

FABRICATION AND CHARACTERIZATION OF NANO-PERFUME: AN INTEGRATED APPROACH EMPLOYING SPECTROPHOTOMETRIC AND ELECTROCHEMICAL ANALYSIS

Asad Hameed Jaffar*

College of Science, Mustansiriyah University, Baghdad, Iraq.

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*Corresponding Author

Asad Hameed Jaffar

College of Science,
Mustansiriyah University,
Baghdad, Iraq.

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ABSTRACT

This study reports on the development of a nanoemulsion-based nanofragrance formulation and its subsequent characterization using spectrophotometric and electrochemical methods. This approach aims to enhance the fragrance stability, prolong its release period, and improve its physicochemical properties compared to conventional perfume products. Spectrophotometry was used to determine the absorption properties and optical stability of the nanodispersion, while electrochemical analysis was used to evaluate the redox properties and potential interactions of the aromatic compounds at the electrode surface. The results indicate improved homogeneity, reduced droplet size, and better controlled release of volatile fragrance molecules. This work demonstrates the feasibility of nanoformulation strategies in the perfume industry. The use of nanotechnology also enables the controlled release of perfume molecules. Chitosan nanoparticles encapsulate the nano-fragrance compounds, allowing them to be released gradually over time. The process of converting commercial perfumes into nano-fragrances improves the quality of the fragrance, regardless of its type or price. Experiments have been conducted on the cheapest types of perfumes available on the market. After nano-conversion, these produced distinctive scents that differed from the original aromatic properties of both men's and women's fragrances. For example, water-based perfumes extracted from flowers were used, and after nano-conversion, they developed completely different scents and viscosities (they became concentrated oils and could be diluted on demand). The stability of perfume nanoparticles in different environments can be leveraged, as nano-fragrances improve their stability in different environmental conditions, reducing the amount of perfume required per application. Therefore, they can be used in various medical fields, including adding them to toothpastes and mouthwashes to provide a fresh breath and strengthen teeth and gums. It can also be used in household cleaners as a stable fragrance in all environments, providing economical use.

KEYWORDS: Nano-perfume, nano-emulsion, UV-spectrophotometry, electrochemical analysis, fragrance delivery.

INTRODUCTION

The development of nanoperfumes represents a cutting-edge advancement at the intersection of nanotechnology, materials science, and cosmetic chemistry. Conventional perfumes, despite their popularity, suffer from limitations such as high volatility, instability under environmental stress, and rapid evaporation, which reduces fragrance stability^[1] (Patel et al., 2021). To overcome these drawbacks, researchers have turned to nanotechnology-based delivery systems capable of encapsulating aroma molecules within nanocarriers, enhancing controlled release, stability, and sensory performance^[2] (Singh and Kaur, 2020). Nanoperfumes typically use nanocarriers

such as liposomes, polymeric nanoparticles, or nanoemulsions to trap volatile perfume compounds^[3] (Kumar et al., 2022). These systems improve the bioavailability and sustained release of fragrance molecules, while reducing degradation due to oxidation or UV exposure^[4] (Alves et al., 2020). The manufacturing process often includes techniques such as solvent evaporation, ultrasound, or emulsification, which allow for precise control of particle size and dispersion homogeneity—key parameters that determine the aroma stability and final product stability^[5] (Sharma et al., 2019). To fully understand the performance characteristics of nanofragrance, optical spectroscopy

and electrochemical analyses are essential. Spectrophotometric methods enable the determination of encapsulation efficiency, optical stability, and the interaction between the carrier matrix and the aromatic compounds^[6] (Kavitha & Ramesh, 2021). Meanwhile, electrochemical analysis provides insights into redox behavior and molecular interactions at the nanoscale interface, enabling a deeper understanding of fragrance release kinetics and chemical stability.^[7] This integrated analytical approach not only ensures comprehensive characterization of nano-fragrance formulations, but also paves the way for the development of next-generation fragrance systems with enhanced durability, efficiency, and consumer appeal. Fragrance formulations have traditionally relied on ethanol-based dispersions of aromatic compounds, which often suffer from volatility, poor stability, and limited skin permanence. Recent advances in nanotechnology have enabled the design of emulsions and nanoparticles as carriers of volatile compounds, offering improved stability, controlled release, and higher bioavailability. Nano-fragrances, based on nano-sized droplets, represent a new opportunity to revolutionize fragrance technology by providing extended aromatic properties and an enhanced consumer experience. Characterizing these systems requires effective analytical methods. Spectrophotometry enables the assessment of the optical stability, turbidity, and absorption spectra of aromatic components, while electrochemical methods provide insights into the redox activity and electron transfer properties of volatile components.

This study presents the fabrication of a nano-perfume system, followed by its characterization using these complementary techniques.

Historically, perfumes have been used primarily for body fragrance. Fragrances are also added to cosmetics to enhance their appeal. These fragrance products release a range of chemicals, including hazardous pollutants, but their components are not fully disclosed on the product label. As a result, they have been found to cause various adverse effects on human health. Adverse effects associated with the use of perfumes include contact dermatitis, contact urticaria, photosensitivity, and phototoxicity. Adverse effects of cosmetics include lung disease, reproductive organ damage, skin allergies, excessive hair growth, headaches, and cancer. Some of the adverse effects of using perfume products, including perfumes, are primarily oxidizing chemicals.^[8] The toxicity of perfumes is largely understood. While most are benign, some can cause adverse health effects, particularly allergic contact dermatitis resulting from skin allergies. As a result, industry guidelines have banned some substances and severely restricted the use of others. Recently, data have been published that have been interpreted to indicate that inhaled perfumes are associated with a variety of health effects, ranging from headaches to asthma attacks. The evidence base for these claims is carefully examined, and the biological basis

and mechanistic plausibility of the causality of these health effects from scented products are explored. Respiratory effects, including irritation and allergic reactions, are unlikely to occur in this manner. It is concluded that adverse health effects from inhaled perfumes are rare and have yet to be identified and confirmed by methodologically rigorous epidemiological studies supported by a convincing biological and mechanistic basis.^[9]

Fragrance compounds (aromatic compounds), such as perfumes, may cause adverse health effects. To assess their importance via inhalation, the effects of the four major airborne odorants (alpha-pinene (APN), limonene (LIM), linalool (LIL), and eugenol (EUG)) on indoor air quality were reviewed. Odor discomfort, sensory irritation, and bronchial sensitization were assessed. Respiratory and cardiovascular effects, work performance, and the effects of gas-phase products and ozone-initiated particle interactions in the bronchial airways were also evaluated. The maximum measured indoor concentrations of APN, LIM, and LIL were close to or above odor thresholds, but well below sensory irritation thresholds in the eyes and upper airways; no information on EUG was traced. Similarly, the reported risk values for long-term effects are much higher than the reported indoor concentrations. Human exposure studies indicate that, in general, the reported lung function effects are likely due to perception rather than the toxic effects of fragrances. In general, the effects on respiratory rate and mood from exposure to fragrances are inconclusive. Fragrances may increase heart rate, but exposure to aerosols during cleaning activities may decrease it. Distracting effects on work performance from exposure to fragrances/scents are frequently reported, but their persistence over time is unknown.^[10] Oxidative stress plays a pivotal role in the pathogenesis of many diseases, but no accurate measure of oxidative stress or antioxidants is useful in a clinical setting. Cyclic voltammetry is a widely used electrochemical technique for analyzing redox states in industrial and research settings. It has also recently been applied to assess the antioxidant status of biological samples *in vivo*.^[11]

MATERIALS AND METHODS

Materials

Aqueous perfumes were taken from perfume shops in popular markets, crustacean shells from sea, sodium hydroxide (NaOH) and, hydrochloric acid (HCl) from E. Merck. Darmstadt, acetic acid, and sodium triphosphate from Technicon Chemicals (Aurec, Tournai, Belgium), and healthy human blood samples were obtained from Baghdad Hospital Center (Iraq).

Methods

Preparation and Characterization of Nano-Perfume Solutions

Aqueous perfumes both for men and women were used in the experiments. They were then lyophilized using a lyophilizer to convert them to nanoparticles, as shown in

Figure 1. After converting them to a nano solution, they were characterized to determine the size of the perfume nanoparticles using electron force microscopy (AFM), which revealed a size of 35.7 nanometers, as shown in

Figure 2. The UV spectrum of the nano-perfume were also studied, and the results revealed the appearance of five absorption peaks, as shown in Table 1 and Figure 3.



Fig. 1: Lyophilizer.

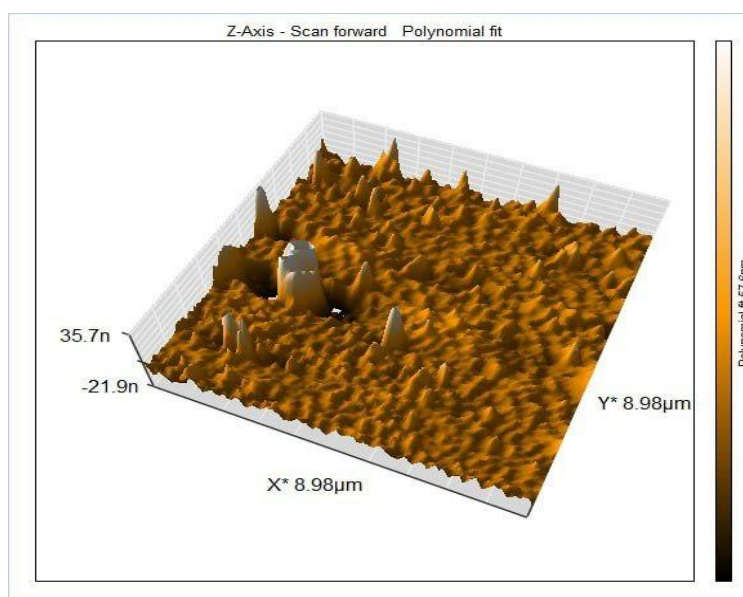


Fig. 2: AFM of Nano perfume.

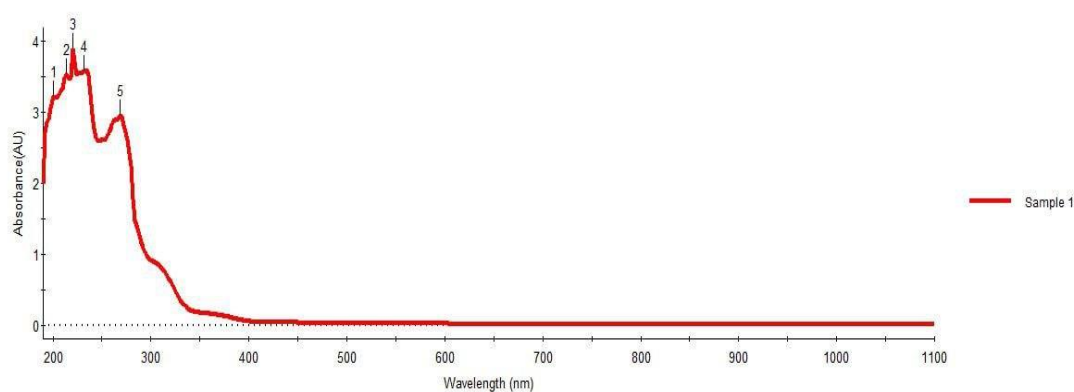


Fig. 3: UV spectrophotometer.

Table 1: UV-spectrophotometer peaks properties.

No.	Peak(nm)	Peak(AU)
1	200.60	3.2589
2	213.00	3.5838
3	220.45	3.9911
4	232.90	3.5997
5	267.80	2.9627

Preparation of Chitosan

Chitosan is generally prepared from crustacean shells through three basic steps: demineralization, deproteinization, and deacetylation. The peels were demineralized by continuous stirring with 5% hydrochloric acid at a ratio of 1:15 (w/v, peel to solution) for 36 hours at room temperature. The demineralized peels were treated with a 5% NaOH solution at a ratio of 1:10 (w/v) at 90-95°C for 6 hours. The deproteinized peels were filtered and washed with tap water until the NaOH was completely removed, then dried overnight in an oven at 55-60°C. The peels were filtered and washed with tap water until they became neutral. Chitosan was then deacetylated by hydrolysis with 80% NaOH at a ratio of 1:20 (w/v, chitin to solvent) at 90-95°C for 5 hours. This product was washed with tap water until it became neutral and dried overnight at 55-60°C. To prepare chitosan solutions, 1.0% (w/v) chitosan was dispersed in a 1.0% (v/v) acetic acid solution.

Preparation of Chitosan Nanoparticles

Chitosan nanoparticles were synthesized using sodium triphosphate as a cross-linking agent via the ion coagulation method. Initially, to create a homogeneous chitosan solution, approximately 1.5 grams of chitosan was dissolved in 200 ml of 2% acetic acid solution under magnetic stirring for approximately 20 minutes. Then, 0.8 grams of sodium triphosphate dissolved in 107 ml of conductive water was added dropwise and stirred thoroughly for approximately 30 minutes to reach equilibrium. A milky-colored emulsion of chitosan nanoparticles was formed upon ionic cross-linking between the sodium triphosphate and the chitosan solution. After reaching equilibrium, the suspension was formed under the above conditions. The nanoparticles were then separated by centrifugation at 20,000 rpm and dried at 14°C for 30 minutes. They were then frozen and stored at $5 \pm 3^\circ\text{C}$.

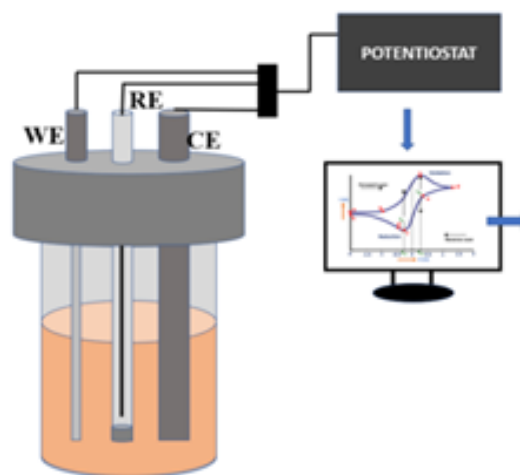
Preparation of nanochitosan with nanoparfumes

1 mg of nanochitosan was added to 10 ml of nanoparfumes and mixed using a magnetic stirrer for half an hour at room temperature (25°C). The mixture was then placed in a sonicator for an hour to complete the dissolution process and transform it into a homogeneous solution.

Cyclic Voltammetry set up

The EZPSV131240 Potentiostat (USA) was used for loop voltammetry measurements in the electrochemical diagnostic study. A 15 ml cell is connected, and a 10 ml blood sample is placed (at a ratio of 1 ml blood to 9 ml

distilled water). Three electrodes are then immersed in the blood, the working electrode (a glassy carbon electrode), the reference electrode (a silver wire coated with silver chloride and immersed in a 3 M potassium chloride solution), and the counter electrode (a 1 mm thick platinum wire). The three electrodes are connected to the cyclic voltammetry, which turned connection into the personal computer, as shown in Figure 4.

**Fig. 4: Cyclic voltammetry set up.**

Results and Discussion

Nanofragrances are alcohol-free, oil-in-water nanoemulsions or encapsulated fragrance carriers designed to increase safety, skin compatibility, and fragrance longevity (sustained release).

The optimized nano-fragrance formulation produced a clear, stable emulsion with droplet sizes of 35.7 nm (measured using AFM). Visual inspection showed no phase separation for at least three days.

Spectrophotometric Analysis

UV-vis absorption spectra showed characteristic peaks corresponding to aromatic compounds in the 200-270 nm range. Stability tests indicated a slight decrease in absorption intensity, indicating high stability of the formulation. The integration of optical spectroscopy and electrochemistry provided complementary insights. While UV/Vis confirmed optical stability, electrochemistry demonstrated functional activity at the electrode interfaces, which is important for understanding molecular interactions and controlled release dynamics.^[12,13]

Stability Study of Nano-Perfumes on Cotton Fabric

Laboratory experiments were conducted on nano-perfumes to determine their stability and durability on clothing. An experiment was conducted by adding a mixture of nano-perfumes and nano-chitosan to a piece of cotton fabric and leaving it exposed to air. A commercial micro-perfume was added to another piece of fabric and left exposed to air. The fabric was

periodically checked every 8 hours. The scent of the micro-perfume deteriorated within a few hours, and its scent disappeared due to the intensity of ultraviolet radiation. Its intensity was lost within the first hours of adding the fragrance, as shown in Figure 5. Meanwhile, we observed the scent persisting on the fabric exposed to

the nano-perfume, lasting for several days, up to three days, with the same scent and strength. This was achieved by maintaining the intensity of ultraviolet radiation on the cotton fabric. This is due to the gradual release of the fragrance from the nano-chitosan over a long period, as shown in Figure 5.

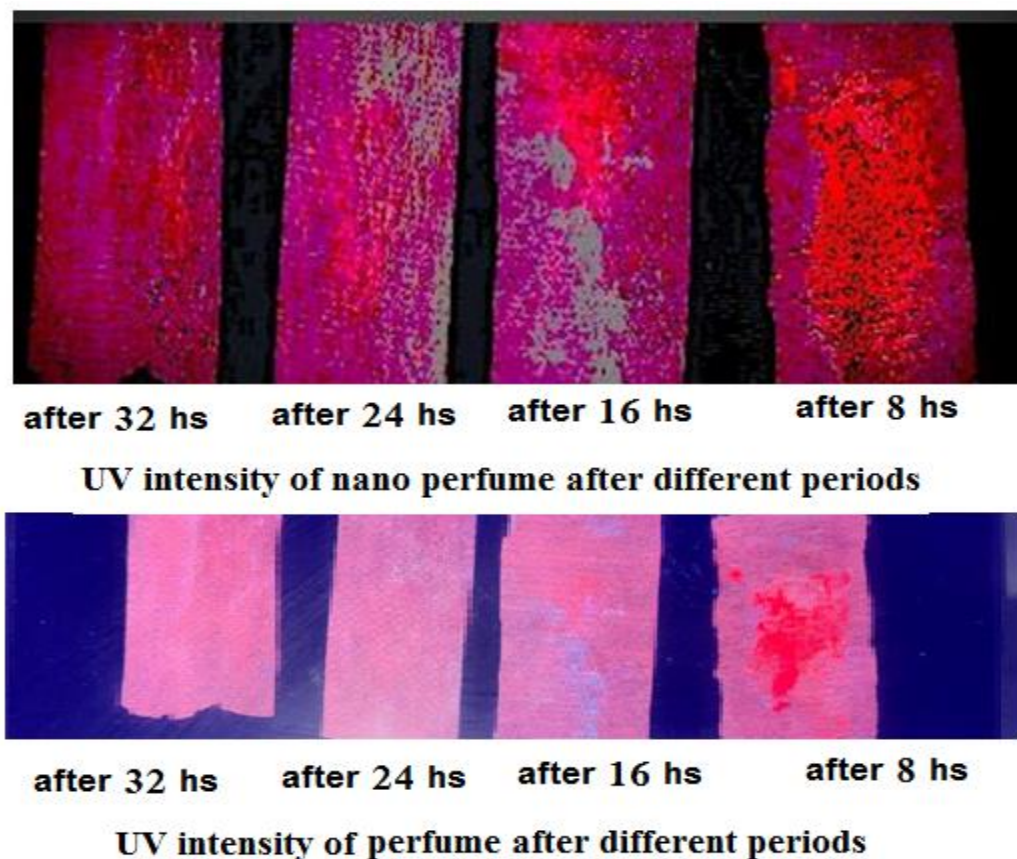


Fig. 5: UV- spectrophotometric study of each perfume and Nano perfume at periods times.

Electrochemical Analysis

Cyclic voltammetry demonstrated reversible redox behavior for the main aromatic molecules, with well-defined peaks at +0.75 V and -0.60 V. The aroma nanoarray exhibited improved current response compared to non-nanoarray formulations, indicating enhanced electrochemical surface interactions.^[14,15]

Studying the Antioxidant Properties of Nanoperfume in Blood

From an analytical study of the electrochemistry of nanofragrances in the bloodstream, the voltammetric diagram showed no oxidation peaks for the

nanofragrances solution. Therefore, the nanofragrances solution is considered an antioxidant in the blood, as shown in Figure 5. The oxidation peak shown in the figure is specific to the blood, which causes this peak to decrease in the presence of the nanofragrances. Nanofragrances with the nanocarrier chitosan also have an antioxidant effect, as the combination of the nanofragrances with the nanocarrier chitosan lowers the oxidation peak in the blood, as shown in Figure 6. Increasing the concentration of the fragrance mixture with the nanocarrier stabilizes the low oxidation peak, as shown in Figure 7.

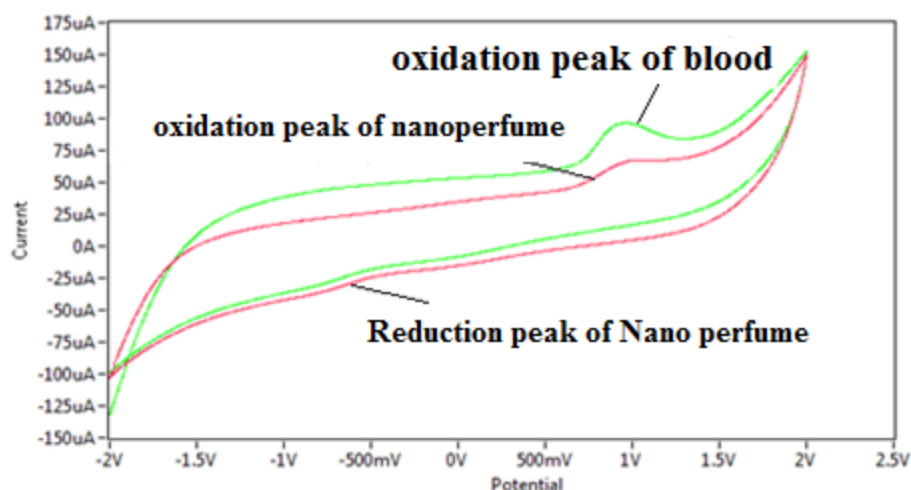


Fig. 6: cyclic voltammogram of each blood medium and Nano perfume in blood medium on GCE versus Ag/AgCl reference electrode at scan rate 0.1 Vsec^{-1} .

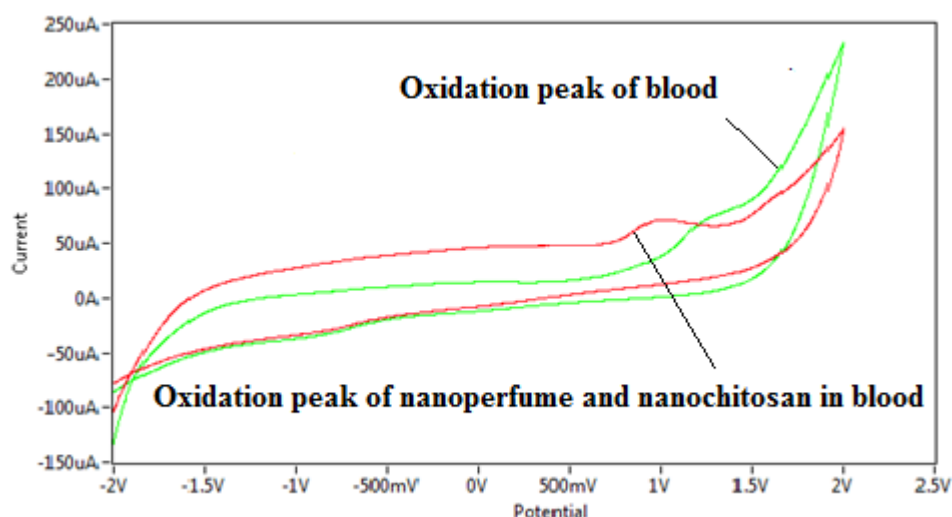


Fig. 7: Cyclic voltammogram of each blood medium and nano perfume with nano chitosan in blood medium on GCE versus Ag/AgCl reference electrode at scan rate 0.1 Vsec^{-1} .

CONCLUSION

The integrated fabrication and characterization of the nano-fragrance formulations presented in this study demonstrate that nanotechnology offers a promising path for improving fragrance stability, controlled release, and product safety. The successful synthesis of emulsion nano-fragrance systems—using optimized surfactant ratios and homogenization techniques—resulted in stable nanodroplets with desirable physical and chemical properties, including uniform size distribution and favorable properties for colloidal stability.

Photoelectron spectroscopy effectively quantified the encapsulation efficiency and monitored the release kinetics of key fragrance compounds, confirming that nanoencapsulation prolongs volatility and prevents premature degradation. Electrochemical methods, particularly voltammetric techniques, enabled the accurate and selective detection of redox-active fragrance markers, enabling real-time assessment of

chemical stability and release behavior. The convergence of these two analytical approaches has enabled a more comprehensive understanding of the physical and chemical interactions that regulate fragrance retention and release at the nanoscale.

Overall, the integrated spectro-electrochemical framework not only validates the structural integrity and functional performance of the synthesized nano-fragrance, but also establishes a reproducible and cost-effective analytical platform for future cosmetic and fragrance research. This dual analytical strategy paves the way for the robust design of advanced nano-fragrance formulations with enhanced sensory performance, environmental stability, and consumer safety.

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