic, and circulatory systems.[(“Nitrogen Doped Lignocellulose/binary Metal Sulfide Modified Electrode: Preparation and Application for Non-Enzymatic Ascorbic Acid, Dopamine and Nitrite Sensing,” 2017)](https://paperpile.com/c/PM4pBV/HTHK). Because these biomolecules cohabit in human physiological fluids, monitoring them is critical for disease detection and prevention.[(Reverté et al., 2014)](https://paperpile.com/c/PM4pBV/USwE) Various methods for detecting biomolecules have been developed, but they frequently suffer from complexity, high costs, and lengthy procedures[(G. & Ganapathy, 2022; I. L. Kumar & Ramesh, 2021)](https://paperpile.com/c/PM4pBV/k972c+m5P3i)). Electrochemical approaches are appealing for biomolecule detection because of their higher sensitivity, simplicity, effectiveness, and rapid response[(“Integration of Electrochemistry in Micro-Total Analysis Systems for Biochemical Assays: Recent Developments,” 2009)](https://paperpile.com/c/PM4pBV/iueo). However, due to overlapping oxidation peaks and electrode fouling, simultaneous identification of these biomolecules remains difficult [(*Evaluation Composite Restoration Posterior Teeth Proanthocyanidin Pretreatment Liner Using Fédération Dentaire Internationale Criteria: Split-Mouth Randomized Controlled Trial*, n.d.; Pranati et al., 2021; Sakthi et al, 2021)](https://paperpile.com/c/PM4pBV/x6ax4+1bpBQ+Rtf02). To solve this, researchers have developed improved materials such as polymers, metal-based nanomaterials, and carbon-based materials to improve electrochemical detection sensitivity and selectivity[(Keerthana & Ramesh, 2021; Murugesan, 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/PM4pBV/wwDuY+BI3ac+Cm3a8)[(Keerthana & Ramesh, 2021; Murugesan, 2021; Subramanian et al., 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/PM4pBV/wwDuY+BI3ac+Cm3a8+RN0lU). The development of a simple and accurate technology for simultaneous detection has great promise for biomedical research and clinical diagnostics[(Kasabwala et al., 2021; Rajeshkumar & Lakshmi, 2021; Varghese et al., 2023)](https://paperpile.com/c/PM4pBV/fvuzz+XAqC4+m21t7). Overcoming the issues of overlapping peaks and electrode fouling will provide vital information about the amounts of these important biomolecules in physiological fluids. Furthermore, the use of new materials will improve the precision and reliability of electrochemical measurements, helping to progress analytical chemistry and medical research.[(“Electrochemical Detection for Microscale Analytical Systems: A Review,” 2002)](https://paperpile.com/c/PM4pBV/zODJ)The fourth industrial revolution has increased the demand for sustainable energy solutions. However, the rapid depletion of fossil fuel supplies has underlined the necessity for a transition to more sustainable energy resources[(Ramakrishnan et al., 2023; Shenoy & Maiti, 2023; J. S. Sindhu et al., 2023)](https://paperpile.com/c/PM4pBV/eX7qP+uqAMl+vBabp). Due to their promising qualities, energy storage devices such as supercapacitors have attracted substantial interest to address this difficulty. Supercapacitors have various advantages, including increased specific power, longer lifespan, fewer maintenance requirements, ease of operation, and improved safety[(Dharman et al., 2023; S. Sindhu et al., 2023; Sreenivasagan et al., 2023)](https://paperpile.com/c/PM4pBV/L5AqH+z51vY+eYgxa). These enticing characteristics have resulted in significant research and development in the field of supercapacitors, since they have the potential to revolutionize energy storage and contribute to a cleaner and more sustainable energy future. The concept of "supercapattery" is a significant improvement in energy storage technology[(Ajay et al., 2023; Chokkattu et al., 2023; Padarthi et al., 2023)](https://paperpile.com/c/PM4pBV/9IYOw+QVtTx+nRNzC). This new technology combines the advantages of both supercapacitors and batteries, with the goal of providing the best of both worlds. Supercapattery is a promising alternative to standard energy storage systems due to its large energy storage capacity, quick charge-discharge rates, and long operating lifespan. Metal sulfides have showed tremendous potential among the numerous materials investigated for supercapattery. Because of their redox activity and ability to supply additional active sites for energy storage, cobalt (Co) and copper (Cu) sulfides, as well as their composites, have piqued the interest of researchers. These metal sulfides have high electrical conductivity and flexibility, allowing for efficient electron movement during the storage and release of energy. Metal sulfides have several benefits over traditional materials such as metal oxides and carbon[(Zhang et al., 2014)](https://paperpile.com/c/PM4pBV/2wgP). They have bigger redox reactions, resulting in greater energy storage capacity. Furthermore, they solve some of the drawbacks of carbon and metal oxide materials, such as poor volumetric capacity, agglomeration concerns, and device manufacturing challenges. The reversible redox processes that occur throughout the charge and discharge cycles distinguish metal sulfides from other materials utilized in supercapacitors. Metal sulfides' unique property adds to their superior energy storage behavior, making them interesting candidates for future energy storage systems. Researchers have investigated nanoarchitecture designs to improve the electrochemical performance of metal sulfides[(Dhakshinamoorthy et al., 2016)](https://paperpile.com/c/PM4pBV/95LV). These designs have demonstrated a strong affinity for enhancing the specific power and energy use of electrode materials in supercapattery systems. Researchers want to enhance the efficiency of metal sulfides in energy storage applications by altering their nanostructure. Cobalt sulfide (CoS) is one metal sulfide that has received a great deal of attention. Various morphologies of CoS nanostructures with unique electrochemical characteristics have been created utilizing the electrochemical method. Because of its substantial characteristics and better electrochemical performance, these discoveries have prompted the investigation of CoS as a possible option for supercapacitor electrode materials [(Chen et al., 2019)](https://paperpile.com/c/PM4pBV/jUBV). The addition of CoS2 to MoS2 greatly improved catalytic performance, resulting in remarkable HDO activity and DDO selectivity. The use of nanostructured materials decreased mechanical stress during the electrochemical process, which improved the overall performance of the catalyst. These findings suggest that highly efficient and stable catalytic systems with applications in renewable energy and environmental remediation have a bright future.[(“Hydrothermal Synthesis of CuS/CoS Nano Composite as an Efficient Electrode for the Supercapattery Applications,” 2021)](https://paperpile.com/c/PM4pBV/l6Ca)COS appears to play a larger part in mammalian chemical biology than previously thought by combining its potential in thermophilic origin hypotheses, tissue sensing, cell permeability, and water solubility[(March et al., 2015)](https://paperpile.com/c/PM4pBV/H5J1). This review digs into COS in biological contexts, including its synthesis, consumption, potential in sulfide transport and illness, emerging chemical techniques for researching it, and putative location within the gasotransmitter family [(Pluth, 2022)](https://paperpile.com/c/PM4pBV/ABTs).

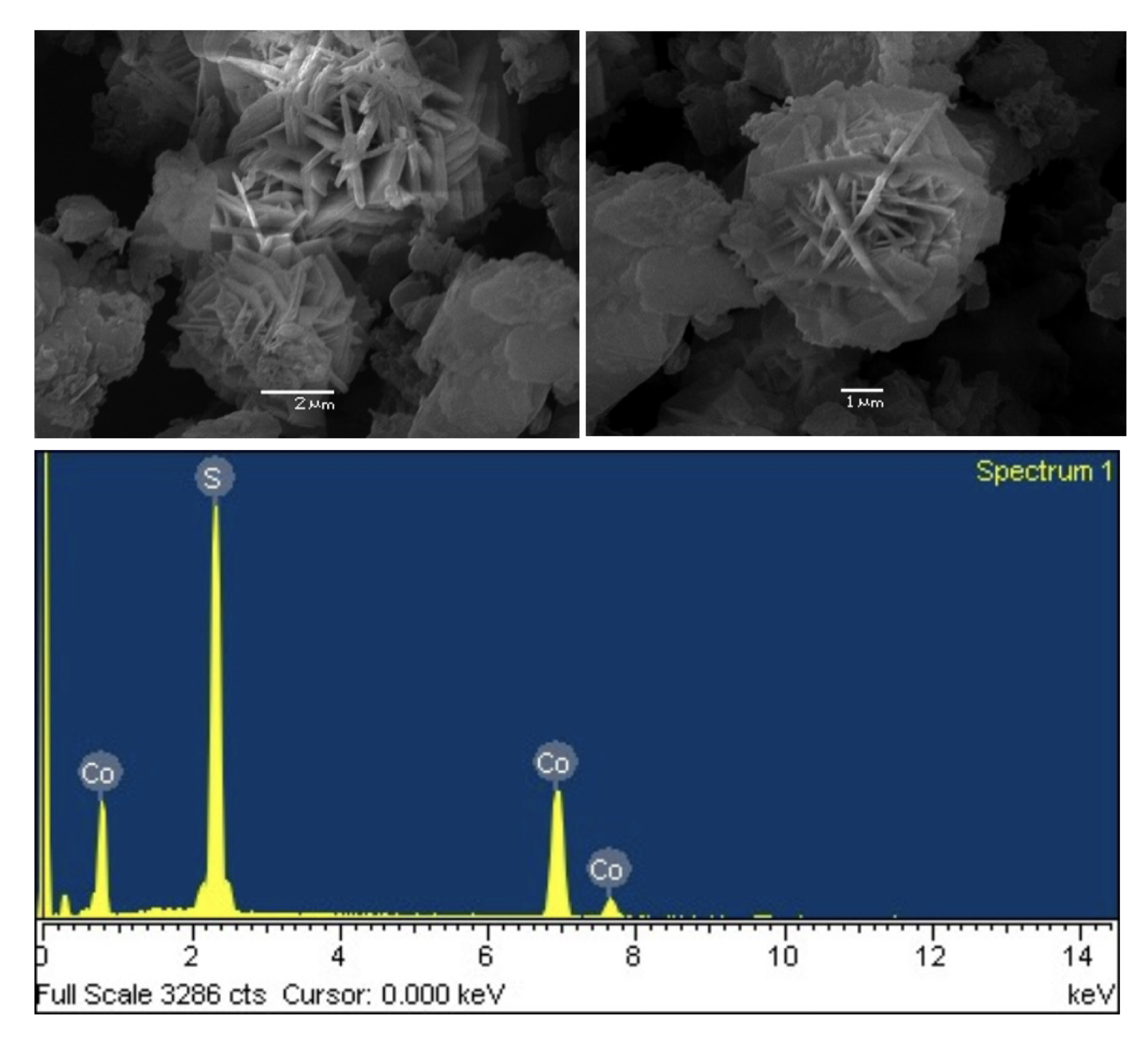
# MATERIALS AND METHODS

The primary apparatus for the production of CoS nanostructures was a Teflon-lined stainless steel autoclave with a capacity of 100 cc. All of the compounds employed were of analytical quality and did not require additional purification. In a typical process, a beaker was filled with 40 mM of Cobalt acetate, 40 mM of thiourea (NH2CSNH2), 20 ml of DI water, and 60 ml of ethanol (en). To ensure full mixing, this mixture was magnetically stirred for 15 minutes.After the hydrothermal reaction was completed, the autoclave was allowed to cool naturally to room temperature.The reaction products were thoroughly washed, with numerous rinses with distilled water and methanol. Finally, the goods were allowed to air-dry at ambient temperature for an additional 12 hours to get the required powders. In the last phase, the as-synthesized sample was annealed in air at a high temperature of 600°C. This annealing procedure was carried out in a muffle furnace for 2 hours. The annealing procedure improved the characteristics of the CoS nanostructures for their intended application much further.

# RESULTS

## XRD ANALYSIS

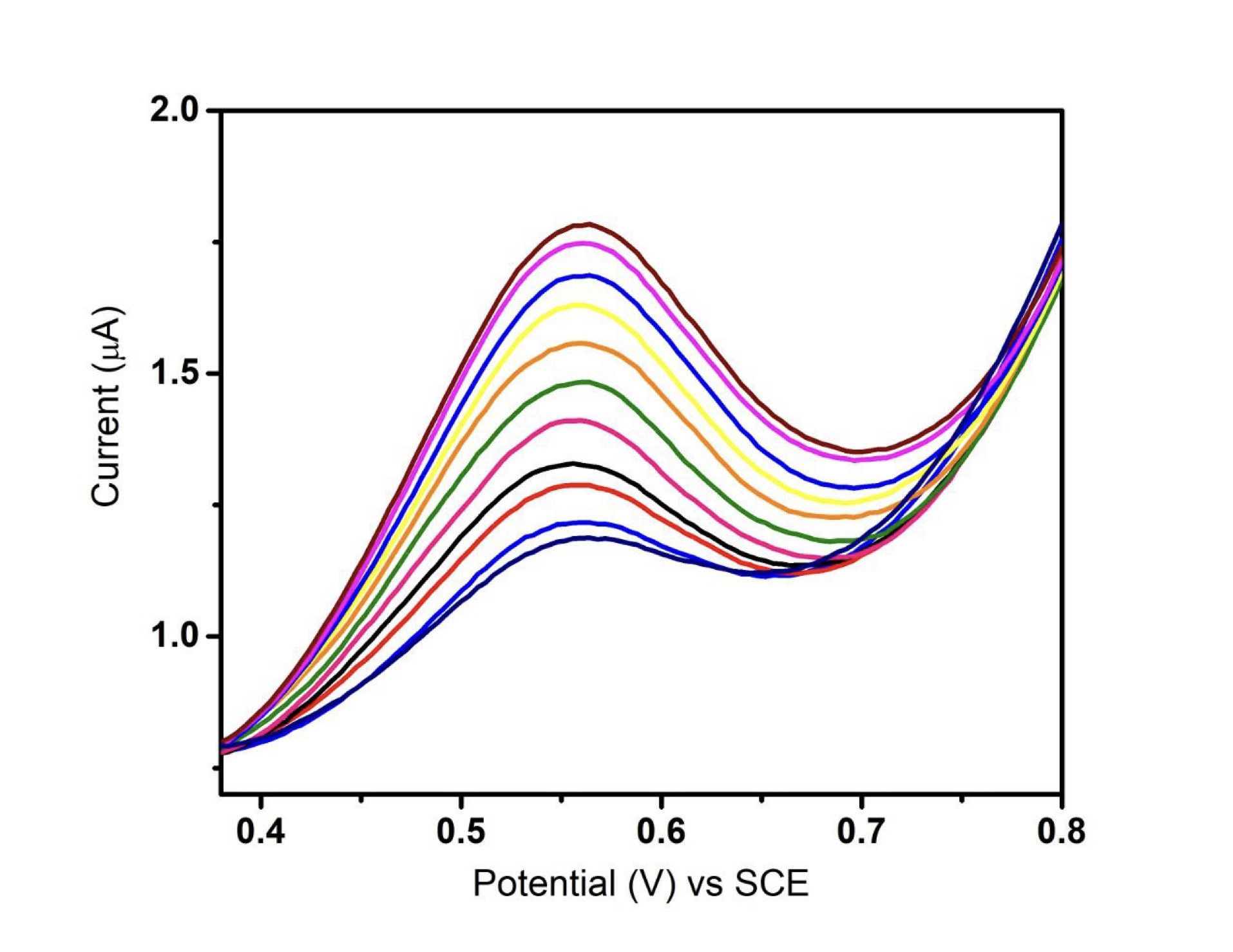


**Figure 1:** An XRD pattern of the electrochemically grown CoS2 nanoparticle after the hydrothermal treatment

In materials science and crystallography, the atomic as well as the molecular structure of the crystalline material is investigated using X-ray diffraction (XRD) research(Nikalje et al., 2024) (Chehelgerdi et al., 2023). The structural nature of the prepared FeS sample is tested by employing the XRD analysis test. We have observed peaks with Miller indices of (100), (101), (102), (012), (110). The sharp peaks obtained from the analysis which can be seen in Figure1 denote the As contrasted to JCPDS No. 19-0366, the synthesized CoS2 had a high crystallinity as shown by the prominent diffraction peaks in the XRD pattern.

## Morphological analysis

**Figure 2:** (a) The FE-SEM images of the CoS2prepared by hydrothermal treatment. (b) The EDX analysis result of the CoS2 particles synthesized

EDX: energy-dispersive X-ray; FE-SEM: field emission-scanning electron microscopy ;CoS2:Cobalt disulfideOur ability to investigate the complex world of tiny structures has been completely transformed by the development of field emission-scanning electron microscopy (FE-SEM), a cutting-edge imaging method .Figure *3a* shows the FE-SEM images of the CoS2 prepared by hydrothermal treatment. Based on the analysis conducted and the results obtained, it can be seen that the compound is homogeneous and has an even morphology with a flower pattern. Due to its high sensitivity in detecting the various elements in tissues, energy-dispersive X-ray (EDX) microanalysis is used in numerous biomedical fields of study .By analyzing distinctive X-ray peak intensities, EDX analysis aided Co/S ratio estimation. Flower-shaped CoS2 particles measuring between 1 and 2 micrometers were discovered using scanning electron microscopy

## Scan rate effect

**Figure 3:** Scan rate effect of CoS2 modified GCE toward ascorbic acid 10-110 mV GCE: glassy carbon electrode; CoS2:Cobalt disulfide ,SCE: saturated calomel electrode; 10-110 mV

The process involves gradually changing the voltage at various scan rates (10-110 mV), which produces diverse modifications in the resulting cyclic voltammograms. Figure *3* shows the scan rate effect test analysis result for CoS2 nanoflower synthesized.As observed from the results and graphs plotted, it can be assessed that there was a subsequent increase in the current response in accordance with the increasing potentials applied subsequently one after the other. This finding confirms the high stability as well as the sensitivity of the CoS2 nanoflower toward the sensing of ascorbic acid.

# DISCUSSION

The research demonstrated that AsA oxidation using a poly(DB71) film-modified GC electrode has improved electrocatalytic activity. Simple AsA determination is made possible by Poly(DB71) films, and the modified electrode exhibits significantly improved electrocatalytic efficiency for AsA while preserving excellent electrode stability in the solution.[(S. A. Kumar et al., 2008)](https://paperpile.com/c/PM4pBV/WuVo) Considering simplicity, sensitivity, and reasonable approach in detecting AA, electrochemical techniques (EM) are well regarded. Electrodes that have been chemically modified—often with polymer films—are often employed. Particularly preferred are electrochemical biosensors and voltammetry due to their high accuracy and low AA detection limits.[(Jiang et al., 2023)](https://paperpile.com/c/PM4pBV/w3kK) A surface-immobilized redox pair would benefit greatly from the improved electrode's appropriate redox response. The pH of the solution has a significant influence on its electrochemical behavior. The improved electrode is significant because it makes it possible to detect AA, DA, and UA all at once in a homogenous solution.[(Lin et al., 2008)](https://paperpile.com/c/PM4pBV/vT9g) The linear response range for AA, DA, and UA was discovered to be 20.0-800.0 mol L1, 5.0-100.0 mol L1, and 1.0-80.0 mol L1, respectively, with detection limits of 5.0, 1.0, and 0.5 mol L1 (S/N = 3). With the modified electrode, remarkable sensitivity and selectivity are displayed [(Das et al., 2022)](https://paperpile.com/c/PM4pBV/c7nw).

# CONCLUSION

In summary, the successful modification of the Glassy Carbon Electrode (GCE) with flower-shaped CoS₂ via a simple drop-coating technique significantly enhanced its electrochemical performance for ascorbic acid detection. The crystalline structure and uniform morphology, confirmed by XRD and FE-SEM analyses, likely played a key role in the improved sensitivity and selectivity of the sensor. These findings highlight the potential of CoS₂ as an efficient electrode modifier for electrochemical sensing applications, offering a promising route for the development of reliable, cost-effective, and high-performance sensors for vitamin C and other biologically relevant analytes.

# REFERENCEs

1. [Ajay, R., JafarAbdulla, M. U., Sivakumar, J. S., Baburajan, K., Rakshagan, V., & Eyeswarya, J. (2023). Dental alloy adhesive primers and bond strength at alloy-resin interface: A systematic review and meta-analyses. *The Journal of Contemporary Dental Practice*, *24*(8), 521–544. https://doi.org/](http://paperpile.com/b/PM4pBV/QVtTx)[10.5005/jp-journals-10024-3514](http://dx.doi.org/10.5005/jp-journals-10024-3514)
2. [Chen, Y., Zhang, X.-F., Wang, A.-J., Zhang, Q.-L., Huang, H., & Feng, J.-J. (2019). Ultrafine FeC nanoparticles embedded in N-doped graphitic carbon sheets for simultaneous determination of ascorbic acid, dopamine, uric acid and xanthine. *Mikrochimica Acta*, *186*(9), 660. https://doi.org/](http://paperpile.com/b/PM4pBV/jUBV)[10.1007/s00604-019-3769-y](http://dx.doi.org/10.1007/s00604-019-3769-y)
3. Chehelgerdi M., Chehelgerdi, M., Allela, O. Q. B., Pecho, R. D. C., Jayasankar, N., Rao, D. P. & Akhavan-Sigari, R. (2023). Progressing nanotechnology to improve targeted cancer treatment: overcoming hurdles in its clinical implementation. Molecular cancer, 22(1), 169.
4. [Chokkattu, J. J., Mary, D. J., Shanmugam, R., & Neeharika, S. (2023). Evaluation clove ginger-mediated titanium oxide nanoparticles-based dental varnish against Streptococcus mutans Lactobacillus Species: vitro study. *World J Dent*, *14*(3), 233–237.](http://paperpile.com/b/PM4pBV/nRNzC)
5. [Das, S., Thomas, S., & Das, P. P. (2022). *Sensing of Deadly Toxic Chemical Warfare Agents, Nerve Agent Simulants, and their Toxicological Aspects*. Elsevier.](http://paperpile.com/b/PM4pBV/c7nw) <https://play.google.com/store/books/details?id=sH9dEAAAQBAJ>
6. [Dhakshinamoorthy, A., Asiri, A. M., & García, H. (2016). Metal–Organic Framework (MOF) Compounds: Photocatalysts for Redox Reactions and Solar Fuel Production. *Angewandte Chemie, International Edition*, *55*(18), 5414–5445. https://doi.org/](http://paperpile.com/b/PM4pBV/95LV)[10.1002/anie.201505581](http://dx.doi.org/10.1002/anie.201505581)
7. [Dharman, S., Maragathavalli, G., Shanmugam, R., & Shanmugasundaram, K. (2023). Curcumin mediated gold nanoparticles analysis its antioxidant, anti-inflammatory, antimicrobial activity against oral pathogens. *Pesquisa Brasileira Em Odontopediatria E Clínica Integrada*, *23*.](http://paperpile.com/b/PM4pBV/z51vY)
8. [Electrochemical detection for microscale analytical systems: a review. (2002). *Talanta*, *56*(2), 223–231. https://doi.org/](http://paperpile.com/b/PM4pBV/zODJ)[10.1016/S0039-9140(01)00592-6](http://dx.doi.org/10.1016/S0039-9140(01)00592-6)
9. [*Evaluation Composite Restoration Posterior Teeth Proanthocyanidin Pretreatment Liner Using Fédération Dentaire Internationale Criteria: Split-mouth Randomized Controlled Trial*. (n.d.).](http://paperpile.com/b/PM4pBV/Rtf02)
10. [G., K. E. V., & Ganapathy, D. (2022). Operator errors in failed composite restoration-A review. *Int J Dent Oral Sci*, *8*(7), 2941–2944.](http://paperpile.com/b/PM4pBV/m5P3i) <https://www.academia.edu/download/73121996/IJDOS_2377_8075_08_702.pdf>
11. [Hydrothermal synthesis of CuS/CoS nano composite as an efficient electrode for the supercapattery applications. (2021). *Journal of Energy Storage*, *40*, 102749. https://doi.org/](http://paperpile.com/b/PM4pBV/l6Ca)[10.1016/j.est.2021.102749](http://dx.doi.org/10.1016/j.est.2021.102749)
12. [Integration of electrochemistry in micro-total analysis systems for biochemical assays: Recent developments. (2009). *Talanta*, *80*(1), 8–18. https://doi.org/](http://paperpile.com/b/PM4pBV/iueo)[10.1016/j.talanta.2009.06.039](http://dx.doi.org/10.1016/j.talanta.2009.06.039)
13. [Jiang, C., Xie, L., Yan, F., Liang, Z., Liang, J., Huang, K., Li, H., Wang, Y., Luo, L., Li, T., Ning, D., Tang, L., & Ya, Y. (2023). A novel electrochemical aptasensor based on polyaniline and gold nanoparticles for ultrasensitive and selective detection of ascorbic acid. *Analytical Methods*, *15*(32), 4010–4020. https://doi.org/](http://paperpile.com/b/PM4pBV/w3kK)[10.1039/d3ay00806a](http://dx.doi.org/10.1039/d3ay00806a)
14. [Kasabwala, H., Nallaswamy, D., Subhashree, R., & Ahmed, N. (2021). Evaluation Of Overall Marginal Accuracy Of DMLS Copings Fabricated Using 3 Different DMLS Printing Machines. *Int J Dentistry Oral Sci*, *8*(7), 3335–3340.](http://paperpile.com/b/PM4pBV/XAqC4) <https://www.academia.edu/download/73133070/IJDOS_2377_8075_08_7085.pdf>
15. [Keerthana, T., & Ramesh, S. (2021). Knowledge, attitude and practice survey on awareness of the association between diet and dental erosion. *International Journal of Dentistry and Oral Science*, *8*(2), 1533–1540.](http://paperpile.com/b/PM4pBV/BI3ac) <https://www.academia.edu/download/72505812/IJDOS_2377_8075_08_2026.pdf>
16. [Kumar, I. L., & Ramesh, S. (2021). Knowledge, Attitude and Practices (KAP) survey of shade selection for indirect veneers. *Int J Dent Oral Sci*, *26*, 2856–2864.](http://paperpile.com/b/PM4pBV/k972c) <https://www.researchgate.net/profile/Sindhu-Ramesh/publication/353259903_Knowledge_Attitude_And_Practices_KAP_Survey_Of_Shade_Selection_For_Indirect_Veneers/links/60efe4d60859317dbde2f353/Knowledge-Attitude-And-Practices-KAP-Survey-Of-Shade-Selection-For-Indirect-Veneers.pdf>
17. [Kumar, S. A., Lo, P.-H., & Chen, S.-M. (2008). Electrochemical selective determination of ascorbic acid at redox active polymer modified electrode derived from direct blue 71. *Biosensors & Bioelectronics*, *24*(4), 518–523. https://doi.org/](http://paperpile.com/b/PM4pBV/WuVo)[10.1016/j.bios.2008.05.007](http://dx.doi.org/10.1016/j.bios.2008.05.007)
18. [Lin, L., Chen, J., Yao, H., Chen, Y., Zheng, Y., & Lin, X. (2008). Simultaneous determination of dopamine, ascorbic acid and uric acid at poly (Evans Blue) modified glassy carbon electrode. *Bioelectrochemistry* , *73*(1), 11–17. https://doi.org/](http://paperpile.com/b/PM4pBV/vT9g)[10.1016/j.bioelechem.2008.01.009](http://dx.doi.org/10.1016/j.bioelechem.2008.01.009)
19. [March, G., Nguyen, T. D., & Piro, B. (2015). Modified Electrodes Used for Electrochemical Detection of Metal Ions in Environmental Analysis. *Biosensors*, *5*(2), 241–275. https://doi.org/](http://paperpile.com/b/PM4pBV/H5J1)[10.3390/bios5020241](http://dx.doi.org/10.3390/bios5020241)
20. [Murugesan, A. (2021). Saravana Dinesh SP evaluation of shear bond strength of ceramic brackets with two different base designs: An in-vitro study. *Int J Dentistry Oral Sci*.](http://paperpile.com/b/PM4pBV/Cm3a8) <https://www.academia.edu/download/72981941/IJDOS_2377_8075_08_304.pdf>
21. Nikalje, A. V., Tajane, S. T., Kocharekar, A., Vekariya, D., & Patil, H. (2024, April). Detecting Cancer through Analysis of Histopathological Images. In 2024 International Conference on Expert Clouds and Applications (ICOECA) (pp. 579-585). IEEE.
22. [Nitrogen doped lignocellulose/binary metal sulfide modified electrode: Preparation and application for non-enzymatic ascorbic acid, dopamine and nitrite sensing. (2017). *Journal of Electroanalytical Chemistry* , *806*, 150–157. https://doi.org/](http://paperpile.com/b/PM4pBV/HTHK)[10.1016/j.jelechem.2017.10.066](http://dx.doi.org/10.1016/j.jelechem.2017.10.066)
23. [Padarthi, L. C., Anumula, L., Chinni, S. K., Sannapureddy, S., & Govula, K. (2023). Evaluation Composite Restoration Posterior Teeth Proanthocyanidin Pretreatment Liner Using Fédération Dentaire Internationale Criteria: Split-mouth Randomized Controlled Trial. *International Journal Prosthodontics Restorative Dentistry*, *13*(4), 191–200.](http://paperpile.com/b/PM4pBV/9IYOw)
24. [Pluth, M. D. (2022). *Hydrogen Sulfide: Chemical Biology Basics, Detection Methods, Therapeutic Applications, and Case Studies*. John Wiley & Sons.](http://paperpile.com/b/PM4pBV/ABTs) <https://play.google.com/store/books/details?id=AIKIEAAAQBAJ>
25. [Pranati, T., Ranjan, M., & Sandeep, A. H. (2021). Marginal adaptability custom made cast post made different techniques-a literature review. *Int J Dentistry Oral Sci*, *8*(8), 3954–3959.](http://paperpile.com/b/PM4pBV/x6ax4)
26. [Rajeshkumar, S., & Lakshmi, T. (2021). Biomedical potential of zinc oxide nanoparticles synthesized using plant extracts. *Int J Dent Oral Sci*, *8*, 4160–4163.](http://paperpile.com/b/PM4pBV/m21t7) <https://www.academia.edu/download/73182974/IJDOS_2377_8075_08_8120.pdf>
27. [Ramakrishnan, M., Shanmugam, R., Neeharika, S., Chokkattu, J. J., Thangavelu, L., & Khanna, N. (2023). Anti-inflammatory activity and cytotoxic effect of ginger and Rosemary-mediated titanium oxide nanoparticles-based dental varnish. *World Journal of Dentistry*, *14*(9), 761–765. https://doi.org/](http://paperpile.com/b/PM4pBV/uqAMl)[10.5005/jp-journals-10015-2299](http://dx.doi.org/10.5005/jp-journals-10015-2299)
28. [Reverté, L., Soliño, L., Carnicer, O., Diogène, J., & Campàs, M. (2014). Alternative Methods for the Detection of Emerging Marine Toxins: Biosensors, Biochemical Assays and Cell-Based Assays. *Marine Drugs*, *12*(12), 5719–5763. https://doi.org/](http://paperpile.com/b/PM4pBV/USwE)[10.3390/md12125719](http://dx.doi.org/10.3390/md12125719)
29. [Sakthi, S., et al. (2021). Thymus vulgaris mediated selenium nanoparticles, characterization and its antimicrobial activity - an in vitro study. *International Journal of Dentistry and Oral Science*, 3516–3521. https://doi.org/](http://paperpile.com/b/PM4pBV/1bpBQ)[10.19070/2377-8075-21000718](http://dx.doi.org/10.19070/2377-8075-21000718)
30. [Shenoy, N. D., & Maiti, S. (2023). Evaluation marginal fit CAD/CAM crowns using CBCT digital scanners. *Annals Dental Specialty*, *11*(3-2023), 37–44.](http://paperpile.com/b/PM4pBV/eX7qP)
31. [Sindhu, J. S., Maiti, S., & Nallaswamy, D. (2023). Comparative analysis on efficiency and accuracy of parallel confocal microscopy and three-dimensional in motion video with triangulation technology-based intraoral scanner under influence of moisture and mouth opening - A crossover clinical trial. *Journal of Indian Prosthodontic Society*, *23*(3), 234–243. https://doi.org/](http://paperpile.com/b/PM4pBV/vBabp)[10.4103/jips.jips\_65\_23](http://dx.doi.org/10.4103/jips.jips_65_23)
32. [Sindhu, S., Maiti, S., & Nallaswamy, D. (2023). Factors affecting accuracy intraoral scanners-a systematic review. *Annals Dental Specialty*, *11*(1-2023), 40–52.](http://paperpile.com/b/PM4pBV/L5AqH)
33. [Sreenivasagan, S., Subramanian, A. K., Mohanraj, K. G., & Kumar, R. S. (2023). Assessment of toxicity of Green Synthesized Silver Nanoparticle-coated Titanium Mini-implants with Uncoated Mini-implants: Comparison in an Animal Model Study. *The Journal of Contemporary Dental Practice*, *24*(12), 944–950. https://doi.org/](http://paperpile.com/b/PM4pBV/eYgxa)[10.5005/jp-journals-10024-3577](http://dx.doi.org/10.5005/jp-journals-10024-3577)
34. [Subramanian, E., Ravindran, V., & Jeevanandan, G. (2021). Comparison of amount of tooth reduction in primary first molar for stainless steel, zirconia and fibre-glass crowns–in-vitro study. *International Journal of Dentistry and Oral Science*, *8*(7), 3427–3430.](http://paperpile.com/b/PM4pBV/RN0lU) <https://www.academia.edu/download/73139190/IJDOS_2377_8075_08_7103.pdf>
35. [Tiwari, A., & Jain, R. K. (2021). The effect of motivational and reminder therapy on the compliance of patients wearing fixed appliances. *Int J Dent Oral Sci*, *8*(7), 3303–3305.](http://paperpile.com/b/PM4pBV/wwDuY) <https://www.academia.edu/download/73131909/IJDOS_2377_8075_08_7079.pdf>
36. [Varghese, R., Maliael, M., & Subramanian, A. (2023). Antibacterial activity of nanoparticle-coated orthodontic archwires: A systematic review. *Journal of International Oral Health: JIOH*, *15*(1), 1. https://doi.org/](http://paperpile.com/b/PM4pBV/fvuzz)[10.4103/jioh.jioh\_152\_22](http://dx.doi.org/10.4103/jioh.jioh_152_22)
37. [Zhang, Y., Li, L., Su, H., Huang, W., & Dong, X. (2014). Binary metal oxide: advanced energy storage materials in supercapacitors. *Journal of Materials Chemistry. A, Materials for Energy and Sustainability*, *3*(1), 43–59. https://doi.org/](http://paperpile.com/b/PM4pBV/2wgP)[10.1039/C4TA04996A](http://dx.doi.org/10.1039/C4TA04996A)