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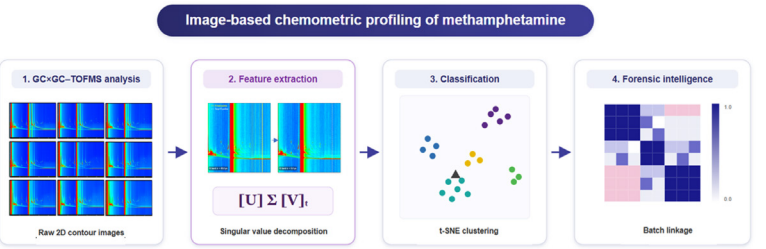

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Forensic Analysis pp. 279-289

Impurity profiling of methamphetamine: A chemometric approach using comprehensive two-dimensional gas chromatography–time-of-flight mass spectrometry

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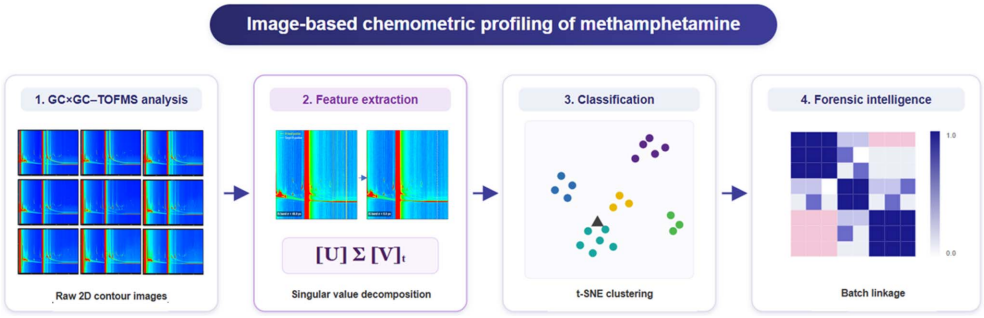

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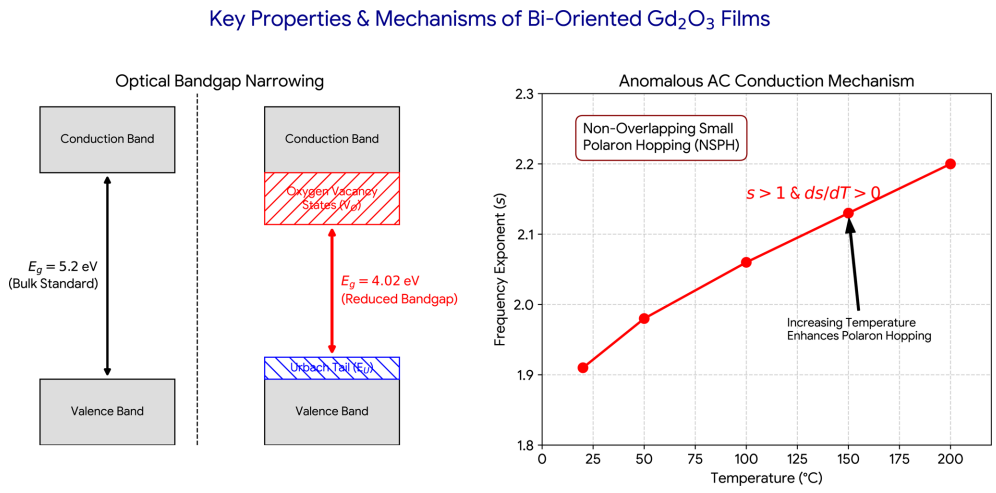
Anomalous AC electrical transport and dielectric relaxation in vacuum-evaporated bi-oriented (301)/(322) Gd_2O_3Thin Films with Enhanced Surface Wettability

F. Trabelsi, I. H. Sharqi, and H. Dhaouadi, and Abdelwaheb Boukhachem



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Impurity profiling of methamphetamine: A chemometric approach using comprehensive two-dimensional gas chromatography–time-of-flight mass spectrometry

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Abstract: Drug impurity profiling serves as an essential forensic approach for elucidating the manufacturing origins and trafficking routes of illicit drugs. However, the recent surge in high-purity methamphetamine (MA) presents a significant analytical challenge, as the high abundance of the major component frequently obscures trace impurities essential for chemical fingerprinting. To overcome these limitations, an advanced chemometric profiling workflow utilizing comprehensive two-dimensional gas chromatography–time-of-flight mass spectrometry (GC×GC–TOFMS) was established. A total of 222 seized MA samples were analyzed utilizing raw pixel-based GC×GC chromatographic images as primary data sources, bypassing conventional peak integration. A custom dual-reference alignment algorithm and singular value decomposition (SVD) were implemented to correct retention time shifts and extract chemical feature vectors. Subsequently, distinct clusters corresponding to specific synthetic routes, such as the Leuckart and Emde methods, were visualized. Chemically linked batches were identified using cosine similarity-based comparisons and hierarchical clustering, and route-related groupings were visualized using t-distributed stochastic neighbor embedding (t-SNE). These results indicate that this image-based approach helps mitigate dynamic range limitations in high-purity analysis, providing law enforcement with reliable forensic evidence.

Key words: impurity profiling, methamphetamine, comprehensive two-dimensional gas chromatography–time-of-flight mass spectrometry, cluster analysis, dual-reference alignment, singular value decomposition

1. Introduction

Drug impurity profiling serves as a crucial forensic technique aimed at generating a unique chemical fingerprint by characterizing the trace organic and inorganic impurities present in synthetic illicit drugs, such as methamphetamine (MA). The United Nations Office on Drugs and Crime (UNODC) categorizes this process as a vital part of drug characterization and advocates for the use of standardized analytical

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protocols (e.g., the ST/NAR series) to elucidate synthetic pathways such as the Leuckart or Emde methods to identify the specific precursors employed.[1,2]

Conventionally, chromatographic methods have been the predominant approach for drug impurity profiling, with the nature and utility of the resulting data being largely determined by the specific detector utilized. A variety of analytical techniques have been developed for the precise characterization of MA, including gas chromatography-flame ionization detection (GC–FID), gas chromatography-mass spectrometry (GC–MS), GC–FID/MS, high-performance liquid chromatography (HPLC), and LC–MS/MS.[3-7] Among these, GC–MS has firmly established itself as a standard method for organic impurity analysis due to its robustness and reliability. When chemometric approaches such as principal component analysis or hierarchical cluster analysis (HCA) are applied to the data obtained from these methods, it becomes possible to establish sample-to-sample linkages between different seizures and to trace manufacturing and distribution networks. Such analytically derived intelligence is crucial not only for apprehending individual users but also for identifying upper-level criminal organizations and substantiating conspiracy links.[8,9] However, the increasing purity of seized MA in recent years has introduced significant analytical challenges. As the concentration of the main component rises, its signal often overwhelms trace impurities, resulting in dynamic range limitations. Conventional one-dimensional GC-MS frequently struggles to distinguish subtle pattern differences caused by co-elution or impurity levels falling below the limit of detection.[9,10]

To address these challenges, comprehensive two-dimensional gas chromatography–time-of-flight mass spectrometry (GC×GC–TOFMS) has been increasingly explored in forensic science. Previous studies have already demonstrated the efficacy of GC×GC systems in drug profiling, specifically noting their capacity to improve sensitivity via cryo-focusing and achieve high-resolution separation of trace constituents within complex matrices.[11,12] While GC×GC provides enhanced separation, the resulting high-dimensional data require advanced processing. Consequently, chemometric strategies utilizing raw chromatographic data—rather than conventional peak-by-peak integration—have been increasingly adopted to enable more robust comparisons of chemical fingerprints across large-scale datasets.[13,14] Building upon these precedents, the system used in this work leverages a quad-jet dual-stage thermal modulator to trap and concentrate analytes from the first-dimension before rapidly reinjecting them into the second-dimension. Integration of TOFMS is critical in this workflow, as it captures the rapid, millisecond-scale separation events in the GC×GC that exceed the capabilities of conventional slow-scanning quadrupole MS. By transforming the resulting three-dimensional data into 2D contour images and applying a chemometric pipeline involving SVD and cluster analysis, this study establishes an advanced profiling workflow for the scientific determination of manufacturing sources of MA. The primary novelty of this work lies in its rapid, non-targeted approach; by bypassing laborious peak-by-peak integration and utilizing raw pixel-level data, the workflow reduces processing time while capturing subtle chemical signatures that are often lost in conventional integration. This image-based comparative framework facilitates a comprehensive characterization of the impurity landscape, allowing for the differentiation of high-purity seizures even when critical trace markers are masked by the dominant component's signal.

2. Experimental

2.1. Chemicals and reagents

The reference materials, *d*-MA, *l*-MA, and *d,l*-MA, were purchased from Cerilliant (Austin, TX, USA) and nonacosane, used as the internal standard (IS), was purchased from Sigma-Aldrich (St. Louis, MO, USA). Ethyl acetate and hexane were of HPLC grade and purchased from Honeywell-Burdick and Jackson (Muskegon, MI, USA) and LC/MS-grade water was purchased from Fisher Chemical (Pittsburgh, PA, USA). All other reagents were of ACS grade and the polypropylene centrifuge tubes (5.0 mL) were purchased from Eppendorf (Hamburg, Germany).

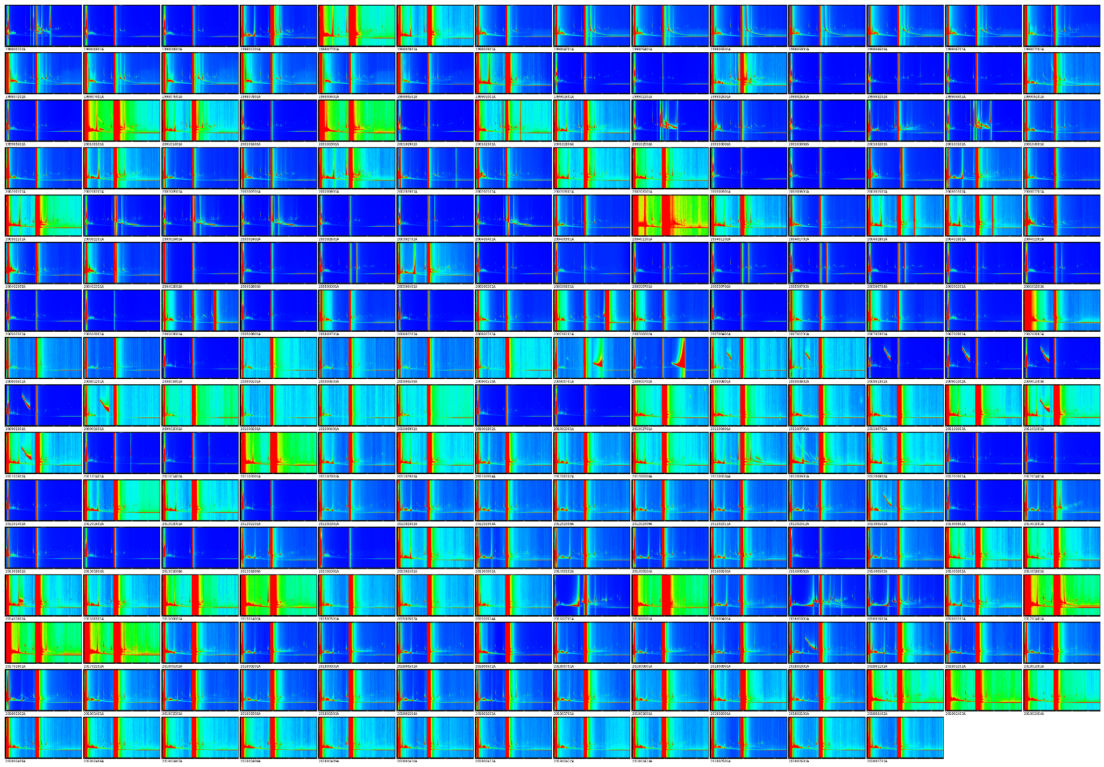

Fig. 1. GC×GC–TOFMS two-dimensional contour images of all 222 analyzed methamphetamine (MA) seizures selected for chemometric profiling.

Nonacosane, as the IS material, was dissolved in hexane and diluted to a final concentration of 10 μg/mL by the addition of ethyl acetate. The IS solutions were placed in sealed containers to prevent leaks and stored at -20°C before use.

2.2. MA seizures and sample preparation

MA seizures were obtained from Narcotics Departments at the District Prosecutors' Offices nationwide. From these, 222 samples were selected for chemometric profiling (*Fig.* 1). These 222 samples were selected to represent the diversity of MA seizures collected by the Forensic Science Division of the Supreme Prosecutors' Office between 1998 and 2018. Selection criteria included: (1) sufficient sample mass for analysis (≥ 50 mg), (2) confirmed MA identity by preliminary GC-MS screening, and (3) geographic distribution across multiple jurisdictions nationwide to ensure the representativeness of the dataset with respect to trafficking routes and manufacturing sources. Samples spanning more than two decades were included to capture temporal variations in synthetic routes and impurity profiles associated with changes in the domestic drug supply.

Each MA sample (50 mg) was weighed, placed in a centrifuge tube, and dissolved in 2 mL of 0.1 M potassium phosphate buffer (pH 7). The pH was then adjusted to pH 11 by the addition of 0.25 mL of 10 % (w/v) Na_2CO_3 solution. To this mixture, 0.5 mL of ethyl acetate containing 10 μg/mL nonacosane was added. The solution was shaken for 10 min for extraction, followed by high-speed centrifugation at 20,000 × g for 10 min. Finally, 2 μL of the organic supernatant was collected and injected into the GC×GC–TOFMS system for analysis.

2.3. Instrumental analysis

For MA impurity profiling, a Pegasus BT 4D

GC×GC–TOFMS system (LECO Corp., St. Joseph, MI, USA) equipped with an Agilent 7890 Gas Chromatograph (Agilent Technologies, Palo Alto, CA, USA) and a quad-jet dual-stage thermal modulator was employed.

The GC separation was performed using a splitless injection mode at 250 °C. The carrier gas was helium (99.999 % purity) at a constant flow rate of 1.2 mL/min. The 1D GC column was a non-polar DB-5MS (30 m × 0.25 mm i.d., 0.5 μm film thickness; Agilent Technologies), and the 2D GC column was a mid-polar Rxi-17Sil MS (1.2 m × 0.15 mm i.d., 0.15 μm film thickness; Restek, Bellefonte, PA, USA), installed in the secondary oven.

The primary oven temperature was programmed as follows: initial temperature of 50 °C held for 1 min, increased to 100 °C at a rate of 5 °C/min, and finally ramped to 300 °C at 10 °C/min, where it was held for 10 min. The secondary oven and the modulator were maintained at offsets of +5 °C and +20 °C, respectively, relative to the primary oven temperature to ensure efficient transfer and focusing of analytes. The modulation period was set to 3 s, with a hot pulse duration of 0.3 s and a cooling time of 1.2 s using liquid nitrogen.

Mass spectrometric detection was carried out using a TOFMS. The ion source temperature was set to 230 °C, and the transfer line was maintained at 280 °C. Mass spectra were acquired in the range of *m/z* 35–650 at an acquisition rate of 200 spectra/s. The detector voltage was set to 1,700 V with an electron energy of 70 eV. Data acquisition and processing were performed using ChromaTOF software (version 4.50, LECO Corp.).

2.4. Data preprocessing

Raw GC×GC-TOFMS contour images exported from ChromaTOF software were first converted to grayscale matrices, where each pixel intensity represents the total ion signal at the corresponding (first-dimension retention time (^1t_R), second-dimension retention time (^2t_R)) coordinate. Prior to comparative analysis, a dual-reference alignment algorithm was applied to correct for inter-run retention time shifts in both dimensions. Specifically, the pixel coordinates of the MA main peak (reference 1) and the nonacosane IS peak (reference 2) were identified in each sample image and compared to those in a designated target template. Linear translational shifts in both dimensions were then calculated and applied to rigidly realign the entire chromatographic matrix.[15] Following alignment, a region of interest (ROI) was cropped from each image to exclude the solvent delay region and column bleed areas. Each cropped image was subsequently normalized by dividing all pixel intensities by the maximum intensity of the IS peak, thereby correcting for variations in injection volume and instrumental response. The normalized image matrices were then vectorized and assembled into a sample-by-pixel feature matrix (n = 222 samples). Singular value decomposition (SVD) was applied to this feature matrix to extract latent chemical features. To prevent overfitting while retaining chemically meaningful variance in this forensic dataset, the number of retained components was capped at 50, or the number of samples if smaller (i.e., the lesser of the two), yielding a compact embedding vector of length $\leq$ 50 for each sample. Cosine similarity was subsequently calculated between all pairs of embedding vectors to construct the similarity matrix used for hierarchical clustering and batch linkage analysis.[14]

It is acknowledged that contour images rendered by ChromaTOF software may be subject to partial intensity compression arising from the internal color scale and bit depth of the rendered output. However, since the downstream similarity analysis is based on cosine similarity between SVD-derived embedding vectors—a metric that is inherently insensitive to differences in vector magnitude—minor attenuation of absolute intensity values introduced by the rendering process does not affect the similarity assessment, which depends on the direction of the embedding vectors rather than their magnitude. The consistent application of identical rendering parameters across all 222 samples further ensures that any systematic intensity constraints are uniformly applied, preserving the relative impurity pattern information critical for batch linkage.

2.5. Chemometric analysis and visualization

To systematically evaluate the chemical relationships among the MA seizures, chemometric analysis was performed using the feature vectors derived via SVD. Cosine similarity was selected over alternative metrics such as Pearson correlation or Euclidean distance because the primary forensic objective is to compare the relative compositional patterns of trace impurities rather than their absolute signal intensities, which may vary independently of chemical origin due to concentration differences or day-to-day instrumental variability. Cosine similarity evaluates the angular divergence between SVD-derived embedding vectors in the reduced latent feature space, making it insensitive to differences in overall signal magnitude while remaining sensitive to differences in compositional pattern—a property well-suited to batch linkage analysis.[16,17] It is important to note that similarity was computed between the SVD-derived embedding vectors rather than between the original pixel matrices; the resulting values therefore reflect proximity in the latent chemical feature space and do not represent direct pixel-to-pixel correspondence. Negative cosine similarity values, which would indicate inverse orientation in the embedding space with no interpretable forensic meaning, were set to zero, consistent with the objective of identifying positive chemical associations. Based on the resulting similarity matrix, HCA was conducted using Ward's linkage method to group samples with homologous impurity profiles into distinct clusters. Ward's method was chosen for its efficacy in minimizing within-cluster variance, generating compact groups for subsequent comparison.[18]

For intuitive visualization of the high-dimensional data structure, t-distributed stochastic neighbor embedding (t-SNE) was employed. This non-linear dimensionality reduction technique projected the complex 222-sample dataset into a two-dimensional latent space, enabling the visual identification of natural groupings and outliers. The t-SNE algorithm was configured with a perplexity of 30 and 1000 iterations to ensure stable convergence of the global structure.[19] Furthermore, to visualize the overall pairwise chemical similarity structure of the dataset, a hierarchically ordered heatmap was generated. In this representation, both the X-axis and Y-axis display the 222 samples ordered by dendrogram clustering, and the color intensity at each cell encodes the cosine similarity score between the corresponding sample pair, providing a comprehensive overview of batch-to-batch similarity and route-specific clustering patterns across the nationwide seizures.[20] All data processing, chemometric computations, and visualizations were executed within the R and RStudio statistical environment using custom scripts (Supplementary material). Core packages included imager for pixel-based chromatogram processing, lsa, proxy, and cluster for similarity measurements and multivariate analysis, and the tidyverse suite combined with ggdendro and dendextend for advanced graphical representations (*Fig.* 2).

To provide visual validation of the similarity analysis, an automated contour retrieval procedure was implemented. For a designated query sample, the five samples with the highest cosine similarity scores were automatically retrieved from the database and their aligned contour images were displayed

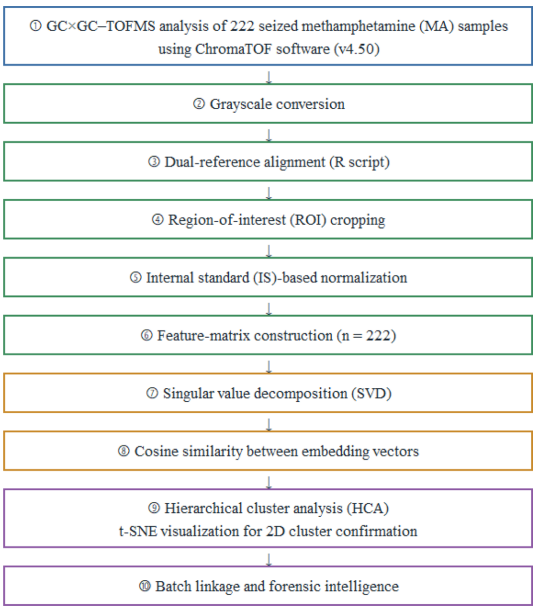

Fig. 2. Schematic overview of the image-based chemometric workflow for GC×GC–TOFMS impurity profiling of MA.

alongside that of the query sample in a six-panel layout. This visual comparison enables direct inspection of the congruence of trace impurity patterns and the positional correspondence of route-specific markers across samples, providing intuitive confirmation of the computed similarity scores.

3. Results and Discussion

3.1. Dual-reference alignment and feature extraction

To ensure the forensic reliability of the comparative analysis, the efficacy of the dual-reference alignment algorithm was first evaluated. In conventional GC×GC–TOFMS analysis, RT shifts often occur due to column aging or minor temperature fluctuations, which can lead to misidentification of impurity peaks. The raw contour images of the 222 MA samples initially exhibited substantial retention time deviations in both the first- and second-dimension retention (^1t_R and ^2t_R) axes (*Fig.* 3A). After applying the custom R-based alignment using the coordinates of the IS and the main MA peak as dual references, the chromatographic profiles were synchronized, converging onto a common coordinate (*Fig.* 3B). Quantitatively, the mean absolute pixel-coordinate residual of the reference peaks across all 222 samples was reduced from 120.4 ± 38.8 to 25.6 ± 44.4 pixels in the first-dimension (^1t_R) and from 156.5 ± 51.6 to 28.3 ± 50.0 pixels in the second-dimension (^2t_R) after dual-reference alignment, confirming the efficacy of the alignment algorithm.

This alignment enabled the application of SVD, reducing the high-dimensional pixel data into essential chemical feature vectors (embeddings). This approach captured the latent variance associated with trace impurity patterns while filtering out instrumental response, thereby providing a consistent basis for chemometric analysis without the need for peak-by-peak integration.

3.2. Quantitative similarity assessment and visual correlation

The pairwise comparison of the extracted feature vectors using cosine similarity quantified the chemical relationships among the seizures. The calculated similarity scores ranged from 0.0 to 1.0, where a score near 1.0 indicated a near-identical impurity profile. To visually validate these metrics, the chromatographic profiles of a representative sample (201802701A) and its five most similar samples were retrieved and compared (*Fig.* 4). As illustrated in the aligned 2D contour plots, the impurity patterns of the queried sample matched closely with those of the retrieved samples such as 200102806A with a cosine similarity of 0.931. Key route-specific markers

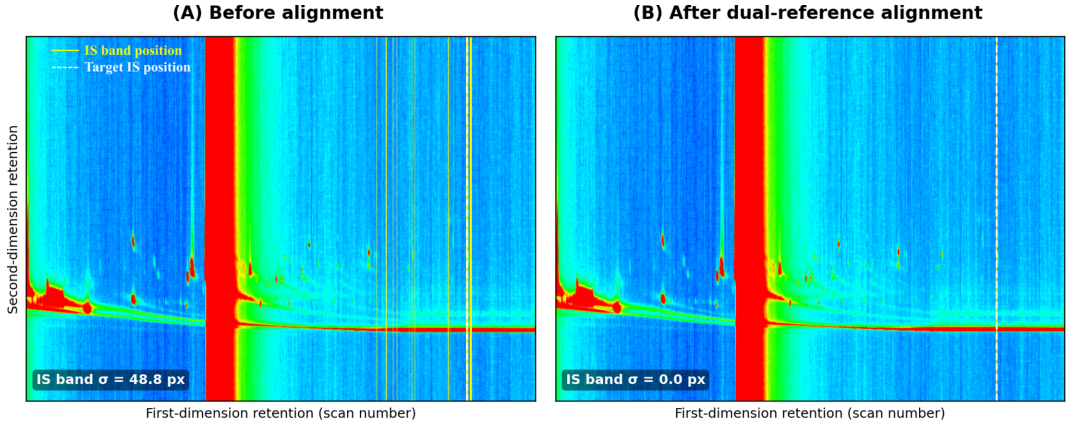

Fig. 3. Representative GC×GC–TOFMS two-dimensional contour image with the internal standard (IS) band positions of all 222 samples overlaid (A) before and (B) after dual-reference alignment, illustrating the correction of retention time deviations in both the first- and second-dimension axes.

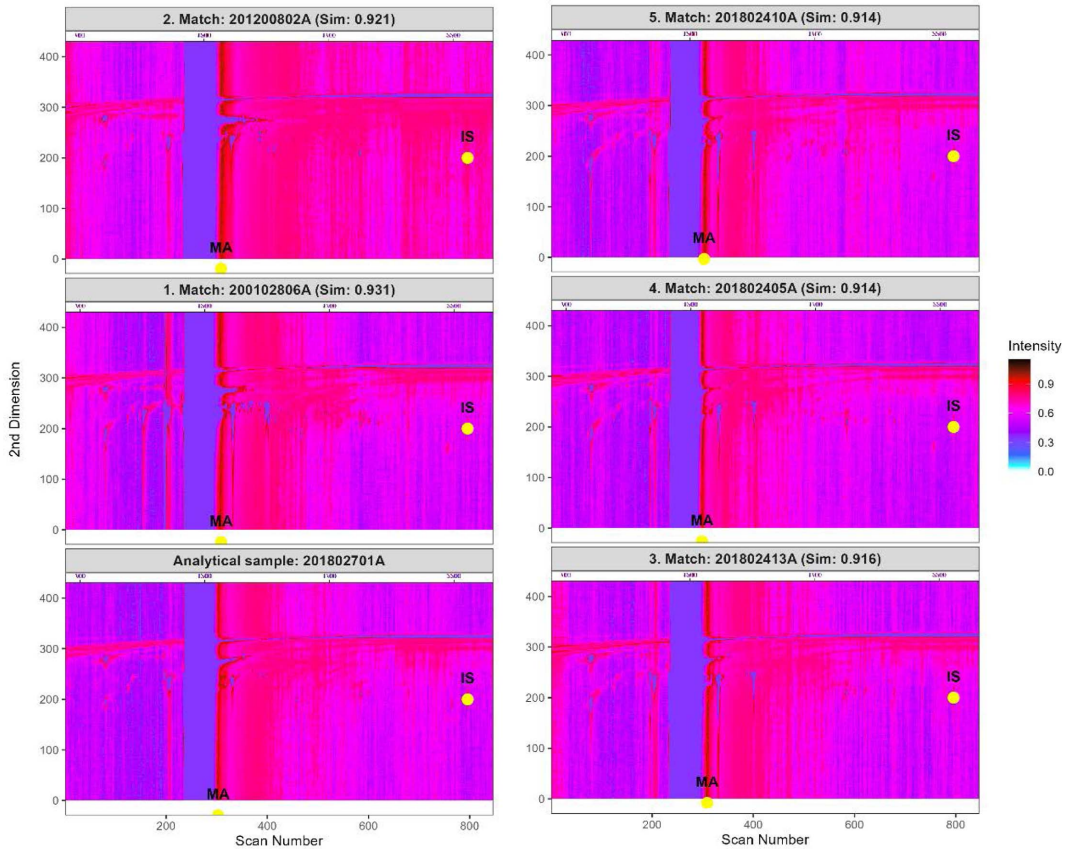

Fig. 4. Aligned GC×GC–TOFMS two-dimensional contour plots of the MA sample (201802701A) and its five most similar samples retrieved from the database.

appeared at identical retention coordinates with comparable intensity ratios. This visual congruence indicates that the SVD-derived cosine similarity accurately reflects the underlying chemical composition, enabling the reliable identification of chemically linked seizures.

3.3. Classification of seizures by route-specific impurity profiles

To interpret the complex relationships within the nationwide dataset, t-SNE and HCA were utilized. The t-SNE projection revealed the formation of several distinct clusters (*Fig.* 5), corresponding to groups of samples sharing specific impurity characteristics.

The clustered heatmap (*Fig.* 6) further elucidated the chemical basis of these groupings. The segregation of samples into major groups such as group A, B, and C was driven by variations in key route-specific impurities. For instance, one major cluster was characterized by high intensities of Leuckart-specific markers such as α,α-dimethyldiphenethylamine while another showed a profile consistent with the Emde method, characterized by the presence of cis- and trans-1,2-dimethyl-3-phenylaziridine. The route-specific impurity markers used to characterize each cluster were confirmed by targeted GC-MS analysis in our laboratory using authentic reference standards. The identities of α,α-dimethyldiphenethylamine as a Leuckart-specific marker and cis/trans-1,2-dimethyl-3-phenylaziridine as markers of the Emde route are well-established in the forensic literature,[21-23] lending additional credibility to the route assignments derived from the image-based chemometric analysis. This clear separation demonstrates the capability of the

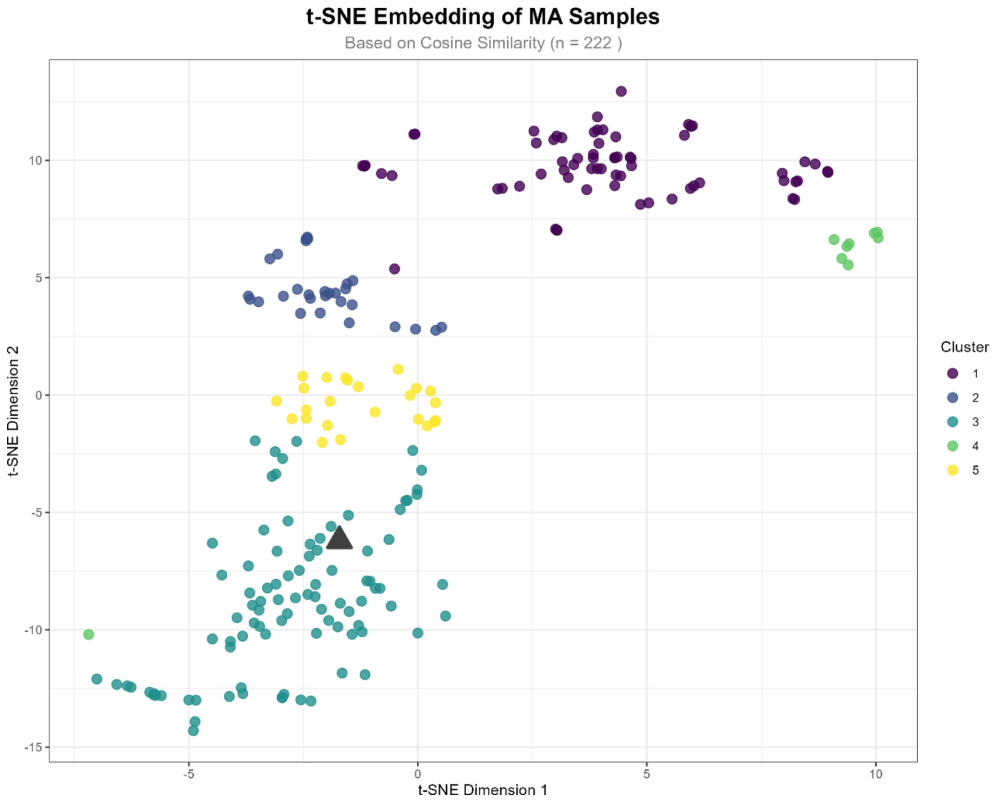

Fig. 5. t-SNE visualization of seized MA samples (n = 222) based on cosine-similarity profiles, with the target sample (201802701A) indicated by a dark gray triangle.

developed chemometric framework to effectively discriminate between different manufacturing origins without a priori knowledge, facilitating precise chemical profiling and grouping of seizures.

3.4. Forensic intelligence and batch linkage analysis

The final goal of this profiling was to derive actionable forensic intelligence. The integration of the similarity matrix and cluster analysis facilitated the identification of batch linkages, which represent connections between seizures that likely share a common production source. Samples grouped tightly within the dendrogram (Euclidean distance < 0.1) were inferred to be batch-linked. The Euclidean distance threshold of < 0.1 for batch linkage inference was determined empirically by evaluating dendrogram stability across a range of candidate thresholds (0.05–0.30). The value of 0.1 was selected as it yielded the most stable and interpretable clade structure, consistent with the approach described by Esseiva et al.[16] for establishing linkage criteria in forensic drug profiling databases.

The chemometric framework thus provides a chemically grounded set of candidate batch linkages that can serve as investigative leads. Establishing the geographic distribution of these linked seizures across jurisdictions, however, requires cross-referencing the chemical groupings with the corresponding case records held by narcotics investigators. Integrating chemical intelligence with investigative case data in collaboration with drug-enforcement authorities would enable the mapping of chemically linked batches to their seizure locations and thereby help reveal potential trafficking networks operating across multiple jurisdictions. In addition, the identification of outliers, defined as samples that did not cluster with any major group, may point to the emergence of new

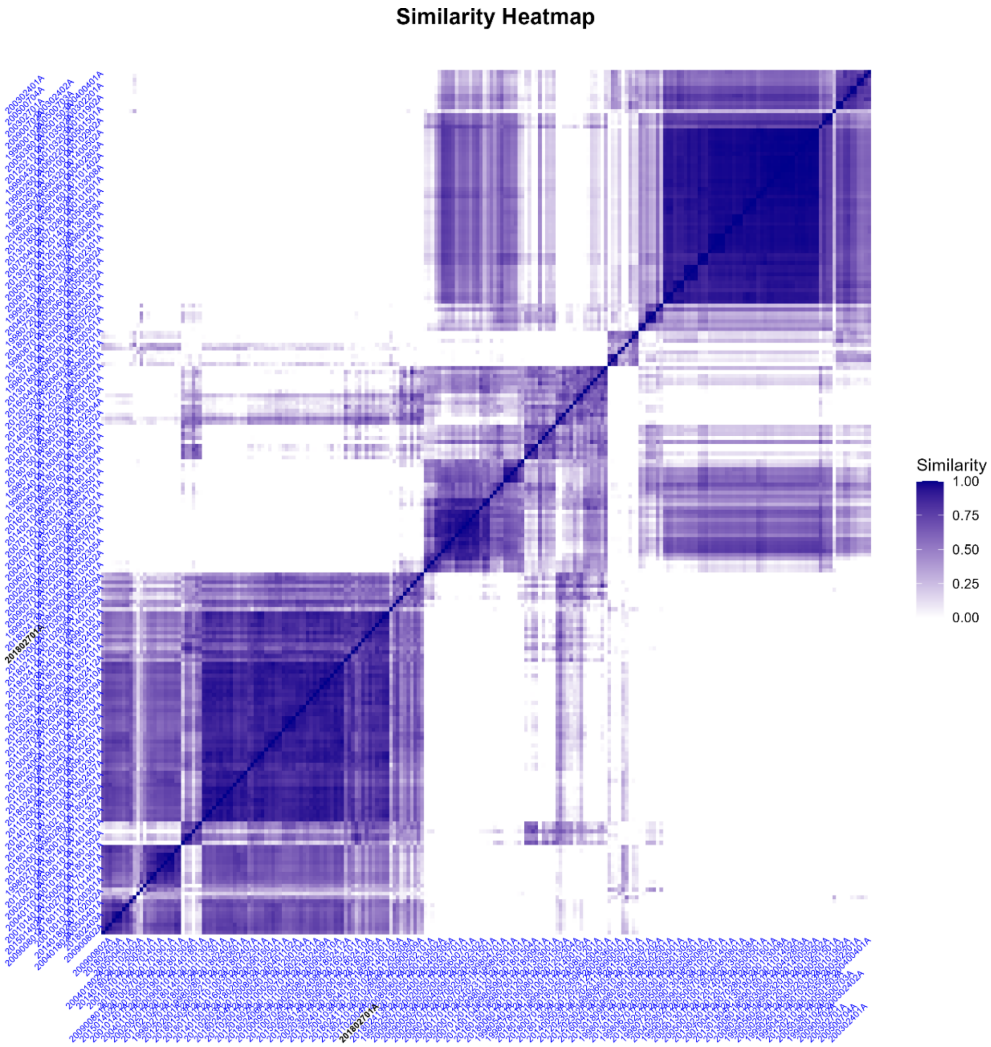

Fig. 6. Hierarchically ordered heatmap of pairwise cosine similarities (0.00–1.00) among the 222 seized MA samples, with both axes ordered by dendrogram clustering and the target sample (201802701A) highlighted.

manufacturing sources or unique adulteration practices. Collectively, these findings indicate that the proposed image-based chemometric approach can translate complex GC×GC–TOFMS data into chemically grounded intelligence that supports subsequent investigations into illicit drug manufacturing and distribution.

4. Conclusion

This study demonstrates the efficacy of GC×GC–TOFMS combined with image-based chemometrics for the impurity profiling of high-purity MA seizures. In particular, the implementation of a dual-reference alignment algorithm followed by SVD-based feature extraction played a key role in the analysis. This approach effectively addressed retention time shifts and dynamic range limitations, allowing for the extraction of latent chemical features directly from raw pixel data. Consequently, high-purity MA samples could be precisely discriminated based on trace-level route-specific impurities, such as Leuckart and Emde markers. The visualization of distinct clusters and batch linkages supports the practical utility of this

method. Furthermore, this study serves as a foundational step for future forensic intelligence. While the current workflow enables efficient, non-targeted screening, the route-specific impurities characterized through this chemometric framework serve as a technical basis for the development of more refined, targeted analytical methodologies. By progressively integrating these findings into a targeted library, law enforcement will be able to perform even more rigorous assessments of potential manufacturing origins.

Supplemental Material

The R script for automated alignment, normalization, and comparative visualization of GC×GC–TOFMS chromatograms is available at https://github.com/paxus11.

Conflicts of Interest

The authors declare no competing financial interest.

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Anomalous AC electrical transport and dielectric relaxation in vacuum-evaporated bi-oriented (301)/(322) Gd_2O_3Thin Films with Enhanced Surface Wettability

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Abstract: Thin films of gadolinium oxide (Gd_2O_3, ~650 nm) were successfully deposited on glass substrates by vacuum thermal evaporation at a base pressure of 10^{-5} Torr.The structural study by X-ray diffraction (XRD) confirmed the presence of a single-phasecubic C-type rare-earth sesquioxide structureexhibiting two preferred orientations along the (301) and (322) planes, with an average crystallite size ranging from 100.31 to 145.35 nm. Field-emission scanning electron microscopy (FE-SEM) confirmed a dense, non-porous granular structure with a predominant grain size concentrated near 100 nm. Optical measurements revealed high transmittance (78–85 %) across the visible and near-infrared ranges, accompanied by a direct fundamental band gap of 4.05 eV and an Urbach energy of 0.31 eV, reflecting high structural order within the crystalline domains.The refractive index dispersion ($n \approx 2.08$–2.13) was accurately determined using Cauchy and Wemple–DiDomenicomodels, yielding a dispersion energy (E_d) of 22.99 eV. Temperature-dependent dielectric analysis revealed a prominent space charge polarization at low frequencies, obeying the Maxwell–Wagner–Sillars (MWS) polarizationlaw. The AC conductivity spectra followed Jonscher's power law, with an anomalous frequency exponent exceeding unity ($1.91 \leq s \leq 2.20$) increasing with temperature, indicating that cooperative hopping and mixed conduction of ions and electrons, mediated by doubly ionized oxygen vacancies (Vö), dominate the AC electrical transport. Furthermore, static contact angle measurements yielded a value of $\theta = 62°$, indicating moderate hydrophilicity and high surface free energy. These interrelated optical, insulating and conductive properties confirm the suitability of vacuum-evaporated Gd_2O_3 films for high-k dielectric applications, photovoltaic coatings, and surface-active sensors.

Keywords: Gd_2O_3 thin films, X-ray diffraction, dielectric spectroscopy, optical properties, electrical conductivity, wettability.

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1. Introduction

Rare-earth oxides (REOs) have emerged as pivotal functional materials for next-generation microelectronics, optoelectronic devices, and protective optical coatings owing to their outstanding thermodynamic stability, high dielectric constants (k), and wide band gaps.[1,2] Among them, gadolinium oxide (Gd_2O_3) stands out as a promising candidate to as an alternative to conventional SiO_2 in high-k gate dielectric stacks, optical filters, and luminescent/magnetic dual-mode biomedical probes.[3-7] Bulk Gd_2O_3 typically exhibits three major polymorphs: cubic (bixbyite-type, space group Ia-3), monoclinic (C^2/m), and hexagonal (P6_3/mmc), with phase transitions occurring above 1473 K and 2443 K, respectively.[3,4] While bulk cubic Gd_2O_3 possesses a wide direct band gap of ~5.2 eV[8] and a high relative permittivity ($\varepsilon r \sim 16$), the physical properties of nanostructured Gd_2O_3 thin films are highly sensitive to deposition parameters, stoichiometric defects, crystallite orientation, and grain boundary structures.[9-12]

Thin films of Gd_2O_3 have been synthesized using various deposition techniques, including sol-gel processing,[17-21] electron-beam evaporation,[22-24] and thermal evaporation,[25] pulsed laser deposition (PLD),[26-29] atomic layer deposition (ALD).[30,31] Vacuum thermal evaporation offers distinct advantages, including high purity, simplicity, good control over stoichiometry, and excellent film uniformity. Despite extensive research on single-crystal and randomly oriented polycrystalline Gd_2O_3 films, the relationships among dual preferred crystallographic orientations (texture), point defects such as oxygen vacancies, and the resulting optical, dielectric, and surface-energy properties remains insufficiently explored. Of particular interest is the anomalous AC electrical transport mechanisms with a Jonscher's power- law exponent exceeds unity ($1.91 \leq s \leq 2.20$), which remains insufficiently understood and requires further investigation to elucidate its underlying physical behavior. In this study, we report a comprehensive investigation of bi-oriented (301) and (322) Gd_2O_3 thin films prepared by high-vacuum thermal evaporation. The crystallographic texture, surface morphology, defect-associated optical band gap narrowing (4.05 eV), Maxwell-Wagner-Sillars dielectric polarization, cooperative ion-hopping dynamics, and surface wettability were systematically investigated to establish a coherent structure-property relationship for device integration.

2. Experimental Details

2.1. Synthesis of Gd_2O_3 powder

Stoichiometric amounts of Gadolinium(III) chloride hexahydrate ($GdCl_3 \cdot 6H_2O$) and aqueous ammonia (NH_4OH, 99 % purity) were reacted in an aqueous solution to synthesize gadolinium hydroxide [$Gd(OH)_3$] precipitates according to the following chemical reaction.

$$GdCl_3 \cdot 6H_2O + 3NH_4OH \rightarrow Gd(OH)_3 \downarrow + 3NH_4Cl + 6H_2O$$

The resulting precipitate was collected by centrifugation, thoroughly washed with deionized water and ethanol to remove residual chloride ions, and dried at 100 °C. Thermal annealing was then performed to promote complete dehydration and phase transformation to Gd_2O_3.

$$2Gd(OH)_3 \xrightarrow{\Delta} Gd_2O_3 + 3H_2O \uparrow$$

Finally, the synthesized Gd_2O_3 powder was placed in a vacuum-sealed quartz tube and calcined at 600 °C

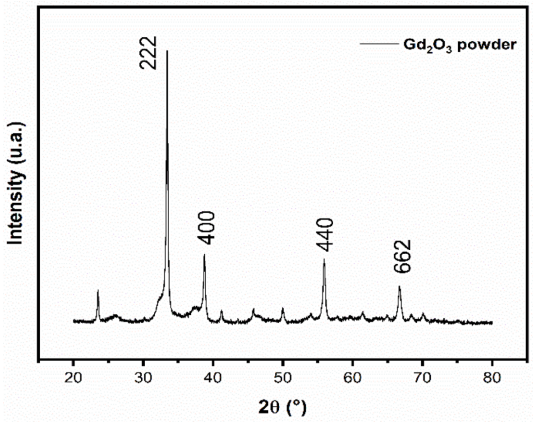

Fig. 1. XRD pattern of Gd_2O_3 powder prepared by chemical coprecipitation and calcined at 600 °C for 48 h.

for 48 h to obtain a well-crystallized cubic phase.

Fig. 1 shows theX-ray diffraction pattern ofthe Gd_2O_3 powder usedin this study. X'Pert High Score software analysis of the XRD patterns confirmes a single-phase cubic Gd_2O_3 structure belonging to the Ia-3 space group, consistent with JCPDS card No. 00-012-0797.

2.2. Preparation of Gd_2O_3 thin films

Thin films of gadolinium oxide (Gd_2O_3) were deposited onto pre-cleaned glass substrates using a vacuum thermal evaporation system equipped with a resistively heated molybdenum boat. Prior to deposition, the glass substrates were sequentially ultrasonically cleaned in acetone, then absolute ethanol, and finally deionized water for 15 min each, followed by drying with dry N_2 flow. The synthesized Gd_2O_3 powder was placed in the boat, and the chamber was evacuated to a basepressure of approximately 10^{-5} Torr. Deposition was carried out on fixed substrates at an elevated temperature of 500 °C at an average deposition rate of approximately 0.2 nm/s and was monitored in situ using a quartz crystal microbalance (QCM). After deposition, the samples were allowed to cool naturally to room temperature inside a vacuum chamber for 12 h to relieve thermal and residual stresses. The final film thickness was measured using a stylus surface profilometer (and cross-verified via optical reflectivity and spectroscopic ellipsometry) and determined to be approximately 650 nm.

2.3. Characterization techniques

Several investigation methods were used to study these samples. The crystal structure of every thin film produced was analyzed using a Philips PW 1729 Table-top X-ray Generator,with monochromatic radiation (Cu-Kα radiation, λ = 1.54059 Å), tests were carried out at room temperature. AJEOL-JSM 5400 SEM was used to determine grain size and surface morphology and microstructure.A spectrophotometer (Perkin-Elmer Lambda 950)with spectral domain 250–2500 nm was used to determine both optical reflectance (*R*) and transmittance (T) of the films,as functions of wavelength. AHewlett–Packard HP 4192 impedance

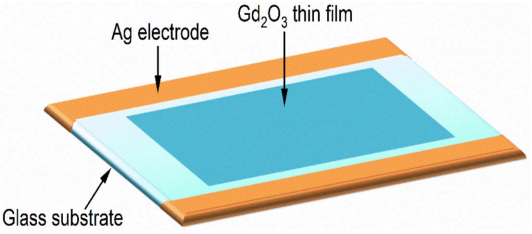

Fig. 2. Schematic illustration of the planarstructure of Ag/Gd_2O_3/Ag samples for the electrical and dielectric characterizations.

analyzer measuredthe dielectric and theelectrical properties of the films over a range of temperatures from 290–373 K and a frequency range of 1 Hz–1 MHz. As reported by Larbi *et al.*[35] the test configuration for the electrical measurements was two-electrodes attached to the two ends of the sample using conductive silver paste (*Fig.* 2).

Finally, the surface freeenergy of thin films at room temperature was deduced from the sessile drop method by studying the contact angle of water.The symmetrical droplet profiles on the horizontal film surface were analyzed using the DSA100 drop shape analyzer (Krüss GmbH, Hamburg).[36] Static contact angle measurements were performed using highly purified deionized water (γL = 72.8 mN/m), via the sessile drop method under ambient conditions (20 ± 1 °C), relative humidity ~ 45 % with a calibrated droplet volume of 3 μL.

3. Results and Discussion

3.1. XRD Investigation

Fig. 3 presents the XRD pattern of the Gd_2O_3 thin film recorded using a Philips PW 1729 tabletop X-ray generator (Cu-Kα radiation, λ = 1.5406 Å) with a 2θ scanning step of 0.02°. Two distinct diffraction peaks were observed at 2θ = 26.12° and 39.54°, which were indexed to the (301) and (322) crystallographic planes, respectively. The observed diffraction peaks are consistent with the cubic phase of Gd_2O_3 (space group $Ia\bar{3}$), in agreement with the standard JCPDS card No. 00-012-0797 and previously reported studies.[37-40] The interplanar spacing d_{hkl} was calculated

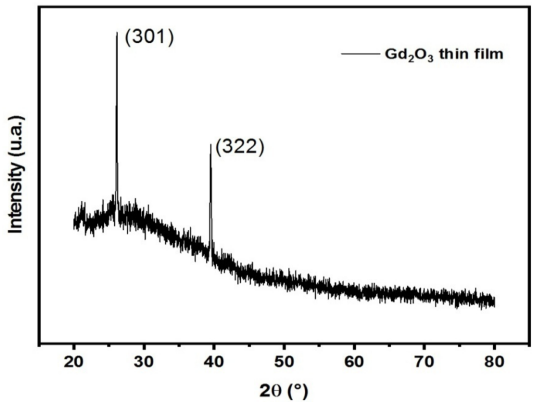

Fig. 3. X-ray diffractionpattern of Gd_2O_3 thin film.

using Bragg's law.

$$2d_{hkl}\sin\theta = n\lambda \quad (1)$$

where n is the order of the diffraction (usually = 1) and λ is the X-ray wavelength.

The lattice parameter (a) for the cubic structure was determined using the relation.[41]

$$d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}} \quad (2)$$

Values of the lattice parameters asdeduced from the two obtained diffraction peaks are given in *Table* 1. These values agreewellwith those given by the International Centre for Diffraction Data (JCPDS 00-012-0797 card) and previous results obtained by Artini *et al.*[42] and Delacotte *et al.*[43] In addition, the crystallite size (D), microstrain (ε), and dislocation density (δ) were calculated according to Eqs. (3)–(5).[44,45]

$$D = \frac{k\lambda}{\beta_{\frac{1}{2}}\cos\theta} \quad (3)$$

$$\varepsilon = \frac{\beta_{\frac{1}{2}}}{4\tan\theta} \quad (4)$$

$$\delta = \frac{1}{D^2} \quad (5)$$

Their values are summarized in *Table* 2.

In comparison with gadolinium and oxygen atomic radii, it is found that the lattice parameter (a) is relatively large due to the high number of Gd_2O_3 formula units per unit cell. *Fig.* 4(a) shows the Gd_2O_3 lattice in the cubic structure. In this structure, Gd^{3+}

Table 1. Lattice parameter of Gd_2O_3 thin film for (301) and (322) planes.

	(301)	(322)	00-012-0797JCPDS card	Shugurov *et al.*, 2025	Larbi *et al.*, 2014
a(Å)	10.7761	10.6853	10.8130	10.8175	10.8113

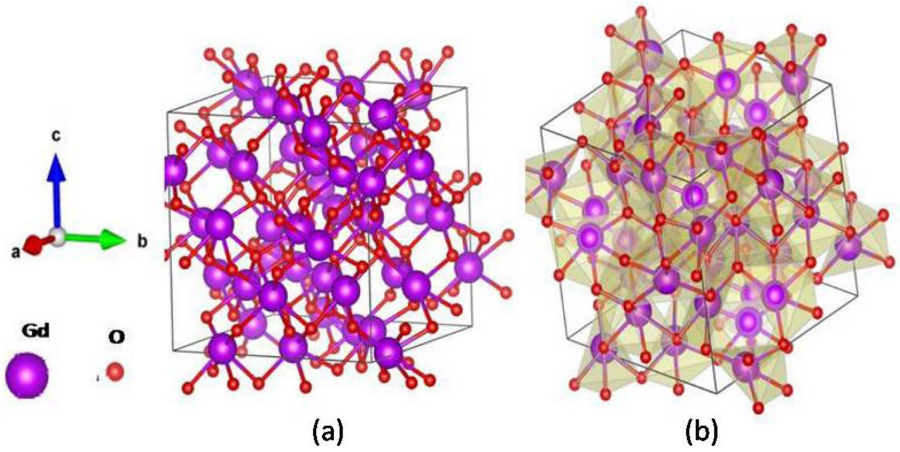

Fig. 4. (a) Unit cell representation of the Gd_2O_3 cubic crystal structure. (b) Coordination polyhedra of Gd.

Table 2. Structural parameters of Gd_2O_3 thin film for (301) and (322) planes.

Plane (hkl)	D (nm)	$(10^{-4})\varepsilon$	δ (10^{13} lines/m^2)
(301)	145.35	10.55	4.73
(322)	100.31	10.22	9.94

ions occupy the centers of octahedra cavities, while O^{2-} ions occupy the vertices of these octahedral *Fig.* 4(b).

3.2. Surface morphology of thin film

Fig. 5 illustrates the FESEM micrographs of the deposited Gd_2O_3 thin film recorded at different magnifications. Low-magnification micrographs (*Figs.* 5(a) and 5(b)) reveal a compact, crack-free, and homogeneous surface coverage across the substrate. At higher magnifications (*Figs.* 5(c) and 5(d)), well-defined polygonal grains and localized aggregates are clearly visible. The observed granular morphology is consistent with the typical nanocrystalline nature of Gd_2O_3 thin films, where the resulting microstructure is governed by deposition and heat treatment conditions.[44] Furthermore, the distinct, faceted grain boundaries support a polycrystalline structure and a preferred crystallographic orientation, indicated by the sharp (301) and (322) diffraction peaks. To gain a quantitative understanding of grain dimensions, the grain size distribution extracted from the surface topography is shown in *Fig.* 6. The distribution is relatively broad, ranging from several tens of nanometers to ~ 250 nm, with a prominent peak centered at around 100 nm. This confirms that the thin film is composed primarily of nanograins along with a small proportion of larger aggregates. The predominant grain size (~ 100 nm) obtained from field-emission scanning electron microscopy (FESEM) analysis closely matches the crystallite sizes ($D \approx$ 100.31–145.35 nm) determined from XRD data using the Scherrer equation. The presence of grains exceeding the crystallite size determined from the XRD data is expected, as individual grains often consist of multiple coherently

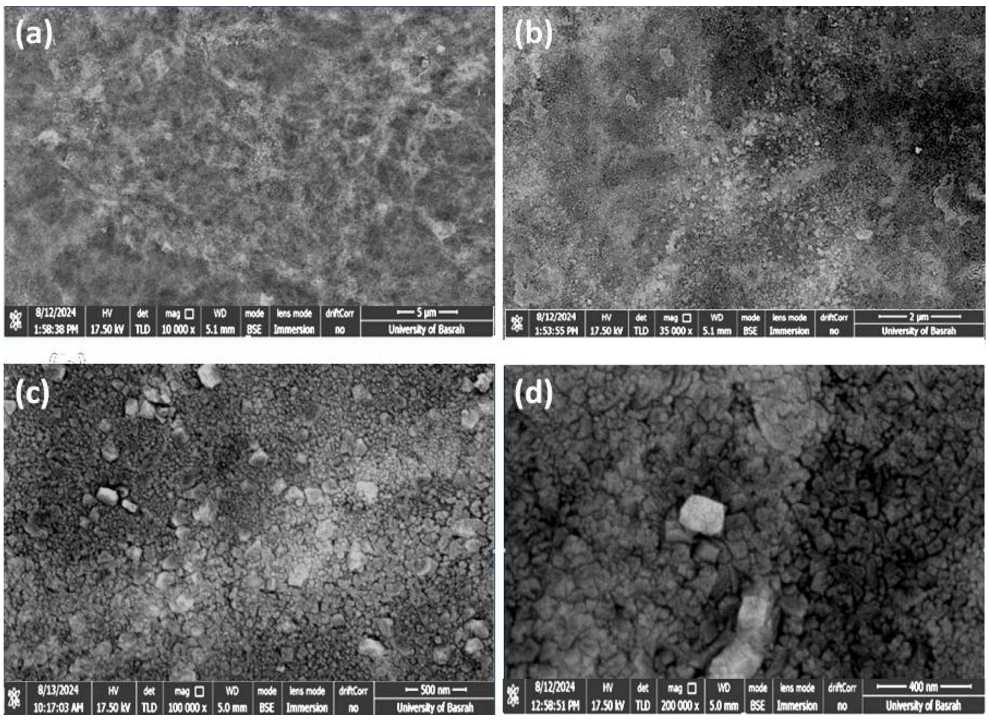

Fig. 5. FE-SEM images of Gd_2O_3 thin film surfaceat different magnifications.

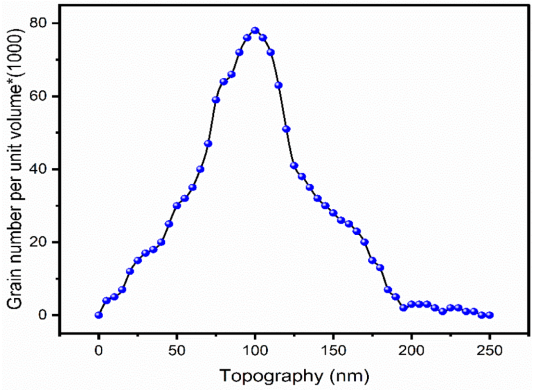

Fig. 6. Grain size distribution of the synthesized Gd_2O_3 thin film.

diffracting domains. Overall, the dense grain coverage in *Fig*. 6, along with the peak size distribution around 100 nm, confirms the successful growth of a coherent Gd_2O_3 thin film.

3.3. Optical properties

3.3.1. Absorption, transmission, and reflection spectra

The optical properties of the thin film fabricated from gadolinium oxide (Gd_2O_3) were evaluated using UV–Vis–NIR spectroscopy.As illustrated in *Fig*. 7(a), strong optical absorption is observed in the short-wavelength spectral region ($\lambda < 500$ nm), reaching a maximum near the fundamental absorption edge (400–450 nm). This strong absorption is primarily attributed to electronic transitions between energy bands, from the occupied O *2p* valence band to the unoccupied Gd*5d/4f* conduction band. As the wavelength extends into the visible region (500–750 nm), the absorption drops sharply to near-zero values, indicating minimal absorption of photons below the band gap and high optical transparency. The slight localized absorption observed around 800 nm can be attributed to instrumental effects or to localized states below the band gap resulting from oxygen vacancies. The transmittance (T%) and reflectance (R%) spectra (*Fig*. 7(b)) cover a wide range of wavelengths (200–2000 nm). In the ultraviolet region ($\lambda < 300$ nm), the transmittance approaches zero, consistent with strong band-gap-related absorption. A sharp transition begins between 350 and 600 nm, after which the film exhibits high optical transparency with an average transmittance of 78 %–85 % in the visible and near-infrared ranges.[45] Simultaneously, the reflectance (*R*%) remains consistently low (around 10–15 %) across the entire spectral window, with a characteristic detector-switching artifact near 860 nm. The combination of a sharp absorption edge, high visible transparency (> 80 %), and low reflectance confirms that the deposited Gd_2O_3 thin film possesses high crystalline quality with low scattering losses and minimal absorption due to defects. These optical

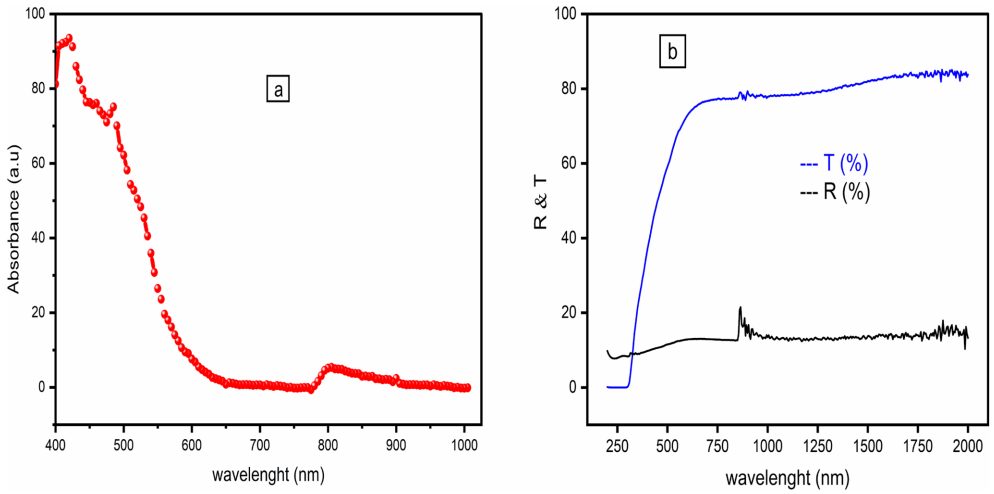

Fig. 7. Optical spectra of the Gd_2O_3 thin film: (a) absorbance spectrum, and (b) transmittance (*T*%) and reflectance (*R*%) spectra.

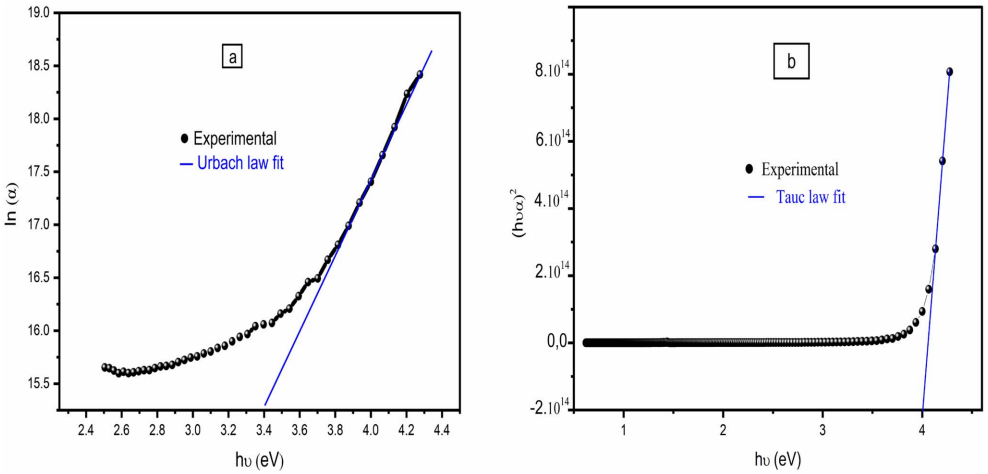

Fig. 8. Urbach and Tauc analyses of the Gd_2O_3 thin film: (a) Urbach plot and (b) direct optical band-gap determination.

properties make Gd_2O_3 thin films highly suitable as transparent dielectric thin films, UV photodetectors, and anti-reflective coatings in photovoltaic and photonic assemblies.

3.3.2. Energy band gap and urbach energy (E_U) calculations

To explore the mechanism of electronic transition and structural disorder near the edge of the optical band, the absorption coefficient (α) was determined using the relation α = 2.303A/t, where A is the absorbance and t is the film thickness. The incident photon energy (hv) was obtained from the fundamental relation hv = hc/λ. These parameters facilitate the evaluation of the band tail effect and the fundamental optical transition threshold in the fabricated thin films. The Urbach energy (E_U) of the low-energy exponential absorption tail was evaluated using the empirical relationship.[48]

$$\alpha = \alpha_o \exp\left(\frac{hv}{E_U}\right) \tag{6}$$

Taking the natural logarithm of both sides yields.

$$\ln(\alpha) = \ln(\alpha_o) + \frac{hv}{E_U} \tag{7}$$

where α_o is a constant, and E_U represents the width of the exponential absorption tail. Thus, E_U is obtained from the inverse slope of the linear segment of the graph ln(α) versus hv shown in *Fig.* 8(a).

$$E_U = \left(\frac{d\ln(\alpha)}{d(hv)}\right)^{-1} \tag{8}$$

Linear fitting in *Fig.* 8(a) gives an Urbach energy of ≈ 0.31 eV. This narrow exponential band tail reflects a low density of localized defect states and minimal structural disorder near the band edges.[48,50] Subsequently, the optical band gap was estimated using Tauc relation.

$$(\alpha hv)^n = B(hv - E_g) \tag{9}$$

where B is a material-dependent constant, E_g is the optical band-gap energy, and n depends on the nature of the electronic transition. For a direct allowed transition, n = 2, giving

$$(\alpha hv)^2 = B(hv - E_g) \tag{10}$$

Extrapolating the linear portion of the $(\alpha hv)^2$ curve versus hv to $(\alpha hv)^2 = 0$ (*Fig.* 8) establishes a direct optical band gap of $E_g \approx 4.05$ eV. This optical limit directly corresponds to the electronic interband transitions from the filled O *2p* valence band to the empty Gd 5d/4f conduction band.[50] The large defined band gap (4.05 eV) and the limited Urbach tail (0.31 eV) closely confirm the high crystal quality and predominant crystal size (100.31–145.35 nm)

calculated from X-ray diffraction data, as well as the dense and compact grain arrangement observed in the FESEM (*Figs.* 5 and 6). The well-defined crystalline domains suppress the scattering of grain boundary defects and bandgap-free transitions, confirming the successful formation of a highly coherent and transparent Gd_2O_3 insulating layer suitable for deep UV photovoltaic integration.[48-51] The measured optical band gap of the deposited thin films (E_g = 4.05 eV) is noticeably narrower than the value typically reported for bulk single-crystal Gd_2O_3) ~5.2 eV).[8] This band gap reduction can be attributed tothree interrelated physical mechanisms:

• **Oxygen Vacancy Sub-Bands:** Vacuum thermal evaporation under a base pressure of 10^{-5} Torr naturally leads to the emergence of sub-stoichiometric oxygen vacancies (Vö). These vacancy defects generate localized donor levels below the conduction band minimum (Gd 5d/4f), effectively inducing band-tailingand narrowing the optical transition threshold.

• **Urbach Band-Tail States:** The presence of structural disorder and localized states near the band edges is quantitatively supported by the extracted Urbach energy (E_U = 0.31eV).

• **Nanocrystalline Grain Boundary Effects:**The high density of grain boundaries within the nano-granular matrix (~100 nm) leads to internal microstrain (≈ 10.22 * 10^{-4}), this leads to possible local fluctuations that increase the shift of the optical absorption edge towards lower energies.

3.3.3. Optical constants and dispersion analysis

The complex refractive index ($n' = n + ik$) determines the optical response and wave propagation withinthe Gd_2O_3 thin film. The extinction coefficient (k), which describes the optical attenuation per unit distance, was calculated using the relationship.[52]

$$k = \frac{\alpha\lambda}{4\pi} \tag{11}$$

where α is the optical absorption coefficient and λ is the incident wavelength. Using the experimental reflectance coefficient (R) and the extinction coefficient (k), the refractive index (n) was obtained from Fresnel's relation.[52]

$$R = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2} \tag{12}$$

Fig. 10(a) illustrates the spectral evolution of the refractive index (n) and extinction coefficient (k) from 250 to 2000 nm. In the high-energy UV region (λ < 350 nm), the extinction coefficient (k) reaches a maximum value of approximately 0.40, indicating strong absorption between the fundamental energy bands across the optical band gap ($E_g \approx$ 4.05 eV). Beyond the fundamental absorption edge (λ > 550 nm), the extinction coefficient (k) drops sharply to negligible values (k < 0.05), confirming the high optical transparency (>80%) and minimal dispersion loss of the film. Simultaneously, the refractive index exhibits anomalous dispersion near the absorption edge, reaching a maximum value of approximately 2.13 at 650 nm, before stabilizing at normal dispersion across the near-infrared (NIR) region at a value of approximately 2.08. To quantitatively describe the dispersionbehavior in the transparent region (λ > 600 nm), the experimental refractive index was modeled using Cauchy's empirical dispersion relation.[53]

$$n(\lambda) = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} \tag{13}$$

Furthermore, the refractive index (n) can be interpreted in terms of optical transitions using the single oscillator model of Wemple and Di-Domenico.[54]

$$n^2 - 1 = \frac{E_0 E_d}{E_0^2 - (h\nu)^2} \tag{14}$$

Where $h\nu$ is the incident photon energy, E_0 is the single-oscillator energy (representing the average

Table 3. Values of Cauchy parameters (A, B and C) and dispersion parameters E_0 and E_d for the Gd_2O_3 thin film.

	A	B (μm^2)	C (μm^4)	E_0 (eV)	E_d (eV)
Gd_2O_3 thin film	2.0755	0.0114	0.0661	7.0204	22.9961

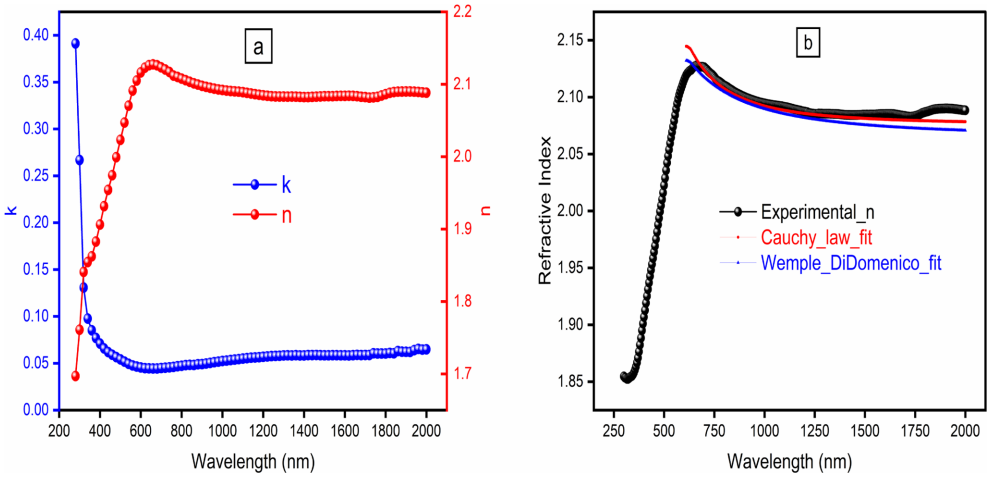

Fig. 9. Optical constants and dispersion analysis of the studied thin films: (a) extinction coefficient (k) and refractive index (n), and (b) refractive index fitting using the Cauchy and Wemple-DiDomenico models.

interband excitation energy), and E_d is the dispersion energy, which determines the average strength of the interband photon transitions. The coefficients extracted from the Cauchy relation and the Wemple-Di Domenico model are listed in *Table* 3.

As shown in *Fig.* 9(b), both the Cauchy and Wemple-Di Domenico models exhibit excellent agreement with experimental data in the normal dispersion regime. The high refractive index ($n \approx$ 2.08–2.13) directly reflects the high optical packing density and film cohesion. This is consistent with the morphology of dense, hole-free grains, confirmed by field-emission scanning electron microscopy (FESEM) (*Fig.* 5), and with the large crystallite dimensions verified by X-ray diffraction (*Fig.* 3), (100.31–145.35 nm). This high micropacking density leads to increased atomic polarization and a reduced internal void ratio, confirming the suitability of the prepared Gd_2O_3thin film as high-k dielectric layers and antireflective optical coatings.[52-54]

3.4. Electrical study

3.4.1. Dielectric study investigation

Figs. 10(a) and 10(b) illustrate the dependence of both the real part (ε') and the imaginary part (ε'') of the electrical permittivity of the Gd_2O_3 thin film on frequency and temperature, respectively. Both ε' and ε" were calculated using the following relationships.[55]

$$\varepsilon' = \frac{C.d}{\varepsilon_0 A} \tag{15}$$

$$\varepsilon'' = \varepsilon' \tan \delta \tag{16}$$

Where C is the capacitance, d is the film thickness, A is the electrode contact area, ε_0 is the permittivity of free space, and tan δ is the tangent of the dielectric loss angle.

At low frequencies (ln(f) < 8), both parameters exhibit high values that steadily decrease with increasing frequency until they reach a stable level. This behavior is consistent with the Maxwell-Wagner model of interfacial polarization and the Koops phenomenological theory.[55] Under the influence of an alternating field, thermally generated oxygen vacancies migrate through the conductive grains and accumulate at the resistive grain boundaries, generating a large space-charge polarization. At high frequencies, these dipoles are unable to keep pace with the rapid field oscillations, thus inhibiting the polarization response. The thermally assisted hoppingexplains the regular increase in permittivity with increasing temperature. These dielectric results are directly consistent with the dense, pinhole-free grain structure observed by field-emission scanning electron microscopy (*Fig.* 5) and with the pronounced diffraction peaks identified by

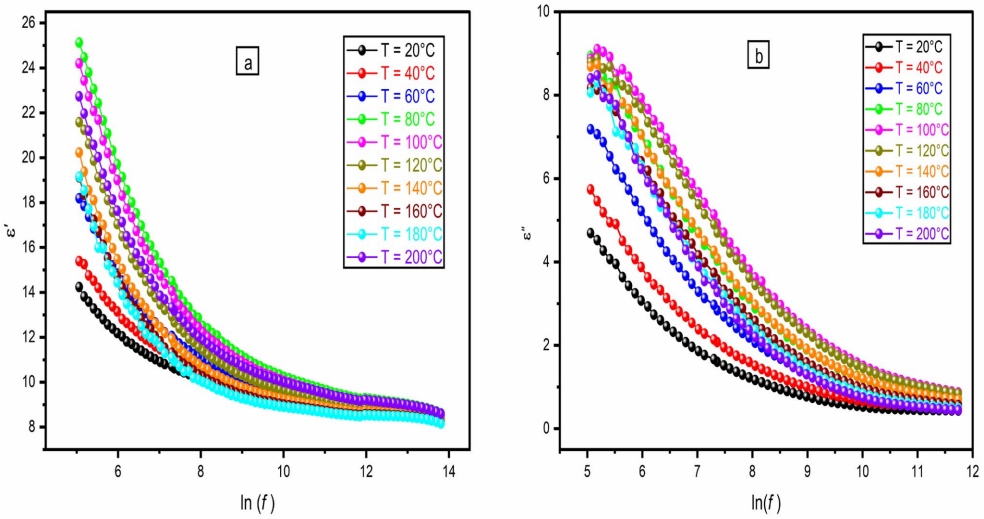

Fig. 10. Frequency and temperature dependence of the dielectric constant: (a) the real part (ε'), and (b) the imaginarypart (ε'') of the Gd_2O_3thin film.

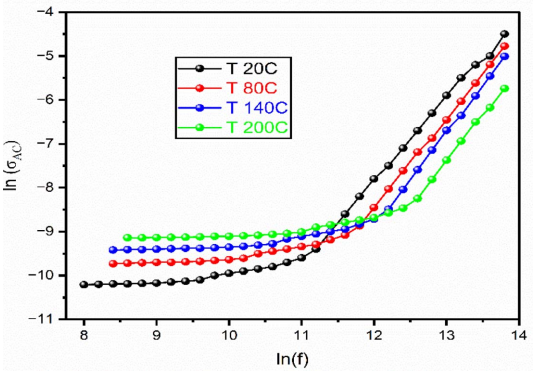

Fig. 11. AC conductivity as a function ofln(f) at different temperatures.

X-ray diffraction (*Fig.* 3), confirming the low leakage due to defects and reinforcing the high-*k* dielectric performance demonstrated by optical analysis.[55]

3.4.2. Electrical conductivity

The frequency dependence of total conductivity σ_{tot} for the Gd_2O_3 thin film at different temperatures (20 – 200 C) is shown in *Fig.* 11. The curves exhibit a frequency-independent DC plateau (σ_{dc}) at low frequencies (ln(f) < 11), followed by significant dispersion at higher frequencies where conductivity rises sharply.The experimental spectra were fitted using Jonscher's universal power law.[56]

$$\sigma_{tot}(\omega) = \sigma_{dc} + A\omega^{s} \quad (17)$$

where $\omega = 2\pi$ fis the angular frequency, A is a temperature-dependent pre-factor, and s is the frequency exponent. As illustrated in *Fig.* 12, the Jonscher model demonstrates an excellent fit with the experimental data. Charge transport is governed by thermally generated mobile oxygen vacancies (Vö). At low frequencies, these carriers hop over long distances across grain boundaries, establishing σdc .At higher frequencies, conduction shifts to short-range localized hopping between defect states, yielding AC dispersion.[56,57] The frequency exponent (s) exceeds unity and increases with temperature, confirming that cooperative hopping and ionic conduction dominate the transport mechanism.[57] These electrical characteristics correlate directly with the preceding structural, optical, and dielectric findings. The dense, pinhole-free morphology observed via FESEM (*Fig.* 5) along with the well-defined crystalline domains verified by XRD (*Fig.* 3) effectively suppress grain boundary scattering and defect-mediated leakage currents. Furthermore, the localized hopping centers correspond to the sub-band gap defect states quantified by E_U, where the high

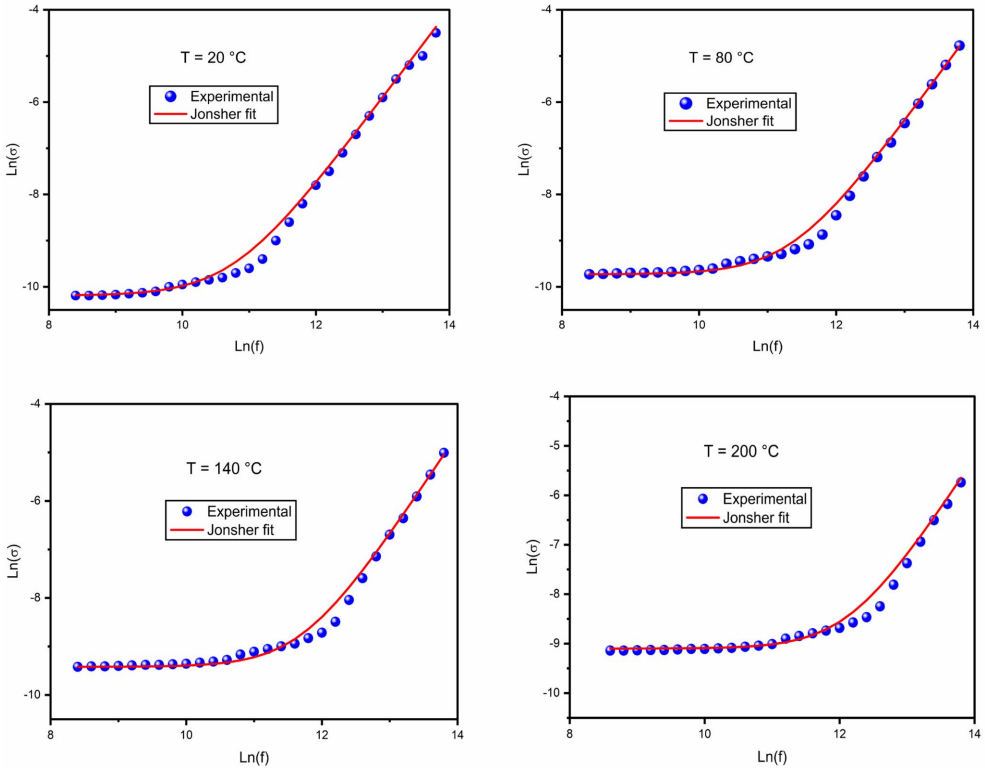

Fig. 12. Experimental AC conductivity spectra fitted with Jonscher's universal power law for the Gd_2O_3 thin film at (a) 20 C, (b) 80 C, (c) 140C, and (d) 200C.

electronic polarizability evidenced by the refractive index ($n \approx 2.08–2.13$) and oscillator strength (E_d) facilitates carrier hopping.[56,57] This transport behavior is fully consistent with the dielectric response, as the onset of conductivity dispersion coincides with the relaxation threshold of both ε' and ε'' *Fig.* 10, confirming that both conduction and interfacial polarization are mediated by the same mobile oxygen vacancy dynamics.

As can be seen from the fitting parameters in *Fig.* 12, the DC plateau extends and shifts toward higher frequencies as the temperature increases. This behavior confirms the thermally activated hopping conduction, where high thermal energy enables charge carriers to overcome local potential barriers, thereby shifting the onset of AC dispersion toward higher frequencies.

Additionally, from this Jonscher fit, the frequency exponent exceeds unity ($1.91 \leq s \leq 2.20$) and increases with temperature (*Fig.* 13). This increase is attributed to

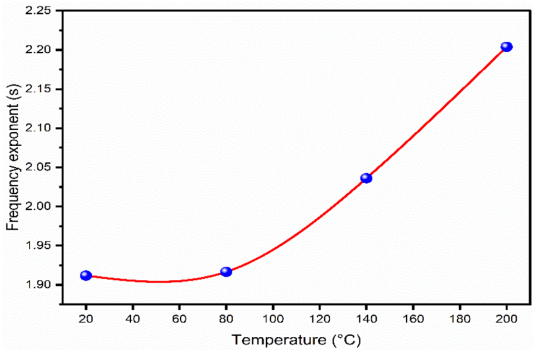

Fig. 13. Variation of the frequency exponent (s) with temperaturefor the Gd_2O_3 thin film.

mixed ionic and electronic conduction. The difference in electronegativity between gadolinium (1.2) and oxygen (3.44) is 2.24.Since this value is greater than 2, Gd_2O_3 has a predominantly ionic character, suggesting that ionic charge carriers contribute to electrical conduction.

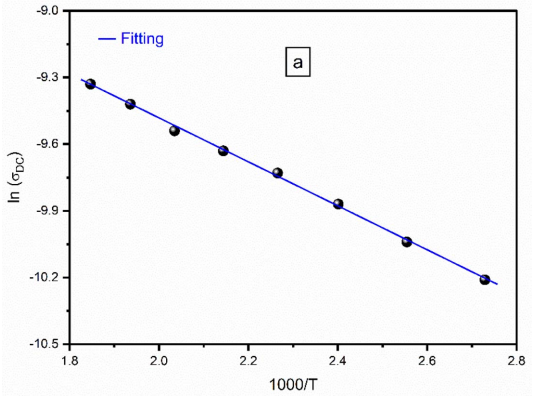

Fig. 14. Arrhenius plotof DC conductivity σ_{DC} versus 1000/T for the Gd_2O_3 thin film.

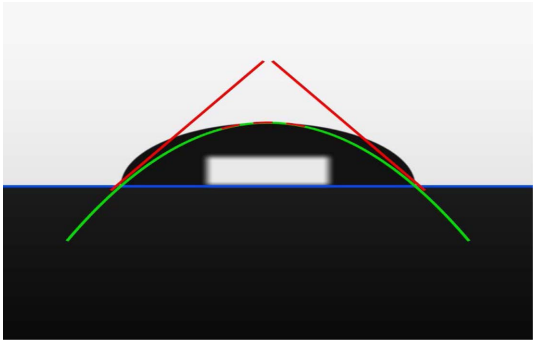

Fig. 15. Sessile drop profile and contact angle measurement on the surface of the Gd_2O_3thin film at room temperature) 20°C).

Fig. 14 presents the Arrhenius plot of $\ln(\sigma_{DC})$ versus 1000/T for thin films of Gd_2O_3. The DC conductivity increases monotonically with increasing temperature, demonstrating typical thermally activated semiconductor behavior according to the Arrhenius relation.

$$\sigma_{dc} = \sigma_0 \exp\left(-\frac{E_a}{k_B T}\right) \tag{18}$$

where σ_0 is the pre-exponential factor, E_a is the DC conduction activation energy, k_B is the Boltzmann constant, and T is the absolute temperature. The linear fit gives an activation energy of E_a = 0.53 ± 0.03 eV. This energy barrier corresponds to the enthalpy of ionized oxygen vacancy migration (Vö), confirming that thermally driven defect migration dominates DC electrical transport in the thin film.

3.5. Wettability properties

The wettability of the fabricated Gd_2O_3 thin film surface was assessed by measuring the static contact angle at an ambient temperature of 20 °C, as shown in *Fig.* 15. The geometrical profile fitting of the sessile water droplet resulted in a calculated contact angle (θ) of 62° over repeated measurements. Because the contact angle is lower than the hydrophobic threshold (θ < 90°), the Gd_2O_3 surface exhibits pronounced hydrophilic behavior, favoring effective liquid–solid interfacial interaction across the substrate surface. Thermodynamically, this low contact angle is associated with high surface free energy and strong interfacial adhesion forces between the solid and liquid.

This favorable wetting behavior indicates a high concentration of chemically active surface states, particularly oxygen vacancies (Vö) on the surface of Gd_2O_3. These defective sites facilitate photon absorption under UV illumination, promoting photochemical reactions and the subsequent generation of reactive oxygen species (ROS). Consequently, this enhanced surface interaction promotes efficient molecular adsorption, suggesting the potential of Gd_2O_3 thin films for heterogeneous photocatalysis, as well as high-performance chemical and biological sensors.[58] It should be noted that while a single polar liquid provides a qualitative assessment of surface wetting behavior, a comprehensive deconvolution into dispersive γ_s^d and polar γ_s^p components requires multi-liquid evaluations (e.g., Owens–Wendt approach), which remains a subject for future study.

4. Conclusions

Thin films of gadolinium oxide (Gd_2O_3) were successfully grown using vacuum thermal evaporation and comprehensively evaluated for their structural, optical, dielectric, electrical, and surface wetting properties. X-ray diffraction (XRD) and field emission scanning electron microscopy (FE-SEM) analysis

confirmedthe formation of a dense, well-crystallized cubic phase with two preferred crystallographic directions along (301) and (322) and a cohesive granular structure. Optically, the films exhibited high transparency in the visible light range (>80 %), a band gap of 4.05 eV, and a low Urbach energy (E_U = 0.31 eV), confirming minimallocalized band-tail states. The high refractive index dispersion and oscillator strength confirmed dense atomic packing. Dielectric spectroscopy revealed interfacial Maxwell–Wagner–Sillars (MWS) polarization resulting from charge carrier accumulation at the resistive grain boundaries. The conductivity spectra followed Jonscher's power law, with the frequency exponent s exceeding unity ($1.91 \leq s \leq 2.20$) and increasing with temperature.This anomalous transport behavior rules out simple single-polaron hopping models (such as CBH) and is attributed to cooperative ion-hopping dynamics facilitated by the strong ionic properties of Gd_2O_3 and mobile oxygen vacancies (Vö), as confirmed by the activation energy of 0.53 ± 0.03 eV. Finally, the moderate hydrophilicity ($\theta = 62°$) and good surface adhesion highlight the great potential of these bi-oriented Gd_2O_3 thin films for multifunctional integration in high-k gate dielectrics, UV-transparent optical coatings, and interfacial sensor platforms.

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편집위원회 관련 규정

제 1 조(목적) 본 규정은 정관 제 5조 의거하여 본 학회에서 발행하는 「분석화학」에 관한 업무를 관장하기 위하여 설치되는 편집위원회(이하 “위원회”라 칭함)의 운영에 관한 사항을 정한다.

제 2 조(구성) 위원회는 다음과 같이 구성한다.

(1) 위원장 1명 (2) 편집간사 2명 (3) 편집위원 20명 내외

위원장은 회장이 이사회의 의결을 거쳐 위촉하고, 위원은 위원장의 추천으로 회장이 위촉한다.

제 3 조(편집위원 선정기준)

고등교육기관이나 관련 연구기관 및 기업체에서 연구능력을 검증 받을 수 있는 자로서 관련 분야의 전문성 및 전국성을 고려하여 인력을 안배한다. 구체적인 선정기준은 다음과 같다.

1. 고등교육기관의 조교수 이상
2. 관련연구기관의 선임연구원 이상
3. 관련 산업체의 전문가 (박사학위 소지자 및 10년 이상의 실무 경력자)
4. 편집위원은 위원으로 선정되기 이전 3년간의 연구실적이 관련 전문분야의 국내외 학회지 또는 학술대회에 3편 이상의 논문을 발표한 자에 한하여 추천토록 한다.

제 4 조(심사위원 위촉)

논문심사 심사위원은 전문분야별 편집위원의 추천을 받아 편집위원장이 위촉한다. 심사위원의 명단을 일체 발표하지 아니하며, 절대 비밀로 한다.

제 5 조(임기) 위원장과 위원의 임기는 2년으로 하되 연임할 수 있다. 단, 부득이한 사정으로 임기 내에 사퇴할 경우 편집위원을 교체하며 임기는 잔여기간으로 한다.

제 6 조(윤리규정)

1. 편집위원은 투고된 논문의 게재여부를 결정하는 모든 책임을 지며, 저자의 인격과 학자로서의 독립성을 존중한다.
2. 편집위원은 학술지에 투고된 논문에 대해서 논문의 질적 수준과 투고 규정에 근거하여 공평하게 다루도록 한다.
3. 편집위원은 투고된 논문평가를 해당분야의 전문지식과 식견이 있는 심사위원에게 의뢰하여야 하며, 심사의뢰 시에는 가능한 한 객관적인 평가가 이루어질 수 있도록 노력한다.
4. 편집위원은 투고된 논문의 게재가 결정될 때까지 심사자 이외의 사람에게 저자에 대한 사항이나 논문내용에 대하여 비밀을 지켜야 한다.

제 7 조(기능 및 사업) 편집위원회는 다음 각 호의 사항을 기획하고 추진한다.

1. 정기 학술지의 편집 및 발행에 관한 사항
2. 논문투고요령에 관한 사항
3. (논문 심사위원 선정 및) 논문 심사규정에 관한 사항
4. 연구윤리규정에 관한 사항
5. 기타 이사회에서 부의하는 사항

제 8 조(관리)

1. 본 위원회의 신축성 있는 활동과 위원회 상호간의 협조에 관련된 사항은 위원장이 총괄한다.
2. 본 위원회에서 독자적으로 추진한 업무위원회 관련된 활동은 행사 종료 후 그 내용을 관련업무 위원회에 제출하여 학회 차원에서 취합할 수 있도록 협조한다.
3. 본 위원회의 의사결정은 재적위원의 다수결을 원칙으로 한다.

제 9 조(연구부정행위에 대한 조치)

1. 투고논문 및 게재된 논문에 대한 연구부정행위 (날조, 변조, 표절, 이중게재 등) 관련 민원이 제출 시에 편집위원회를 통해서 연구부정행위 여부를 판명하도록 한다.
2. 연구부정행위로 판명될 경우, 배포이전의 논문은 편집과정에서 해당논문은 삭제하며, 배포된 논문의 경우는 온라인 게재사이트에서 삭제하도록 한다.
3. 연구부정행위에 대한 내용은 학회 홈페이지에 대하여 공지하며, 해당 논문의 투고자는 2년간 본 학회의 학술지투고 및 학술대회 발표를 금지한다.

제 10 조 본 규정은 이사회에서 통과된 날부터 시행한다.

논문심사규정

제 1 조 한국분석과학회에 투고되는 논문의 심사 및 채택은 본 규정에 따른다. 속보(communication), 단신(note)및 논평(comment)도 논문으로 취급한다.

제 2 조 편집위원장은 심사위원을 위촉한다.

제 3 조 모든 논문은 심사위원 3명의 심사를 원칙으로 하며, 최소 2명의 심사를 거쳐서 편집위원장 또는 편집위원이 게재여부를 정한다.

제 4 조 (윤리규정)

(1) 심사위원은 편집위원장이 의뢰하는 논문을 학회규정에 따라 객관적으로 평가하고 평가결과를 편집위원장에게 통보해 주어야 한다.

(2) 심사위원은 심사논문에 대해서 객관적 기준에 의해 공정하게 평가하며, 충분한 근거없이 논문을 탈락시키거나, 심사자 본인의 관점이나 해석과 상충된다는 이유로 논문을 탈락시켜서는 안 되며, 심사대상 논문을 성실히 평가해야 한다.

(3) 심사위원은 투고자의 인격과 전문성을 존중해야 하며, 논문평가서에는 논문에 대한 자신의 평가를 명확하게 밝히되, 보완이 필요하다고 판단되는 부분에 대해서는 그 이유도 함께 상세하게 기록한다.

(4) 심사위원은 심사논문에 대한 비밀을 반드시 지켜야 한다. 또한 투고된 논문을 외부에 유출하거나 투고된 논문이 출판되기 전에 그 논문의 내용을 인용할 수 없다.

(5) 편집위원장은 심사위원의 명단을 일체 발표하지 아니하며, 절대 비밀로 한다.

제 5 조 심사결과는 '무수정 채택가(No revision)', '수정후 채택가(Minor revision)', '수정후 재심사(Major revision)', '채택불가(Reject)'의 4종으로 구분한다.

(1) '무수정 채택가'로 판정된 논문은 수정없이 채택한다.

(2) '수정후 채택가'로 판정된 논문은 심사위원이 지적한 사항을 저자가 수정한 후 편집위원장 또는 편집위원이 이를 채택한다.

(3) '수정후 재심사'로 판정된 논문은 심사위원이 지적한 사항을 저자가 수정한 후 심사위원에게 다시 심사를 거쳐 편집위원장 또는 편집위원이 이를 채택한다.

제 6 조 논문의 내용이 아래의 어느 항에 해당된다고 심사위원이 인정할 경우에는 '채택불가'로 판정하고 그 이유를 구체적으로 밝혀야 한다.

(1) 독창성이 뚜렷하지 아니한 경우

(2) 원고 내용에 저자가 알아낸 사실 또는 착상이 뚜렷하지 않거나, 기지의 사실이라도 인용된 문헌에 나타나 있는 방법 또는 관점과 다른 각도에서 이를 종합분석 또는 고찰한 것이 뚜렷하지 않은 경우

(3) 논문의 내용이 사회적 물의를 일으켜 학회에 손해를 입히리라 예상되는 경우

(4) 기타 본 학회지에 게재하기에 부적당하다고 인정될 경우

제 7 조 논문이 회지 투고규정에 부적합하다고 편집위원회가 인정할 경우에는 투고 논문을 접수하지 않을 수도 있다.

제 8 조 외국어로 작성된 원고로서 문맥이 분명하지 않거나 문법적으로 그 해독이 곤난할 경우에는 편집위원회 또는 심사위원이 저자에게 수정하거나 국문으로 작성하여 투고할 것을 권고할 수 있다.

제 9 조 심사위원 2명 이상이 '채택가'로 판정한 논문은 채택되며, 2명 이상이 '채택불가'로 판정하거나, 1명의 '채택불가'와 1명이상의 '수정후 재심사'로 판정한 논문은 채택되지 않는 것을 원칙으로 한다. 만일 가부 판정을 확실히 할 수 없는 경우에는 편집위원회가 이를 심의하여 채택여부를 결정한다.

제 10 조 투고된 논문이 2차 심사를 완료하고도 심사결과에 대한 수정이 불완전하다고 판단되는 때에는 편집위원회의 심사에 따라 게재 여부를 결정할 수 있다.

제 11 조 논문의 채택 여부를 결정하기 위하여 필요한 때에는 전문 분야별 편집위원으로 구성된 소위원회를 소집할수 있다. 소위원회는 편집위원장이 반드시 참석해야만 한다.

제 12 조 심사위원은 심사 위촉 후 15일 이내에 위촉받은 원고를 심사하고 심사의견을 원고와 함께 본회에 반송해야만 한다.

제 13 조 본회는 심사위원의 심사의견을 받은 후 일주일 이내에 그 사본을 저자에게 반송한다.

제 14 조 심사위원이 심사 위촉 후 30일 이내에 심사의견을 제출하지 아니한 경우에는 심사의뢰를 해촉할 수 있다. 이 경우 원고는 즉시 본회로 반송하여야 한다.

논문투고규정

제 1 조 (원고의 종류 및 내용)

(1) 학회지에 게재할 수 있는 원고는 화학, 화공, 재료, 약학, 농학, 식품, 환경 등의 분석에 관한 것으로 논문(원저, article), 속보(communication, 또는 letter)), 단신(note), 논평(해설, comment) 및 총설(review)로 구분한다.

(2) 학회지에 투고할 원저 논문과 단신 등은 다른 학술잡지에 원보로서 투고하거나 발표하지 않은 것이어야만 한다.

제 2 조 (투고 자격) 학회지에 대한 투고자의 자격은 본 학회의 회원에 한한다. 투고된 논문이 본 학회에서 정해진 심사규정에 따라 심사한 후 채택된 경우에는 공동발표자도 학회에 모두 가입해야만 하며, 소정의 연회비를 납부해야만 게재될 수있다. 단, 학생(대학원 석사 과정 이하)의 경우에는 예외로 할 수 있다.

제 3 조 (윤리 규정) (1)투고자는 투고논문에 대하여 본 학회의 윤리강령을 준수하여 제출하여야 한다. (2)투고자는 국내외를 막론하고 이전에 출판된 자신의 연구물을 중복하여 투고할 수 없다. (3) 위조, 변조, 표절과 같은 연구 부정 행위가 있는 논문은 게재하지 않으며, 관련 세부사항은 편집위원회에서 정한다. (4)투고논문을 제출할 때 투고자는 모든 공동저자의 동의를 얻어야 한다. 공동저자는 투고논문에 학술적으로 중요한 기여를 한 사람이어야 하며, 결과에 대하여 책임과 공적을 공유할 수 있어야 한다. (5) 학술자료 및 다른 연구자의 결과를 인용할 때는 반드시 그 출처를 정확하게 참고문헌으로 밝혀야 한다.

제 4 조 (원고 심사) 본 학회에 투고된 원고의 심사, 채택여부, 게재순서 및 인쇄체제는 본 학회 회원으로 구성된 편집위원회에 일임해야 하며, 편집위원회는 별도로 정한 논문 심사규정에 따라 심사하여 필요한 경우 원고의 내용이 크게 변경되지 않는 범위내에서 수정을 요구할 수 있다.

제 5 조 (원고의 제출 및 채택)

(1) 논문은 온라인 논문투고시스템(KISTI-ACOMS)에 직접 접수하며, 논문원고와 투고자 정보를 함께 입력하여야 한다. 논문의 접수일자는 온라인상으로 접수된 날짜로 하고, 논문투고시스템에서 요구하는 양식에 맡게 작성해야한다.

(2) 원고의 채택은 별도로 정한 논문 심사 규정에 의거 심사 후 채택한다.

(3) 원고의 채택이 확정되면 저자는 최종 원고의 내용을 투고한 논문투고시스템에 올린다.

제 6 조 (원고 작성 언어 및 표기)

(1) 원고 작성에 사용하는 언어는 국어 또는 영어를 원칙으로 한다.

(2) 원고의 서식은 가로쓰기로 하고, A4용지에 한 면에만 워드 또는 한글(HWP)로 작성하며 제목을 제외한 활자의 크기는 10포인트 이상이며, 줄간격은 1줄(워드), 250%(한글)로 한다.

(3) 원고 작성 시 문법에 맞도록 띄어 쓰되 쉼표 다음에는 1칸을, 마침표 다음에는 2 칸을 띄어 쓰는 것을 원칙으로 한다.

(4) 원고의 분량은 표와 그림을 포함하지 않고 15면을 초과해서는 안 된다.

제 7 조 (원고의 형식)

(1) 원고의 표지(1면)에는 제목, 연구자의 이름, 직위, 소속 및 주소, 우편번호, 국가명을 본문에 사용된 언어에 상관없이 국문과 영문의 순서로 표기해야만 한다. 다수의 연구자로 인해 소속과 주소가 다른 경우에는 별표(*) 등을 이용하여 알기 쉽게 표기한다. 단 영문 주소, 우편번호, 국가명은 이탤릭체로 한다.

(2) 국문 연구 논문의 형식은 표지, 요약(국문초록), Abstract(영문초록), Key words(다섯 단어 이하로 하고 반드시 소문자로 기록), 서론, 이론, 실험(방법), 결과, 고찰(혹은 결과 및 고찰), 결론, 사사(감사의 글), 참고문헌, 표, 그림의 순서로 하되 불필요한 항은 생략할 수 있다. 또한 국문 원고는 한글 사용을 권장하되 인명, 지명, 잡지명 등과 같이 혼동을 일으키기 쉬운 경우에는 한자 혹은 영어를 사용할 수 있다.

(3) 영문 연구논문의 형식은 표지, Abstract, Key words, Introduction, Experimental, Results, Discussion(혹은 Results and Discussion), Conclusion(혹은 Summary), Acknowledgement, References, Tables, Figures의 순서로 하되 불필요한 사항은 생략할 수 있다.

(4) 국 · 영문 초록은 논문의 목적과 주요성과를 구체적으로 알 수 있는 동시에 본문 없이도 이해할 수 있도록 요약해야만 한다. 단, 총설 또는 해설 등에는 국 · 영문 초록을 기재하지 않아도 되며, 영문 연구논문은 국문초록을 생략할 수 있다. 초록의 분량은 국문의 경우에는 700자 이내, 영문은 250단어 이내로 한다.

(5) 원고 내의 용어는 가능한 한 학술용어 사용을 권장하며, 단위는 SI계 사용을 원칙으로 하지만 C.G.S. 단위를 사용할 수 도 있다. 약어를 사용하는 경우, 원고에서 약어가 처음 사용될 때, 원래 용어를 기록해 주어야 한다.

(6) 시간의 단위인 h 와 온도의 단위인 ºC를 포함한 모든 단위는 아라비아 숫자 수치와 한 칸 띄어서 표기하도록 규정한다.

(7) 국문 원고에서 사용하는 영어는 문장의 첫 글자와 고유명사의 첫 글자를 제외하고는 모두 인쇄체 소문자로 표기하는 것을 원칙으로 한다.

제 8 조 (표와 그림의 표기 방법)

(1) 표와 그림의 제목과 설명은 모두 영문(이탤릭체, *Table*, *Fig.*)으로 하고, 본문의 내용을 참고하지 않고도 그 내용을 알 수 있도록 표현해야 하며, 아라비아 숫자로 일련번호를 붙여야 한다(예, *Table* 1, *Fig.* 2). 모든 표와 그림은 본문뒤에 이어서 나타내도록 한다.

(2) 표의 경우 제목의 단어 중 인명, 고유명사, 약어, 특수기호 등을 제외하고는 문장의 첫글자만 대문자로 하며 제목 끝에 마침표를 붙이지 않는다. 또한 표 내의 긴 단어는 적당한 약어로 대치하고 표의 하단에 사용한 약어의 원명을 기록해야만 한다. 표의 각주기호는 윗첨자로 a), b), c) 등의 형태로 표시하고, 그 설명은 표 하단에 나타낸다.

예) *Table* 1. Instrumental parameters for ICP/MS

(3) 그림의 원본은 흰바탕이어야 하며 선의 굵기와 그림에 삽입된 어귀의 크기는 약 1/2로 축소될 것을 고려해야 한다. 또한 제목의 첫글자와 고유명사의 첫 글자만을 대문자로 하고 나머지는 모두 소문자로 한다. 또한 제목의 끝에는 마침표를 한다.

예) *Fig.* 1. Analytical results of germanium in hot spring water.

(4) 사진은 축소시키지 않으므로 가로의 길이가 65 mm 또는 130 mm가 되도록 하며, 스캔한 사진의 경우는 해상도가 최소 1200 dpi 이상은 되어야 한다. 각 사진마다 우측 하단에 scale-bar를 표시해야만 한다. 또한 사진은 복사하여 인쇄하게 되므로 반드시 원판을 제출하여야 한다.

제 9 조 (참고문헌 표기 방법)

(1) 본문 중 참고문헌 인용부분은 참고문헌 목록에 표기된 아라비아 숫자를 윗첨자로 표기한다.

예 1) A의 연구결과는 B의 연구결과[2]와 같이……

예 2) 이 결과는 추후 A에 의해서 개선되었다.[1-3,5]

(2) 참고문헌 목록은 영문표기를 원칙으로 한다. 단 영문표기가 불가능한 경우, 해당국가의 언어로 표기한다. ISSN의 단어 약어 표기법에 따라 저널명은 표준 약어로 표기한다. (http://www.issn.org/2-22661-LTWA-online.php).

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학술지 예 2) B. Kim and S.-W. Myung, *Anal. Sci. Technol.*, **23**(6), 572-578 (2010)

학술회의 예 3) J. E. Graham, S. A. Andrews, G. J. Faruhar and O. Meresz, Water Quality Technology Conference, AWWA, New Orleans, LA, 757-772 (1995).

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온라인 문서 예 6) WHO Chemicals assessment, http ://www.who.int/ipcs/assessment/en/, Assessed 7 Mar 2011.

학위 논문 예 7) Silvia, S. 'Effects of Sampling Error and Model Misspecificationon Goodness of Fit Indices for Structural Equation Models' Ph. D. Dissertation, Ohio State University, Columbus, Ohio, 1988.

정부 고시 예 8) Ministry of Environment Notification No. 2010-48(2010.07.14), Republic of Korea.

(3) 본 학술지의 참고문헌 형식은 endnote에서 제공하는 style을 참고로 작성할 수 있으며, 학회홈페이지의 자료실에서 받을 수 있다.

제 10 조 (속보와 단신)

(1) 연구가 완료되기 전에 얻어진 중요한 연구결과는 속보 또는 단신으로 투고할 수 있다.

(2) 단신에는 국문초록을 생략하며, 속보는 항목별로 나누지 않고 종합적으로 서술한다.

제 11 조 (교정)

(1) 채택된 원고의 일차 교정은 저자가 하지만, 이차교정은 편집위원회가 담당함을 원칙으로 한다. 저자에 의한 교정은 인쇄상의 오류 이외의 자구수정, 내용삽입 혹은 변경은 허용하지 않는다.

(2) 편집위원회는 채택된 원고의 내용이 변경되지 않는 범위에서만 교정할 수 있다.

제 12 조 (게재료와 투고료)

(1) 게재된 투고 논문은 기본 (6면) 150,000원, 기본 페이지 (6면)을 초과시 초과 페이지 1면당 20,000원의 게재료를 납부해야하며, 출판과 관련된 추가비용은 별도로 납부하여야 한다. (사진판에 아트지를 사용, 칼라 도면 요구, 30부를 초과하는 별쇄본 요구 등)

(2) 편집위원장 또는 편집위원회에서 추천되어 회원 전체의 학술활동에 크게 이익이되는 해설 또는 총설을 투고한 저자에게는 면당 20,000원의 투고료를 지불하는 것을 원칙으로 한다.

제13조 (저작권 및 라이센스)

분석과학지는 Open Access 저널로서 Creative Commons Attribution Non-Comme-rcial License (Http://creativecommons.org/licenses/by/3.0/) 정책에 따라서 출판되고 배포된다. 이 정책에 의하여 저자는 해당 저작물에 대한 저작권을 보유하지만 원저자와 출처를 명시할 경우, 비상업용에 한해 제한 없이 자유롭게 이용할 수 있고 저작물을 변경하거나 이를 이용해 2차 저작물을 만들 수 있다.

제14조 (학회지 구독정보)

본 학회지의 구독을 원할 경우 아래 연락처로 연락한다.

한국분석과학회

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제15조 (원고투고 문의처)

본 학회지에 원고투고시 문의처는 다음과 같다.
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전화: +82-42-821-5477
E-mail: jkkim48105@cnu.ac.kr

제16조 (위임사항)

기타 본 규정에 명시되지 않은 사항에 대한 결정은 편집위원회에 위임한다.

제17조 (발행의 시기)

본 학회지는 년 6회, 격월 25일에 발행한다.

제18조 (규정의 발효)

이 규정은 이사회 승인날부터 소급 시행한다.

논문발행규정

제 1 조(목적) 이 규정은 한국분석과학회 정관 제4조에 의하여 본 학회에서 발행하는 모든 학술지 발행에 관한 일반적 사항을 규정하는 것을 목적으로 한다.

제 2 조(학술지 및 언어)

① 본 학회는 국내 학술지로 “분석과학”(Analytical Science & Technology, Anal. Sci. Technol.)를 발행한다.

② 각 학술지의 사용언어는 해당 학술지의 투고규정에 따른다.

제 3조(발행시기) “분석과학”지는 연 6회(격월 25일) 발행한다.

제 4 조(논문투고 및 게재심사) 논문지에 투고된 논문은 해당 논문지의 투고규정을 준수해야 하며, 논문 게재 여부는 해당 논문지의 논문심사규정에 따른 심사절차를 통하여 편집위원회에서 결정한다.

제 5 조(판권) 분석과학지는 Open Access 저널로서 Creative Commons Attribution Non-Commercial License (Http://creativecommons.org/licenses/by/3.0/) 정책에 따라서 출판되고 배포된다. 이 정책에 의하여 저자는 해당 저작물에 대한 저작권을 보유하지만 원저자와 출처를 명시할 경우, 비상업용에 한해 제한 없이 자유롭게 이용할 수 있고 저작물을 변경하거나 이를 이용해 2차 저작물을 만들 수 있다.

제 6 조(배포) 논문지는 본 학회의 회원들에게 무상으로 배포한다. 회원이 아닌 개인이나 단체에서 구독을 요청할 경우 이의 승인 및 구독료는 이사회에서 결정한다.

제 7 조(창간, 증간 및 폐간) 새로운 논문지를 창간하고자 할 경우나, 기존의 논문지 간행 횟수를 변경 혹은 폐간하고자 할 경우에는 이사회에서 이를 결정한다.

한국분석과학회 연구윤리 규정

[시행 2023. 10. 05.] [2023. 10. 05. 제정]

제1장 총칙

제1조(목적) 본 규정은 한국분석과학회(이하 학회)의 연구활동 및 논문출판과 관련하여 연구진실성을 확보하고 연구부정행위가 발생하지 않도록 기본적인 원칙과 방향을 제시함을 목적으로 한다.

제2조(용어의 정의) 이 규정에서 사용하는 용어의 정의는 다음 각 호와 같다.

1. 연구부정행위(이하 "부정행위"라 한다)라 함은 연구의 제안, 연구의 수행, 연구결과의 보고 및 발표 등에서 이루어진 다음 각 호를 말한다.
   가. "위조"는 존재하지 않는 연구 원자료 또는 연구자료, 연구결과 등을 허위로 만들거나 기록 또는 보고하는 행위
   나. "변조"는 연구 재료·장비·과정 등을 인위적으로 조작하거나 연구 원자료 또는 연구자료를 임의로 변형·삭제함으로써 연구 내용 또는 결과를 왜곡하는 행위
   다. "표절"은 일반적 지식이 아닌 타인의 독창적인 아이디어 또는 창작물을 적절한 출처표시 없이 활용함으로써, 제3자에게 자신의 창작물인 것처럼 인식하게 하는 행위
   라. "부당한 저자 표시"는 연구내용 또는 결과에 대하여 공헌 또는 기여를 한 사람에게 정당한 이유 없이 저자 자격을 부여하지 않거나, 공헌 또는 기여를 하지 않은 사람에게 감사의 표시 또는 예우 등을 이유로 저자 자격을 부여하는 행위
   마. "부당한 중복게재"는 연구자가 자신의 이전 연구결과와 동일 또는 실질적으로 유사한 저작물을 출처표시 없이 게재하는 행위게재한 후, 연구비를 수령하거나 별도의 연구업적으로 인정받는 경우 등 부당한 이익을 얻는 행위
   바. "연구부정행위에 대한 조사 방해 행위"는 본인 또는 타인의 부정행위에 대한 조사를 고의로 방해하거나 제보자에게 위해를 가하는 행위
   사. 그 밖에 각 학문분야에서 통상적으로 용인되는 범위를 심각하게 벗어나는 행위
2. "편집인"이란 논문 투고부터 출판 그리고 출판 후 사후관리 과정에 관련되는 사람을 의미한다.
3. "저자(author)"란 연구의 전체 또는 특정 부분에 상당한 지적 기여를 하고, 이에 책임을 지는 사람을 의미한다.
4. "심사자(peer reviewer)란 투고된 논문 원고의 학술적 가치와 연구수행의 진실성 등을 고려하여 해당논문의 가치를 판단하는 동료 연구자를 의미한다.
5. "제보자"라 함은 연구부정행위를 인지한 사실 또는 관련 증거를 학회 또는 분석과학지(Analytical Science & Technology) 편집위원회에 알린 자를 말한다.
6. "피조사자"라 함은 제보 또는 한국분석과학회 편집위원회의 인지에 의하여 연구부정행위의 조사 대상이 된 자 또는 조사 수행 과정에서 연구부정행위에 가담한 것으로 추정되어 조사의 대상이 된 자를 말하며, 조사과정에서의 참고인이나 증인은 이에 포함하지 않는다.

제3조 (적용범위) 이 규정은 분석과학지에 투고한 저자, 본 학회에서 주관하는 학술행사의 발표자, 학회에서 발간한 출판물의 저자, 그 밖에 학회에서 수행하는 연구활동과 관련된 저자에 대해 적용한다.

제2장 출판윤리

제4조(편집인) 편집인은 다음 각 호의 사항을 준수하여야 한다.

1. 편집인은 출판의 원고를 최종 결정하는 권한을 가진다.
2. 편집인은 학술지에 게재할 목적으로 투고된 논문을 저자의 성별, 나이, 소속 기관, 국적 또는 저자와의 개인적인 친분에 관계없이 논문의 질적 수준과 투고규정을 근거로 공평하게 취급하여야 한다.
3. 편집인은 출판물의 내용과 관련하여 그에 대한 선정, 출판 과정 등에서 진실성이 보장되도록 성실히 일할 책임을 가진다.
4. 편집인은 논문을 심사할 자격이 있는 전문가를 심사자로 선정해야 한다.
5. 편집인은 투고된 논문에 관한 정보를 평가 과정이 끝날 때까지 저자나 심사자 외에 다른 사람에게는 공유해서는 안 된다.
6. 편집인은 저자의 인격과 학자적 독립성을 존중해야 한다.
7. 편집인이 투고된 논문에 대하여 이해충돌이 있는 경우, 해당 논문의 게재 결정과정에서 해당 편집인을 배제하여야 한다.

제5조(저자) 저자는 다음 각 호의 사항을 준수하여야 한다.

1. 저자는 연구를 계획하거나, 자료의 수집·분석 및 해석에 상당한 참여를 한 사람, 논문의 초고를 작성하거나 학문적으로 주요한 내용을 검토한 사람, 연구내용 또는 결과에 대하여 책임지는 것에 동의한

사람만이 될 수 있다. 연구비 수주, 단순한 자료 수집, 연구 관리만을 담당한 사람은 저자가 될 수 없으나, 연구에 직.간접적으로 도움을 준 사람에 대하여 사사 표기를 할 수 있다.

2. 저자는 연구의 내용과 그 중요성에 대하여 객관적으로 정확하게 기술하고, 연구의 결과를 임의로 제외하거나 첨가하지 않으며, 저자는 발표하고자 내용과 동일하거나 유사한 내용의 출판 여부를 최선을 다하여 확인하여야 한다.
3. 연구 논문에는 학술적으로 충분한 가치가 있는 결론과 그것을 뒷받침할 수 있는 종합적인 논거가 포괄적으로 포함되어 있어야 한다. 이미 발표한 논문과 동일한 결론을 주장하는 연구 논문을 투고하는 경우는 새로운 논거에 중대한 학술적인 가치가 있어야 한다.
4. 공개된 학술 자료를 인용할 경우에는 정확하게 기술하고, 일반적 지식에 속하는 자료가 아닌 경우에는 반드시 그 출처를 명확하게 밝혀야 한다.
5. 연구 논문으로 학술지에 발표되었거나 투고하여 심사 중인 논문의 내용을 담은 논문을 이중으로 투고할 수 없다.
6. 저자는 연구와 관련하여 이해충돌이 발생할 가능성이 있는 경우에는 연구에 부정적인 영향을 미치지 아니하도록 최선의 노력을 하여야 하며 학술지에 이를 밝혀야 한다.

제6조(심사자) 심사자는 다음 각 호의 사항을 준수하여야 한다.

1. 모든 학회구성원은 학술지의 편집인이 의뢰하는 논문을 심사규정이 정한 기간 내에 성실하게 심사하여 학술 발전에 기여할 의무가 있다.
2. 심사자는 높은 수준의 학술적 기준을 적절하게 유지하면서 논문에 포함된 내용을 객관적으로 심사하여야 한다. 완벽하게 검증되지 않은 개인의 학술적 신념이나 가정에 근거하여 심사하지 않으며, 자신의 연구나 저자와의 개인적인 친분 관계를 떠나 공정하게 심사하여야 한다.
3. 심사자는 전문 지식인으로서의 저자의 인격과 독립성을 존중하여야 한다. 편집인에게 보내는 심사의견서에는 논문에 대한 자신의 판단과 보완이 필요하다고 생각되는 부분을 그 이유와 함께 상세하게 설명하여야 한다.
4. 심사자는 심사를 의뢰한 논문에 대한 비밀을 보장하여야 한다. 논문이 게재된 학술지가 출판되기 전에는 저자의 동의 없이 논문의 내용을 인용할 수 없다.
5. 심사자는 논문의 내용과 관련된 중요한 연구가 정확하게 인용되어 있는가에 세심한 주의를 기울여야 한다. 심사하는 논문의 내용이 이미 학술지에 공개된 다른 논문과 유사할 경우에는 편집인에게 그 사실을 알려야 한다.
6. 심사자는 빠른 시일에 심사를 마치고, 의견서를 편집인에게 보내야 한다. 만약 자신이 논문의 내용을 심사하기에 적임자가 아니라고 판단되는 경우에는 심사를 의뢰한 편집인에게 지체 없이 그 사실을 통보하여야 한다.
7. 심사자는 편집인에게 논문에 대한 의견을 편향시킬 수 있는 이해충돌을 공개해야 하며, 편향의 가능성이 있는 경우 특정 원고에 대한 심사를 스스로 회피해야 한다. 공정한 심사를 제공하지 못하게 하는 이해충돌을 발견할 경우 이를 학술지에 알리고 조언을 구해야 한다.
8. 심사자는 학술지의 허가 없이 저자에게 직접 연락해서는 안 된다.

제3장 연구부정행위 의혹 처리 절차

제7조(연구부정행위의 판단) ① 연구부정행위는 다음 각 호의 기준으로 판단한다.

1. 연구자가 속한 학문 분야에서 윤리적 또는 법적으로 비난을 받을 만한 행위인지
2. 해당 행위 당시의 정부의 '연구윤리 확보를 위한 지침' 및 해당 행위가 있었던 시점의 보편적인 기준을 고려
3. 행위자의 고의, 연구부정행위 결과물의 양과 질, 학계의 관행과 특수성, 연구부정행위를 통해 얻은 이익 등을 종합적으로 고려

② 제2조 제1호에서 정한 '그 밖에 각 학문분야에서 통상적으로 용인되는 범위를 심각하게 벗어난 행위'를 판단하고자 할 때에는 분석과학분야에서 부정한 행위라는 인식이 널리 퍼져 있는지 등을 고려하여야 한다.

제8조(제보자의 권리 보호) ① 어떠한 경우에도 제보자의 신원을 직·간접적으로 노출시켜서는 아니 된다.

② 제보자가 연구부정행위 신고 이후의 조사·처리 절차 및 일정 등에 대해 알고자 할 경우 학회는 이에 성실히 응해야 한다.

③ 제보의 내용이 허위인 줄 알았거나 알 수 있었음에도 불구하고 신고한 제보자는 권리 보호 대상에 포함되지 않는다.

제9조(피조사자의 권리 보호) ① 한국분석과학회 회장(이하 '학회장'으로 칭한다)은 연구부정행위 여부에 대한 검증이 완료될 때까지 피조사자의 명예나 권리가 침해되지 않도록 주의하여야 하며, 무혐의로 판명된 피조사자의 명예회복을 위해 피조사자가 요청하는 경우 적절한 조치를 취해야 한다.

② 연구부정행위에 대한 혐의는 검증 결과가 확정되기 전까지는 외부에 공개하지 않아야 한다.

③ 피조사자가 연구부정행위의 조사·처리 절차 및 일정

등에 대하여 알고자 할 경우 학회는 이에 성실히 응해야 한다.

④ 학회는 피조사자에게 최초 제보 또는 추가적인 제보에서 주장된 사실에 대해서 의견을 제출하거나 해명할 기회를 부여하여야 한다.

제10조(연구부정행위의 검증원칙) ① 연구부정행위에 대한 검증 책임은 원칙적으로 해당 연구가 수행될 당시 연구자의 소속 기관에 있다.

② 학회는 제보된 연구부정행위 혐의에 대하여 피조사자의 소속기관에 검증을 요청할 필요가 있는지 여부를 결정하며 이에 대한 책임은 조사위원회에 있다.

③ 조사위원회는 제보자와 피조사자에게 의견진술, 이의제기 및 변론의 권리와 기회를 보장하여야 하며 관련 절차 및 일정을 사전에 알려주어야 한다. 이 경우 피조사자에게는 해당 제보 내용을 함께 알려주어야 한다.

④ 조사위원회는 연구자의 소속기관 검증 결과를 토대로 연구부정행위 여부를 최종 결정한다.

제11조(연구부정행위 검증 절차) ① 학회가 연구부정행위를 검증하고자 할 경우에는 "예비조사"와 "본조사", "판정"의 절차를 거쳐야 한다.

② 연구부정행위 아님이 매우 명백한 경우와 피조사자가 연구부정행위 사실을 모두 인정할 경우에는 피조사자의 소속 기관에 검증을 요청하지 않고 예비조사 단계에서 바로 판정을 내릴 수 있다.

③ 학회는 연구자의 연구부정행위를 제보받아 검증하였을 때에는 그 결과를 해당 연구자의 소속 기관에 통보하여야 한다.

제12조(편집위원회의 구성 및 운영) ① 학회의 편집위원회가 연구윤리위원회의 역할을 수행하며 그 구성은 학회 편집위원회 규정에 따른다.

② 위원회는 다음 각 호에 대해서 심의·의결한다.

1. 연구윤리 및 연구부정행위 관련 제도의 수립·운영에 관한 사항
2. 연구윤리 확립 및 교육에 관한 사항
3. 연구부정행위 제보의 접수와 처리에 관한 사항
4. 예비조사 및 본조사 실시를 위한 위원회 구성·운영에 관한 사항
5. 예비조사 및 본조사의 조사 결과 승인에 관한 사항
6. 제보자 및 피조사자 권리 보호에 관한 사항
7. 연구부정행위 검증 결과의 처리 및 후속조치에 관한 사항
8. 기타 위원장이 부의하는 사항

제13조(연구부정행위의 제보 및 접수) ① 제보자는 구술·서면·전화·전자우편 등 가능한 모든 방법으로 제보할 수 있으며 실명으로 제보함을 원칙으로 한다. 다만 익명으로 제보하고자 할 경우 서면으로 논문명 및 구체적인 연구부정행위의 내용과 구체적인 증거를 제출하여야 한다.

② 학회는 제보되지 아니한 사안이라도 필요한 경우 편집위원회의 의결을 거쳐 조사할 수 있다.

제14조(예비조사) ① 예비조사는 연구부정행위 의혹에 대하여 본조사 실시 여부를 결정하기 위한 요건을 검토하는 절차로, 제보를 접수한 날로부터 30일 이내에 착수하고, 착수 후 30일 이내에 완료하는 것을 원칙으로 한다. 단, 이 기간 내에 조사가 이루어지기 어렵다고 판단될 경우 제보자 및 피조사자에게 그 사유를 통보하고 조사 기간을 연장할 수 있다.

② 예비조사는 예비조사위원회를 구성하여 실시하되, 예비조사위원회 구성에 관한 구체적인 사항은 편집위원장이 자율적으로 정한다.

③ 학회는 연구부정행위 아님이 명백한 경우와 피조사자가 연구부정행위 사실을 모두 인정할 경우에는 본조사를 거치지 않고 바로 판정을 내릴 수 있다.

④ 예비조사위원회는 제보내용이 제2조제1호의 연구부정행위의 의혹이 구체적이고 명확하여 피조사자의 소속 기관에 검증을 요청할 필요가 있는지 여부를 조사한다.

⑤ 학회는 예비조사가 종료된 날로부터 10일 이내에 제보자에게 예비조사 결과를 문서로 통보하여야 하며, 본조사를 실시하지 않기로 결정한 경우에는 이에 대한 구체적인 사유를 포함하여야 한다. 단, 익명제보의 경우는 그러하지 않는다.

제15조(본조사) ① 본조사는 연구부정행위의 사실 여부를 판단하기 위한 절차로, 제16조에 따른 조사위원회를 구성하여 실시하여야 한다.

② 조사위원회는 제보자와 피조사자에게 의견진술 등의 기회를 주어야 하며, 당사자가 이에 응하지 않을 경우에는 이의가 없는 것으로 간주한다.

③ 조사위원회는 필요한 경우 연구자 소속기관의 최종 판정결과와 그 근거를 검토한 후 연구자의 연구부정행위 여부를 최종 결정한다.

제16조(조사위원회의 구성) ① 학회는 본조사를 위해 편집위원 3인, 외부 위원 2인 등 5인의 위원으로 구성하며, 위원장은 호선한다.

② 조사위원회에 포함되는 편집위원과 외부 전문위원은 접수된 제보와 관련된 연구분야 및 전문 경험을 고려하여 편집위원장이 임명한다.

③ 조사위원회 위원장은 조사위원회의 운영을 주재하고 조사결과보고서 작성의 책임을 진다.

④ 다음 각 호의 어느 하나에 해당하는 경우에는 당해 사건에 조사위원이 될 수 없다.

1. 제보자 또는 피조사자와 민법 제777조에 따른 친인척 관계가 있거나 있었던 자
2. 제보자 또는 피조사자와 사제관계에 있거나 공동으로 연구를 수행하거나 하였던 자
3. 기타 조사의 공정성을 해할 우려가 있다고 판단되는 자

제17조(판정) ① “판정”은 학회장이 조사결과를 확정하여 이를 제보자와 피조사자에게 문서로 통보하는 것을 말한다.

② 본조사 착수 이후 판정까지의 모든 조사는 3개월 이내에 종료하여야 한다. 단, 이 기간 내에 조사가 이루어지기 어렵다고 판단될 경우 학회는 제보자 및 피조사자에게 그 사유를 통보하고 조사 기간을 연장할 수 있다.

제18조(이의신청) ① 제보자 또는 피조사자는 조사 결과에 이의가 있을 경우 그 결과를 통보받은 날로부터 30일 이내에 학회에 서면으로 이의신청을 할 수 있다.

② 학회는 이의신청에 대하여 특별한 사유가 없으면 이의신청이 접수된 날로부터 60일 이내에 처리하여야 한다.

③ 학회는 이의신청이 이유 있을 때에는 종전의 판정을 취소하고 다시 판정을 하며, 이의신청이 이유 없을 때에는 이를 기각한다. 이 같은 학회의 결정에 대하여 다시 이의신청을 할 수 없다.

제19조(조사결과보고서의 제출) ① 조사위원회는 조사 종료 후 15일 이내에 조사 결과보고서를 편집위원회에 제출하여야 한다.

② 조사결과보고서에는 다음 각 호의 사항이 포함되어야 한다.

가. 제보의 내용

나. 제보자와 피조사자의 진술내용

다. 조사결과

라. 해당 연구에서의 피조사자의 역할과 연구부정행위의 사실 여부

제20조(조사의 기록과 정보의 공개) ① 학회는 조사과정의 모든 기록을 음성, 영상, 또는 문서의 형태로 5년 이상 보관하여야 한다.

② 조사보고서 및 조사위원 명단은 판정이 끝난 이후에 공개할 수 있다.

③ 조사위원, 증인, 참고인, 자문에 참여한 자의 명단 등은 당사자에게 불이익을 줄 가능성이 있을 경우 공개하지 않을 수 있다.

제4장 연구부정행위에 대한 조치

제21조(편집위원회의 제재 조치) ① 연구자의 연구부정행위에 대한 판정이 최종 확정된 후 편집위원회는 피조사자의 연구부정행위에 대해 적절한 조치를 취할 수 있다.

② 편집위원회는 조사위원회의 최종 결과보고서를 접수한 날로부터 30일 이내에 편집위원회 회의를 개최하고 연구자에 대한 제재 조치를 결정하여야 한다.

③ 제1항의 규정에 의한 편집위원회 조치의 종류는 다음 각 호와 같다.

1. 해당 논문의 모든 저자에게 연구부정행위에 관한 사실을 알린다.
2. 투고된 논문은 수정 또는 게재불가 처리한다.
3. 출판된 논문은 정식으로 취소(retraction)한다.
4. 향후 논문 작성 시 주의하도록 모든 저자에게 서면 주의 또는 서면 경고 조치한다.
5. 연구부정행위에 대한 내용을 담은 사설을 게재한다.
6. 연구부정행위에 책임이 있는 저자에게 명시된 기간 동안 논문의 투고를 금지한다.
7. 해당 논문의 모든 저자의 소속 기관장, 연구비 지원 기관, 또는 색인기관에 공지한다.
8. 기타 논의하여 정하는 사항

④ 편집위원장은 연구자에게 편집위원회 조치 사항을 알리고, 연구자는 조치 사항을 통보받은 날로부터 2주 이내에 편집위원회에 서면으로 이의신청을 할 수 있다. 편집위원회는 이의신청이 이유 있을 때에는 종전의 조치 사항 결정을 취소하고 다시 결정을 하며, 이의신청이 이유 없을 때에는 이를 기각한다. 이 같은 편집위원회의 결정에 대하여 다시 이의신청을 할 수 없다.

제22조(학회의 제재 조치) ① 피조사자의 연구부정행위에 대한 판정이 최종 확정된 후 편집위원회는 피조사자의 연구부정행위에 대해 적절한 조치를 학회장에게 건의할 수 있다.

② 학회는 편집위원회의 건의를 접수한 날로부터 30일 이내에 이사회를 개최하고 피조사자에 대한 조치를 논의한다.

③ 제1항의 규정에 의한 학회 조치의 종류는 다음 각 호와 같다.

1. 명시된 기간 동안 학회 웹사이트에 해당 학회원의 연구윤리 위반 사실을 공지한다.
2. 해당 학회원의 회원 자격을 일정기간 정지한다.
3. 해당 학회원의 회원 자격을 취소한다.
4. 기타 논의하여 정하는 사항

④ 학회장은 피조사자에게 학회 조치 사항을 알리고, 피조사자는 조치 사항을 통보받은 날로부터 2주 이내에 학회에 서면으로 이의신청을 할 수 있다. 학회는 이의신청이 이유 있을 때에는 종전의 조치 사항 결정을 취소하고 다시 결정을 하며, 이의신청이 이유 없을 때에는 이를 기각한다. 이 같은 학회의 결정에 대하여 다시 이의신청을 할 수 없다.

기타 규정

한국분석과학회 윤리위원회는 편집위원회가 겸무한다.

부칙(2023. 10. 05. 제정)

이 규정에서 정한 것 이외에 관한 사항은 이사회의 결의에 따른다.

(시행일) 본 규정은 제정한 날부터 시행한다.

Author's Guide

1. The type and content of the manuscript

(1) Manuscripts that can be published in the Journal include analyses of chemistry, chemical engineering, material science, pharmaceutics, agriculture, food and environmental sciences. These manuscripts can be classified as article, communication or letter, note and review.

(2) All submissions must be original, unpublished, and not under consideration for publication elsewhere.

2. Submission qualification

Contributors to the Journal must be members of the Society. Co-presenters of manuscripts that have been accepted and posted to the Journal after examination must apply for membership to the society and pay the annual fee to publish. However, exceptions may be made for students (below graduate MSc).

3. Code of Ethics

(1) Contributors must submit the paper in compliance with the code of ethics of the Society.

(2) Contributors cannot post a study that has been previously published in any other journal.

(3) Research papers that are forged, falsified, or plagiarized will not be published, and the relevant details shall be referred to the Editorial Board.

(4) Contributors must obtain the consent of all coauthors when submitting papers. All people who made important contributions to academic submissions must share the responsibility for the studies and results.

(5) When results of other researchers or academic materials are quoted, authors must determine and specify the sources as references.

4. Manuscript review

Review process, acceptance, publication order, and printing of the manuscripts submitted to the Society are entrusted to the Editorial Board, which is composed of members of the Society. The Editorial Board may request modifications of the manuscript, if necessary.

5. Manuscript submission and acceptance

(1) Manuscripts shall be submitted directly through the online manuscript submission system (KISTI ACOMS), and they must include all information of the paper and the author(s). The reception date of the paper will be the date it is submitted online, and the date must be created to conform with the required format of KISTI ACOMS.

(2) Acceptance of the manuscript shall be decided after examination by selected reviewers.

(3) Upon acceptance of the manuscript, the authors will be asked to upload the final version of the manuscript to the online manuscript submission system.

6. Language of the Manuscript and Format

(1) The language of the manuscript will be Korean or English in principle.

(2) The manuscript should be written in Microsoft Word (single-spaced) or HWP (250%) with font size greater than 10pt.

(3) Spacing shall include one space after commas and two spaces after the periods.

(4) The manuscript should not exceed 15 pages without tables and graphs.

7. Form of Manuscript

(1) On the cover of the manuscript (first page), titles, researchers name, affiliation or address, postal code, and country name must be given in Korean followed by English, regardless of the language used in the text. If the affiliation and addresses are different for researchers, an asterisk (*) shall be used to mark this to provide an easy-to understand structure. English addresses, zip codes, and country names should be in italics.

(2) The format of the Korean research paper should

include the cover, Abstract (Korean), abstract (English), Key words (less than 5 words and make them lower case), Introduction, Theory, Experimental section (method), Results, Discussion, Conclusions, Acknowledgements, References, Tables and Figures in that order. However, it is possible to omit unnecessary sections. In addition, it is recommended to use Korean, but if a person's name, a place name, a journal name, etc., is prone to confusion, it is acceptable to use English or Chinese characters.

(3) The format of the English research paper should include the cover, Abstract, Key words, Introduction, Experimental section, Results, Discussion (or Results and Discussion), Conclusion (or Summary), Acknowledgements, References, Tables, and Figures in that order. It is acceptable to omit unnecessary sections.

(4) Korean and English abstracts of the papers must specifically contain the purpose of the study and the major results that can be easily understood without the full text. However, Comment and Review papers may omit an abstract, and Manuscripts that is prepared in English may omit a Korean abstract. The abstract should less than 700 characters or 250 words in English.

(5) Scientific terms should be used as much as possible and it is best to use of SI units but, CGS units may also be used. Abbreviations may be used, after an original term is used.

(6) All units, such as h for the hour unit or °C for the temperature unit, should include a space after the Arabic numeral.

(7) With the exception of the first letter of the sentence and the first letter of proper nouns, English used in the Korean manuscript must be written in lower case.

8. Notation of Table and Figure

(1) All the titles and descriptions of tables and figures should be in English (Italics, Table, Fig.) with the numbers in Arabic (ex, Table 1, Fig. 2). All figures and tables should be placed at the end of the manuscript.

(2) For a table, with the exception of the following words in the title (person's name, proper nouns, abbreviations, and special symbols), capitalize only the first letter of a sentence and do not put a period at the end of the title. Long words in the table should be replaced with suitable abbreviations and original term for the abbreviation must be recorded at the bottom of the table. Footnotes of Table displays with superscripts in the form of a), b), or c), and its description shows the bottom of the table; for example Table 1. Instrumental parameters for ICP/MS.

(3) Backgrounds of the figure should be white. Line thicknesses and the size of words that are inserted into figure should be reduced to about 1/2. The first letter of the title and proper nouns should be uppercase, while everything else should be lower case. In addition, there should be a period at the end of the title; for example, Fig. 1. Analytical results of germanium in hot spring water.

(4) The length of the sides must be between 130 mm and 65 mm since photos do not reduce. Scanned photographs, must be a minimum of 1200 dpi. A scale-bar must be included at the bottom right in each photo. In addition, you must submit the original photos to ensure quality printing.

9. Notation of references

(1) Citations in the text must be expressed as superscript Arabic numerals described in the reference list;

For example:

1) The research results of A as a research result of B2……

2) This result was improved by A at later.1-3, 5

(2) The reference list should be in English format. However, if English is not possible, it can be in the language of the originating country. The title of the journal will abbreviated based on the abbreviation of the of ISSN. (http://www.issn.org/2-22661-LTWA-online.php).

For example:

1) L. S. Anker and P. C. Jurs, *Anal. Chem.*, **64**(10), 1157-1164 (1992).

2) B. Kim and S.-W. Myung, *Anal. Sci. Technol.*, **23**(6), 572-578 (2010).
3) J. E. Graham, S. A. Andrews, G. J. Faruhar and O. Meresz, Water Quality Technology Conference, AWWA, New Orleans, LA, 757-772 (1995).

Book ex)

4) L. R. Snyder, J. J. Kirkland and J. W. Dolan, 'Introduction to Modern Liquid Chromatography', 3rd Ed., Wiley, New Jersey, 2010.

Inside Book ex)

5) L. C. Crig and D. Crig, In 'Technique of Organic Chemistry', 2nd Ed., Vol. 3, p149, A. Weisberger, Ed., Wiley, New York, 1956.
6) WHO Chemicals assessment, http://www.who.int/ipcs/assessment/en/, Assessed 7 Mar 2011.
7) Silvia, S. 'Effects of Sampling Error and Model Misspecificationon Goodness of Fit Indices for Structural Equation Models' Ph.D. Dissertation, Ohio State University, Columbus, Ohio, 1988.
8) Ministry of Environment Notification No.2010-48 (2010.07.14), Republic of Korea.

(3) Form of reference of this journal can be created with reference style provided by the endnote and it can be downloaded from the homepage of the Society.

10. Communication and Note

(1) An important research results obtained before the study is complete can be posted as a Note or a Communication.
(2) The Note can omit the Korean abstract and Communications shall be described in a comprehensive manner without using section headings.

11. Rectification

(1) The primary rectification of the accepted manuscript shall be done by the author, however, the editorial board is responsible for the secondary rectification in principle. Rectification by the author can only be performed on typographical error of the content, while not allowing phrase modification, insertion, or change.
(2) The editorial board shall be able to correct the content only to the extent that the content of the accepted manuscript is not changed.

12. Publication and Submission fee

(1) The authors of submitted papers that have been published need to pay a publication fee of 150,000 won (or $150) for up to 6 pages and additional 20,000 won (or $20) for each additional page. Additional costs involved with the publication must be paid separately (use of art paper for photographic plates, including color figures, and requiring over 30 copies of pull-out).
(2) A person who posts a review commentary, recommended by Editor-in-Chief or Editorial Board, that greatly benefits the academic activities of all the members, will be paid a submission fee of 20,000 won per page.

13. The Copyright and Licensing

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14. Subscription Information

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15. Editorial Information

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16. Terms of Reference

Other decisions of matters that are not expressly stated in this provision are delegated to the Editorial Board.

17. Date of Publication

The journal is published six times a year on the 25th day of every other month.

18. Effect of provision

This provision is retroactively enforced from the date of approval by the Council.

Reviewer's Guide

1. Adoption and review of papers to be posted to the Korea Society of Analytical Sciences is in accordance with this regulation. 'Communication', 'Note', and 'Comment' will also be treated as papers.

2. The Editor-in-Chief will appoint the reviewers.

3. All the papers will be examined by three reviewers, and through the examination of at least two people, the Editor-in-Chief or the editors will determine whether to accept it or not.

4. Code of Ethics

(1) Reviewers will evaluate the paper objectively on the basis of the regulations and shall notify the Editor-in-Chief of the evaluation results.

(2) In reviewing papers, reviewers will fairly evaluate, according to objective criteria, and not to drop the paper without sufficient evidence. Reviewers will not poorly evaluate a paper because of conflict with their own points of view or interpretations. Review papers must be evaluated in good faith.

(3) Reviewers will respect the expertise and personality of the author, reveal clearly in the paper evaluation report the evaluation of the paper, and record in detail portions that the reviewer finds necessary to be supplemented with reasonable explanations.

(4) The reviewers shall not disclose details of the examined paper. Further, submitted papers will not be distributed or referenced before the paper is posted.

(5) The list of reviewers will not be announced and Editor in-Chief will not reveal the reviewers.

5. Review results will be one of four responses; "No revision", "Minor revision", "Major revision", or "Reject".

(1) The papers that are determined to be 'No revision' are adopted without amendment.

(2) The papers that are determined to be 'Minor revision' are accepted by the Editor-in-Chief or the editors after the author has modified the point identified by the reviewers.

(3) The papers that are determined to be 'Major revision' will be reexamined after the author has modified the point identified by the reviewers, and then the Editor-in-Chief or the editors may accept the paper.

6. When the reviewers classify the paper as "Reject", the reasons must be specifically explained. These may include (1) when creativity is not clear, (2) when the facts or ideas of the authors have found are not clear in the manuscript, or when it is not obvious that a comprehensive analysis or consideration has been made at a different angle from the method or point of view indicated in the references cited, (3) when the contents of the papers would damage to the Society by evoking social criticism, or (4) when it is found to be inappropriate for publication in this journal.

7. If the editorial board determines the paper as inappropriate for the journal, the submission will not be accepted.

8. When the manuscript that is written in a foreign language is either difficult to decode or grammatically not clear, the editorial board or reviewer may recommend the author modify or write in Korean.

9. Manuscripts that two or more reviewers have classified "No revision" will be accepted. Manuscripts that two or more reviewers have classified "Reject" or classified by one as "Reject" and one or more as "Major revision" will not be accepted in principle. If it is not possible to reliably reach classification, the Editorial Board will discuss whether to accept the manuscript or not.

10. If the submitted paper, after a second examination, is still not classified as "No Revision", the Editorial Board will review the manuscript.

11. A subcommittee composed of specialized editorial board members may be convened when necessary to decide whether to accept the paper. The subcommittee must be present by the Editor-in-Chief.

12. Manuscripts will be reviewed within 15 days and the examination commission and reviewers must return the manuscript to the Society, along with the

review comments.

13. After receiving the review comments of the reviewers, the Society should return a copy to the author within one week.

14. If a reviewer does not submit the evaluation opinion within 30 days after the examination is commissioned, the examination request can be canceled. In this case, the manuscript should be returned to the Society immediately.

Editor's Guide

1. Purpose : In accordance with Article 5 of the Articles of Association, this provision specifies matters concerning the operation of the Editorial Board which is set up to oversee the work of the Society related to “analytical chemistry”.

2. Organization: The committee is comprised of the following members. (1) Chief editor, (2) two managing editors, and (3) up to 20 of reviewers.

3. Staff commission: The Editor-in-Chief will appoint the reviewers.

4. Term: Members and the Editor-in-Chief shall have a two year term and may be reappointed. However, if a member wishes to decline during their term because of circumstances beyond one's control, the member shall be replaced and the new member’s term will be the period remaining of the original term.

5. Code of Ethics

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