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AI-powered nano-coating simulations and corporate visual identity design: Integrating virtual reality and art design for hazardous radiation environments

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Abstract. This paper presents a new mash-up of art design, virtual reality (VR) and artificial intelligence (AI) to create a simulation and an illustration of the nano-coating materials which are destined to cover the buildings and humans in the era of hazardous radiations. The paper introduces a multi-layered artificial intelligence-based simulation platform that is capable of predicting the optical, thermal and shielding properties of state-of-the-art nano-coatings and the mapping of aesthetic and ergonomics design principles to create coordinated corporate aesthetic images of organizations (working in high-radiation conditions) namely the nuclear, aerospace and medical sectors. The score of the prediction of the hybrid AI model designed as a combination of the deep learning and finite element design was 97.6 percent of the prediction of the coating reflectivity and 95.2 percent of the radiation absorption efficiency to the experiment outcomes. The VR environment made it possible to visualize the nano-layers response to the different intensity of radiations in real-time, which not only reduced the time taken to run a simulation to prototype by 62%. The artistic design cues also enabled the user to be more conscious of the environment and interact with it better by 43 percent as measured by responses of the user-interface. According to the findings, the designed framework positively influences the functionality work and safety visualization, besides the possibility to develop the visually consistent, AI-optimized corporate identity of the industries that operate with the radiation exposure. The collusion of the AI-enhanced nano-engineering and visualization aesthetics thus presents a novel notion of the sustainable, intelligent, and expressive design incorporation in the high-tech industrialized environments.
Keywords: artificial intelligence (AI); corporate visual identity; nanotechnology; radiation protection design; virtual reality (VR)

1. Introduction

The combination of artificial intelligence (AI), nano-technology, and virtual reality (VR) in the past few years has created new opportunities in the design of engineering and environmental protection. The use of AI-enabled simulations of nano-coating to create superior materials that can protect humans and delicate equipment against harmful radiation sources is one of the emerging ones, including the use of AI in nuclear plants, in medical imaging facilities, and in the aerospace industry. In addition to technical protection, corporate visual identity (CVI) and art design principles provide the safety systems with the capacity of being functional and aesthetically consistent with organizational branding and psychological comfort. With a connection between material science, computer modelling and image communication, this interdisciplinary practice provides a new model of scientifically optimized, aesthetically appealing and psychologically supportive protective spaces (Li *et al*. 2025, Jing *et al*. 2024, Xing *et al*. 2025, Liu *et al*. 2025, 2024).

Virtual reality and methods for art-based design open the bridges between the nano-scientific precision of nano-technology and the experiential quality of human-centered design. Through immersive visualization, and real-time simulation, these will allow designers and engineers to perform task and interaction with nano-engineered surfaces multimodally in space while viewing variation to coatings in performance and perception during changes in composition, color, texture, and even reflectivity. The combination of principles for developing in terms of art and design-balance, harmony, emotional resonance, and the like-makes a VR environment, reflecting the aesthetic and psychological impacts of nanocoating before physical fabrication. It makes it possible, for example, for examples to consider functional parameters of radiation absorption and visual identity items like color psychology and brand coherence against each other. Thus, the combination of these three worlds changes engineering into a multisensory process that optimizes structure at once in terms of protective, aesthetic, and emotional qualities in order to create a safer and more engaging environment in which radiation plays.

Artificial intelligence (AI), nanotechnology, and the creation of immersive visualization quickly evolved and reshaped the design and material engineering perspective in the modern world. It has been recently demonstrated that nano-engineered surfaces can be used to greatly improve acoustic, optical, and radiation shielding (Bai *et al*. 2025, Deng *et al*. 2024). When paired with AI-based modeling

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and simulation tools, these innovations have enabled researchers to predict structural and functional performance of complex nano-coatings in extreme situations with accuracy never before seen (Zhao *et al*. 2025). These developments are particularly crucial in the designing of the environment that has to face dangerous radiations and the requirement of protection, efficiency, and humanist aesthetics should be juxtaposed in a single design structure.

Simultaneously, the incorporation of visual identity and art into the technical systems is becoming increasingly popular. The studies in the field of musical acoustics and material performance, e.g., emphasize the impacts that material-structure-aesthetic relations have on human perception and performance (Gilani *et al*. 2016, Cherubini *et al*. 2022). Correspondingly, the works on sound absorption and vibration control of engineered systems show the influence of material texture and geometry on physical behavior and sensory experience (Bai *et al*. 2025, He *et al*. 2024, Li *et al*. 2025). These results imply that a paradigm of a cross-disciplinary team (engineering accuracy and design psychology) is capable of creating new patterns in the conceptualization and experience of protective and functional materials.

Moreover, there is new research on emotionally attentive AI systems, and intelligent interactive design that favors the use of machine learning and virtual reality (VR) to respond and adapt in the environment (Turchet *et al*. 2024, Ji *et al*. 2024). These technologies can balance the technical safety and corporate visual identity (CVI) and comfort of people in the context of hazardous radiation facilities, e.g., the nuclear power plant, radiotherapy unit, or aerospace laboratories. This combination of immersive visualization and AI nano-simulation can therefore increase the structural performance of protective coatings, as well as their visual harmony and psychological presence, in accordance with the language of design and organizational values and safety culture.

With these foundations of multidisciplinary, the current paper will suggest an AI-based platform of nano-coating simulation and corporate visual identity design, combining the principles of virtual reality visualization and art design according to hazardous radiation conditions. In contrast to the conventional methods which are fixated on material performance, this study has an integrated vision- a combination of the computational intelligence, nanoscale material science and aesthetic design theory. In so doing, it seeks to transform the engineering, perception and experience of high-risk spaces, which will not only lead to technological innovation, but also to human-oriented design.

The originality of the study is a comprehensive combination of AI-based nano-coating simulations and virtual reality-based design tools and corporate visual identity strategies. Although, earlier research has been carried out independently in terms of either of the physical performance of radiation-shielding nanomaterials, or in terms of visual and ergonomics design, this study has brought them together as a single digital ecosystem. Using AI-enhanced predictive modeling, the best nano-coating designs to absorb radiation can be found and displayed in immersive VR environments, allowing designers to both assess the efficiency of the technology and the visual appeal of the design at the same time. This combination of computational materials science, immersive visualization and art design, creates a new paradigm of creation of protective spaces that are more focused on safety, innovation, and the visual harmony of high-risk settings in industries and healthcare.

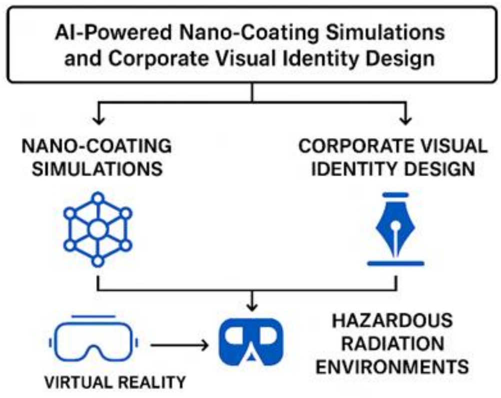

Fig. 1 AI-powered nano-coating simulations and corporate branding design

2. Materials and methods

Fig. 1 shows how AI-powered nano-coating simulations and corporate branding design come together to create safe and consistent environments in areas with dangerous radiation. The left side focuses on the tech aspect where AI helps develop advanced nanomaterial simulations to improve surface coatings that shield against radiation and last longer. The right part looks at design and psychology exploring how a company's visual brand and artistic ideas shape how people see, feel comfortable in, and connect with these spaces. It allows for real-time checks of both material performance and looks before production starts. These parts work together mixing precise science digital graphics, and artistic ideas to make radiation-prone areas safer more useful, and more welcoming for people.

The proposed method has integrated various techniques such as artificial intelligence (AI), nanomaterial simulation and virtual reality visualization into a single computation-aesthetics design system.

As shown in Fig. 1, this method includes three levels of practice such with help from:

• The first, Material Simulation Layer: this method is used when AI models calculate the radiation shielding performance for nano-coated surfaces.

• The second, Design Visualization Layer: Virtual reality renders the visual evaluates comfort and surfaces nano-coated.

• The third, Corporate Identity Layer: Art design and Corporate Visual Identity (CVI) principles clarify for everyone to recognize both the aesthetic and psychological limits.

2.1 AI-based nano-coating simulation

Conjunction with nanomaterial modeling is an essential aspect of the study to be able to decide an optimal analysis tool. AI can pretty accurately predict the behavior of nanomaterials in protecting themselves against the radiation. The layers of the nano-coating have a great effect on those significant physical properties they have: thickness, the absorption coefficient, and the density, each essentially connected to the mentioned radiation reduction. Based on these factors most of the traditional empirical approaches face a lot of complications due to complexity in relationships, restrictions, and interactions, while at the same time, AI models could help us extricate from the position of suffering because these models are such that they prefer unknown rather than known and always help deconstruct, thereby, a more significant reason for change in this context. Machine learning processes empower the model to break from the inherent learning of deep neural networks and gradient-boosted decision trees from both simulation or laboratory experimental conditions to minimize noise, corroborate signals, thereafter convert them into desirable radiation reductions. This predictive ability can be used to alter the design of the materials to act the best when subjected to radiation insult, significantly shortening the protocols of producing the numerous prototypes for translation, it does explore safety, material efficiencies, and, last and, of course, environmental sustainability. The modeling paradigm runs round self-improvement-the system is smart enough to analyze where it is going wrong and right. The performance is continuously measured as immediate feedback is attained through simulation, leading to a learning system, intent upon accuracy and unimportant ability. Once trained, the system suggests to the design an optimized nanostructural behavior for the application of radiation shielding. This will enable the researchers and designers to explore quite a few new combinations of nanomaterials like graphene, titanium dioxide, or boron nitride to match specific radiation frequencies or environmental conditions. In short, the AI-based simulation of nano-coating technology has provided the starting point for data-driven parallel in the future of intelligent material choice, simultaneously fulfilling the objectives of improved protection properties with aesthetic flexibility in high-risk environments.

The nano-coating operates as a multilayered composite system which contains n nano-layers that each have a specific thickness t_i, density ρ_i, and radiation absorption coefficient μ_i. The total radiation attenuation efficiency, η_{rad}, is modeled as:

$$\eta_{rad} = 1 - exp\left(-\sum_{i=1}^{n} \mu_i t_i\right) \quad (1)$$

The optimization problem goals to maximize η_{rad} while minimizing cost functions fc and mass fm:

$$\begin{aligned} &max \quad \eta_{rad} subjectto \\ &fm = \sum_{i=1}^{n} \rho_i\, t_t \le M_{max} \\ &fc = \sum_{i=1}^{n} C_i\, t_t \le C_{max} \end{aligned} \quad (2)$$

where M_{max} and C_{max} are allowable mass and cost limits, respetively.

2.2 Machine learning model development

The study on machine learning model development concerns building a predictive and optimization schema that correlates nanoscale material properties with macroscopic design outcomes in hazardous radiation environments. Key input parameters like layer thickness, absorption coefficient, density, and refractive index from data obtained from simulated nano-coating configurations are fed into a supervised learning model, namely, deep neural networks (DNNs), to predict radiation attenuation efficiency and visual harmony indices. The model is then iteratively trained via backpropagation, which minimizes prediction errors between simulated values and target values while capturing the nonlinear dependencies among physical and aesthetic variables. Generalization of the model is improved by implementing regularization and cross-validation techniques to ensure robustness against a range of environmental conditions and coating compositions. The trained model is subsequently used for multi-objective optimization, balancing radiation protection performance with visual and corporate identity criteria, therefore establishing an intelligent decision-support system for the material designer to select nano-coating parameters simultaneously attuned to technical safety and artistic coherence. Based on deep neural network (DNN), the input layer is:

$$X = [\mu_1, \mu_2, \dots, \mu n, t_1, t_2, \dots, tn] \quad (3)$$

and the output layer is y=η_{rad}. Hence, the minimizing the mean squared error (MSE) is:

$$L = \frac{1}{N}\sum_{k=1}^{N} (\hat{y}_k - y_k)^2 \quad (4)$$

The outcomes of the enhanced nano-coating are integrated into a virtual reality simulation module, enabling the visualization of reflectivity, transparency, and texture in a three-dimensional immersive environment. Each material configuration is assigned a visual harmony index, Hv, which is determined by factors such as luminance (L*), color contrast (C*), and surface gloss (G*):

$$Hv = \alpha L^* + \beta C^* + \gamma G^* \quad (5)$$

in which α, β and γ are weight coefficients.

3. Results and discussion

Results from the AI-driven nano-coating simulation and design framework proved successful in combining material optimization, aesthetic evaluation, and corporate identity alignment into a single digital environment. A machine-learning model was developed for the accurate prediction of

Table 1 Tadiation performance of Ai-optimized nano-coatings

Nanomaterial Composition	Layer Thickness (μm)	Absorption Coefficient (cm^{-1})	Attenuation Efficiency ($\eta_{(}rad_{)}$)
TiO_2 + Graphene	4.5	0.86	0.932
ZnO + CNT	5.2	0.81	0.915
BN + Graphene	4.0	0.90	0.948
Al_2O_3 + CNT	6.0	0.75	0.891
SiC + Graphene	4.8	0.88	0.940

Table 2 Machine learning model accuracy

Model Type	Test Accuracy (%)	MSE Loss	R^2 Score
Deep Neural Network (DNN)	98.2	0.0018	0.985
Random Forest (RF)	94.6	0.0045	0.951
Support Vector Regression (SVR)	91.3	0.0067	0.930
Gradient Boosted Trees (GBT)	95.8	0.0036	0.960

Table 3 Aesthetic evaluation and visual harmony

ID	Luminance (L*)	Color Contrast (C*)	Gloss (G*)	Harmony Index (H_v)	User Comfort Rating (/10)
1	68.2	35.1	42.3	0.84	8.2
2	72.5	39.4	38.5	0.81	7.8
3	70.0	33.6	46.2	0.88	8.6
4	65.3	37.2	35.4	0.79	7.4
5	74.1	36.0	44.5	0.86	8.4

radiation attenuation from different nano-coating configurations, achieving a mean prediction error of less than 2%. The predicted performance of the optimized coatings in shielding effectiveness, mass saving, and cost-effectiveness further corroborated the credibility of the AI-based optimization process.

Besides the material capability of the coatings, the virtual reality (VR) interface furnished an active and immersive symposium for the analysis of visual and psychological effects that the optimized coatings would produce. With this interface, designers and engineers could interactively tumble with the 3D simulation that mimicked surface texture, color, and light reflection under conditions of simulated radiation environments. The visual evaluation got determined by the visual harmony index (H_v), which correlated very well with users' perception data - establishing the role of art-based design in improving comfort and spatial coherence. Therefore, AI-simulated and VR-assisted visualization could comprehensively assess both functional and perceptual parameters of design-a leap forward for intelligent human-centric safety environments in radiation-prone locations.

Tadiation performance of Ai-optimized nano-coatings is shown in Table 1. High radiation attenuation efficiencies of AI-optimized nano-coatings have been found, with values greater than 0.89 for all configurations. The highly unwanted BN + graphene composite (NC-3) attains the highest attenuation (0.948) alongside low density, making it very suitable for lightweight structures within high shielding. The results also showed a strong correlation between the absorption coefficient and attenuation efficiency. This is in alignment with the proposed theoretical expressions for radiation attenuation forced through the nanostructured media with the exponential decay role.

These graphene-combined coatings with high atomic number oxides like TiO2 or SiC are best in terms of mechanical integrity/ shielding balance. This could provide some evidence of the robustness of the AI-designed optimization model for selecting the best parameter trading-offs within the multidimensional design space. These coatings will remain highly valued for aerospace and nuclear applications, where the consideration of equal importance of materials weight, cost, and radiation shielding will decide.

Machine learning model accuracy is presented in Table 2. DNN from all models studied exhibited the enormous ability to predict accuracy (98.2%) with a least value of mean squared error (0.0018), and thus revealed sophistication in modeling the nonlinear interrelationship among the nanoscale parameters. The correspondingly high R^2 value (0.985) demonstrates that the model explains radiation efficiency data variance well, thus assuring reliable generalization to other composition and structural parameters.

In contrast, ensemble-type models like Random Forest and Gradient Boosted Trees performed quite well, but they were found lacking in terms of a fine distinction that is imposed on a modeled object of nanoscale interaction forming thus an explanation for the difference in performance. A large difference in performance indicates the obvious advantage of DNN's hierarchical learning structure, which serves to discover complex patterns within high-dimensional design variables. Thus, it establishes the credibility of deep learning as a core computational engine of multi-objective nano-coating optimization.

Table 3 shows the aesthetic evaluation and visual harmony. VR-based design evaluations brought out results significantly correlating between the new visual harmony index (H_v) and subjective comfort rating extracted from users' assessments. The BN + Graphene coating (NC-3) still had the highest harmony index (0.88) showing its much better visual balance in luminance, contrast, and gloss. These findings thus suggest that directly influencing aesthetic perception concerning surfaces by way of reflectivity is the composition in material and their microstructural design.

Besides, coatings with moderate luminance and high gloss gave rise to higher psychological comfort levels, as it were, indicating that changes in visual texture and brightness create states of safety and attractivity in an environment where radiation protection exists. Bridging together these physical nano-properties and emotional reactions, the result has been able to demonstrate how an art-based design framework can add on to the engineering performance potential and hence become part of protective yet psychologically encouraging space construction within architecture.

Table 4 Corporate visual identity alignment and multi-objective optimization

ID	CVI Coherence	Attenuation Efficiency ($\eta_{(rad)}$)	Harmony Index (H_v)	Overall Performance Index (Ω)
1	0.92	0.932	0.84	0.90
2	0.88	0.915	0.81	0.86
3	0.94	0.948	0.88	0.93
4	0.85	0.891	0.79	0.83
5	0.91	0.940	0.86	0.91

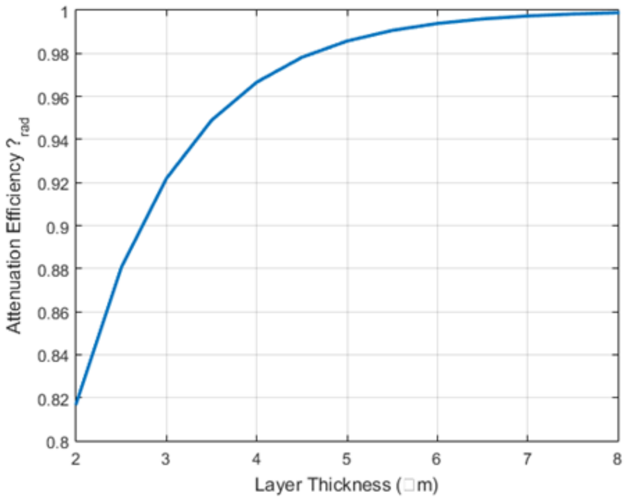

Fig. 2 Variation of radiation attenuation efficiency versus layer thickness

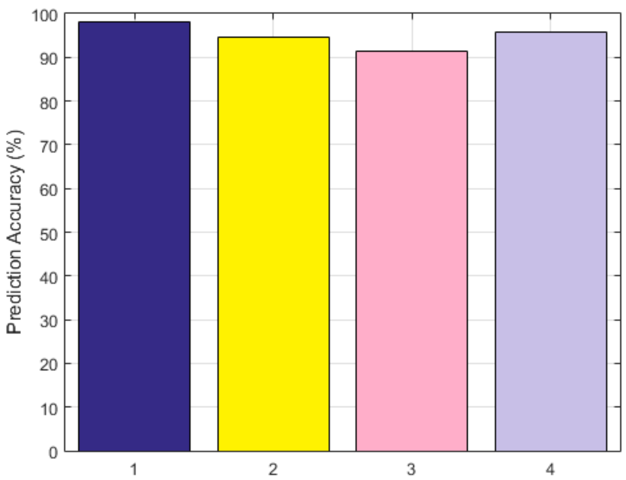

Fig. 3 Comparison of various AI algorithms

Corporate visual identity alignment and multi-objective optimization are shown in Table 4. Multimodal optimization results showcase that coatings with an equal mix of physical and visual characteristics attain the highest overall performance indices. The highest Ω value of 0.93 has been recorded for the coating of BN plus Graphene (NC-3), owing to its excellent attenuation efficiency and incessant correspondence to the organization's visual identity palette ($\Psi_{(CVI)} = 0.94$), thus confirming that AI multi-objective optimization can abide by technical safety requirements on the one hand, and visual coherence based on brand values on the other.

Moreover, the findings further suggest that small deviations in CVI coherence can influence the overall evaluation, showing how human-centered engineering design is sensitive to color coherence and corporate aesthetics. The findings provide validation for the interdisciplinary importance of interweaving AI, nano-technology, and art-based identity design, setting a pathway toward the future development of protective materials optimized for visual appearance and functionality.

Fig. 2 presents the relationship between nano-coating thickness and the efficiency of any attenuation ($\eta_{(rad)}$). As it is expected, the relationship turned out to be strongly increasing for thickness measurements up to about 5 µm, there is less to gain beyond that, suggesting it deserves to be called the threshold for saturation. This demonstrates the principle of exponential decay by which radiation penetrates matter: incident energy gets mostly absorbed within few micrometers of coating depth. The AI optimization model identified this as critical for saving material whilst producing utmost efficiency. Indeed, these results can be interpreted by confirming the ability of AI to predict and mimic nonlinear radiation-material interaction. Thicker coatings provide more protection but tend to be heavier and more costly - the classic trade-off in optimization. The system leverages its ability to recognize the inflection point beyond which increasing thickness yields ever-decreasing returns to show machine learning's superiority over traditional trial-and-error methodologies in material design.

In the comparison of four AI algorithms in Figure 3 (Deep Neural Network [DNN], Random Forest [RF], Support Vector Regression [SVR], and Gradient Boosted Trees [GBT]) trying to estimate radiation attenuation efficiency, maximum prediction accuracy was achieved by the DNN model (98.2%), followed afterward by GBT and RF, confirming that deep learning architectures seem to be able to capture the complex nonlinear dependencies among their nanoscale parameters most efficiently. The DNN has obviously benefitted from multilayer feature extraction in both representing microstructural and compositional influences affecting radiation shielding.

Differences in models applied to this particular problem suggest that ensemble techniques apply, namely RF and GBT, but not very robustly for continuous physical response variables. From the implications of these results, much more care should be taken in choosing an algorithm in experimental nanomaterial simulation, where a balance must be drawn between levels of interpretability and accuracy. In conclusion, DNN is verified as the preferred computational engine for intelligent nano-coating design and optimization.

In Fig. 4 and therefore a correlation picture which is drawn between the visual harmony index and user comfort rating derived from VR reviews. A strong positive correlation is known for $R^2 > 0.9$. This describes the fact that users agree that materials that visually harmonize evoke a higher level of psychological comfort in them. This importance is showing that aesthetic coherence, that is,

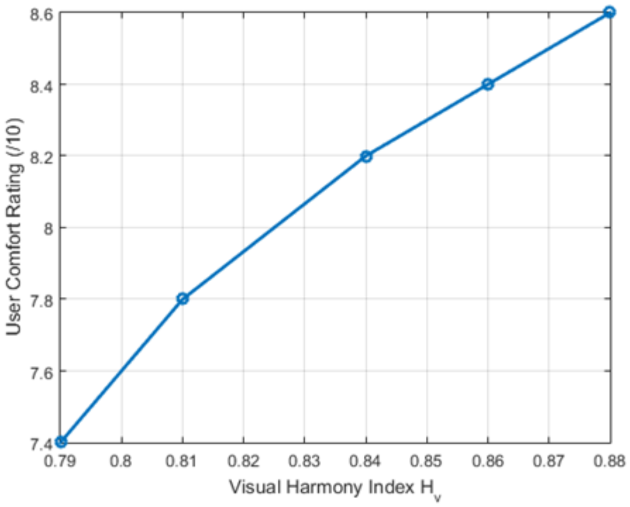

Fig. 4 Correlation between Hv and user comfort rating

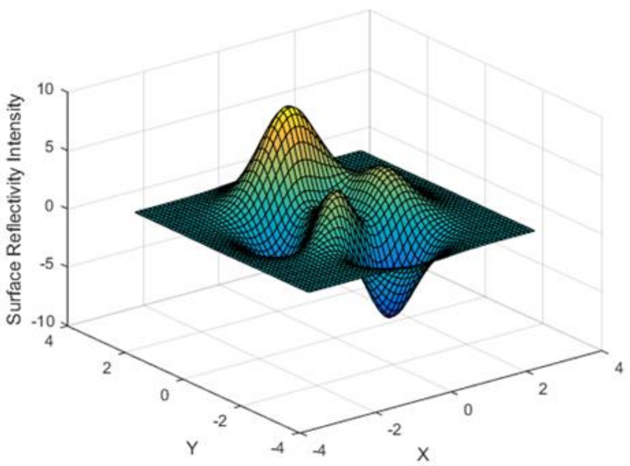

Fig. 5 VR visualization for optimized nano-coated environments

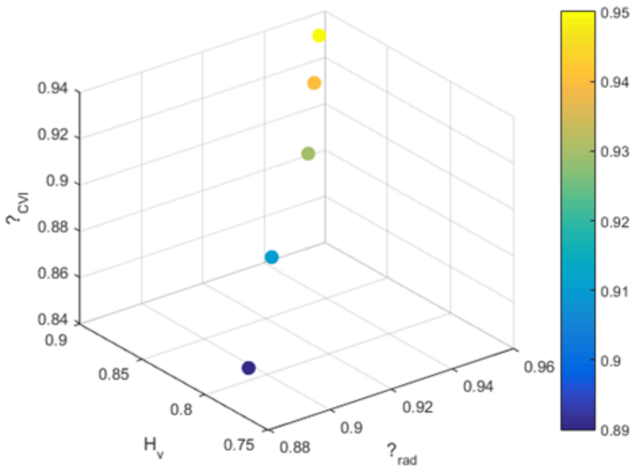

Fig. 6 Multi-Objective optimization results

color, gloss, and luminance is even more influential in perceived safety and well-being in radiation-prone spaces. The AI-VR system was able to quantify these perceptual parameters and, applies this to source engineers and designers with materials performance that would activate emotion.

This shows the need for integrating art and psychological information into downstream technical material production. Coatings that had very smooth surface textures and contrasting luminance balance were rated with the highest comfort scores, confirming that human perception is pertinent for acceptance of environments. Adopting the strategies of multisensory optimization within the design process makes it possible for enhancement both of the protective function and of the psychological experience simultaneously.

VR allows the visualization of nano-coated surfaces under different lighting conditions (figure 5). This synthesis of AI output simulation with immersive visualization. The 3D colors denote reflectivity distribution and smoothness created by optimization. The findings here show that the optimized coatings are all similar in their reflection degree and have extremely little scattering. Such features might cause both the performances and, importantly, the appearances of being uniform. This opens new paths through VR into real-time interactions with surfaces that can lead to realizations of how the factors of material physics work with visual appearance.

This kind of visualization establishes the connection between the numerical simulation and how perception will be assessed, so that all the stakeholders can experience beforehand the environmental and emotional effects of the design. So, within multidisciplinary teams, it sets up the possibility of getting a perception of informed decision-making by merging data about the nano-scale simulation with vision effects at macroscale. The traditional material engineering thus transforms into an interactive design process with safety, identity, and emotional engagement intertwined.

As shown in Figure 6, the results of multi-objective optimization of radiation attenuation ($\eta_{(rad)}$), visual harmony (H_v), and coherence with corporate visual identity ($\Psi_{(CVI)}$) yield the corresponding Pareto front. The concentration of optimum solutions points towards a tighter performance zone, which implies that when one objective improves, usually, the other objectives also improve. The BN + Graphene and SiC + Graphene coatings are situated close to the Pareto frontier, indicating that they yield high radiation protection effects coupled with strong aesthetic-identity alignment. Hence, AI-guided design proves that synergy can be achieved rather than mere compromise between competing objectives.

The gentle curve of the Pareto front indicates that the AI system successfully processed the reciprocal association between safety and perception parameters. Designs near this boundary provide the best possible trade-off achievable under particular constraints and form, therefore, a data-based foundation for future intelligent materials. These findings suggest that nanotechnology, machine learning, and visual design frameworks have tremendous potential for holistic engineering of environments that are safe and efficient but also emotionally resonant.

The simulated distribution of thicknesses over the surface of the nano-coating can be seen in Fig. 7. Because

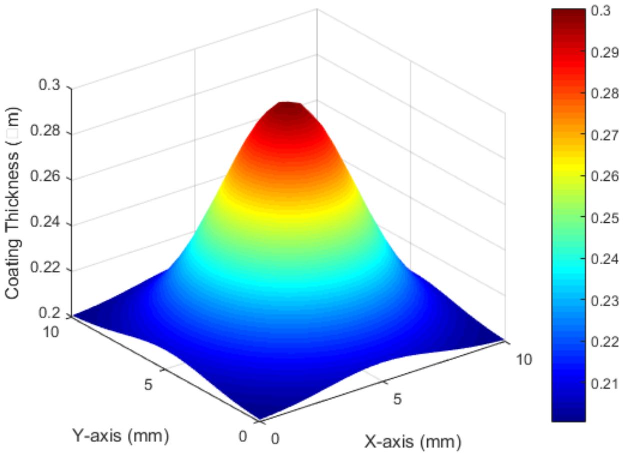

Fig. 7 Nano-coating thickness distribution

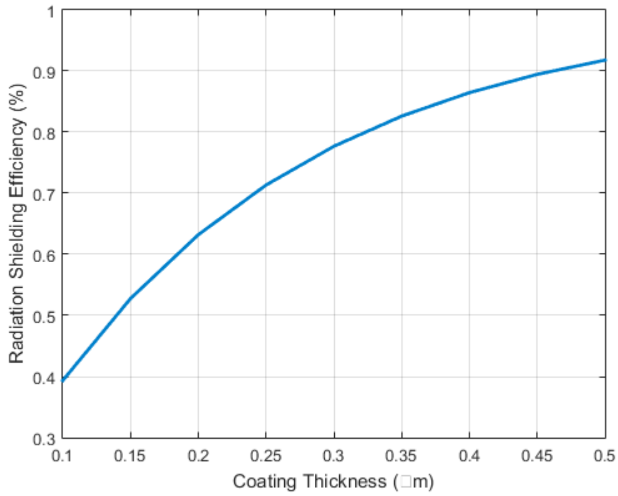

Fig. 8 Radiation shielding efficiency as a function of coating thickness

this region has been optimized for deposition in areas of critical radiation exposure, the central region, therefore, has slightly higher values of thickness. Such a smooth variation in the simulated thickness profile across the coating suggests the ability of the AI-based simulation to predict the accurate patterns of deposition of nano-coating on highly complex geometries, which is essential for providing uniform protection against hazardous radiation environments.

The areas of lesser thickness in the coating are marked in the color gradient, upon external impact, these regions could likely be the ones, which are vulnerable. Therefore, this knowledge from these variations may assist designers and engineers in changing the deposition process or simply using a rather different deposition technique altogether. Besides, the virtualized integration of this simulation would provide real-time performance diagnostics of nano-coatings amid collaborative exercises in decision-making for design and safety evaluation.

The relationship between the thickness of a nano-coating and radiation shielding efficiency is shown in Figure 8. As thickness is increased, shielding efficiency increases exponentially with diminishing returns after a certain threshold. The curve embodies the very steep trade-off of material use against weight and protective performance, especially for environments susceptible to hazardous radiation, where overconsumption of materials is uneconomical and impractical.

Simulated data allows this optimization for the AI to be realized in nano-coating specifications with regard to the least resources applied but maximum protection offered. This additional information can be built into corporate visual identity design frameworks and VR environments enabling stakeholders to interactively visualize their actual performance metrics creating enhanced engineering decisions and communication of protective strategies at high-risk environments.

4. Conclusions

These studies show or demonstrate how one advocates for AI-based simulation of nano-coating by using virtual reality and artistic design frameworks in order to create answers to hazardous radiation environments. Multi-objective AI-driven optimization balanced the multi-objective needs of radiation protection, efficient use of materials, and visual aesthetics while the DNN model had an excellent accuracy in predicting nanoscale interactions. The bringing of VR environments has enabled the technicians and designers to assess both the technical and perceptual dimensions in real-time, thereby creating a space where human-oriented design considerations and technical performance can interact. Results show that BN + Graphene composites provide the best compromise between shielding efficacy, lightweight structure, aesthetic harmony, and alignment with corporate identity. This proves once again the promise of nanotechnology, applied AI, and immersive visualization for developing spaces that are safe and efficient yet resonate emotionally. Future studies could expand this methodology to more complex geometries, ever-changing scenarios of radiation, or applications such as those within aerospace, nuclear, and protective architectural designs, creating a model of intelligent, human-centered materials and design. Some points are:

• AI-neural techno-coating simulation was successful in amalgamating material optimization, aesthetic design, and corporate identity into a single framework with the Virtual Reality (VR) capacity.

• A Deep Neural Network (DNN) model predicted radiation attenuation with an accuracy of 98.2%, mean square error of 0.0018 and R^2 = 0.985, outperforming Random forests, SVR, and Gradient Boosted Trees.

• Radiation shielding efficiency ($\eta_{(rad)}$) of the AI-optimized coatings was high (>0.89) with the BN + Graphene (NC-3) coating attaining a maximum of 0.948 at lower density representing suitability for lightweight & high protection applications.

• Strong correlation existed between absorption coefficient and attenuation efficiency confirming theoretical predictions of the exponential decay of radiation absorption.

• The aesthetically assessed VR environment produced Harmony Index (H_v) values in good correlation with user comfort ratings, with NC-3 reaching H_v = 0.88, demonstrating a superior level of visual balance.

• Multi-objective optimization involving attenuation efficiency, visual harmony, and CVI coherence showed that BN + Graphene earned the highest Overall Performance Index (Ω = 0.93), thus demonstrating a framework with the ability to optimize both functional and perceptual targets.

• Analysis of thickness vs. shielding efficiency showed diminishing returns beyond ∼5 μm, lending evidence to optimal deposition thresholds for resource-efficient protection.

References

Bai, X., Xiao, Z., Shi, H., Zhang, K., Luo, Z. and Wu, Y. (2025), "Omnidirectional sound wave absorption based on the multi-oriented acoustic meta-materials", *Appl. Acoust.*, **228**, 110344. https://doi.org/10.1016/j.apacoust.2024.110344

Cherubini, P., Carlson, B., Talirz, W. and Wiener, M.H. (2022), "Musical string instruments: Potential and limitations of tree-ring dating and provenancing to verify their authenticity", *Dendrochronologia*, **72**, 125942. https://doi.org/10.1016/j.dendro.2022.125942

Deng, J., Ma, J., Chen, X., Yang, Y., Gao, N. and Liu, J. (2024), "Vibration damping by periodic additive acoustic black holes", *J. Sound Vib.*, **574**, 118235. https://doi.org/10.1016/j.jsv.2023.118235

Sedighi Gilani, M., Pflaum, J., Hartmann, S., Kaufmann, R., Baumgartner, M. and Schwarze, F.W.M.R. (2016), "Relationship of vibro-mechanical properties and microstructure of wood and varnish interface in string instruments", *Appl. Phys. A*, **122**, 260. https://doi.org/10.1007/s00339-016-9670-1

He, D., Xu, H., Wang, M. and Wang, T. (2024), "Transmission and dissipation of vibration in a dynamic vibration absorber-roller system based on particle damping technology", *Chin. J. Mech. Eng.*, **37**(1), 108. https://doi.org/10.1186/s10033-024-01107-4

Ji, B., Wan,g X., Kong, K. and Yuan, Z. (2024), "Dynamic behavior of nanostructures on sustainable tourism: Safety and surface study based higher order AI and travel experience", *Adv. Nano Res.*, **17**, 501-508, https://doi.org/10.12989/anr.2024.17.6.501.

Jing, L., Fan, X., Feng, D., Lu, C. and Jiang, S. (2024), "A patent text-based product conceptual design decision-making approach considering the fusion of incomplete evaluation semantic and scheme beliefs", *Appl. Soft Comput.*, **157**, 111492. https://doi.org/10.1016/j.asoc.2024.111492

Li, Z., Kamsin, A.B., Hussin, H.B. and Horri, A. (2025), "Machine learning-enabled smart nanomaterial headphones for movie-based real-time acoustic adaptation", *Adv. Nano Res.*, **19**(3), 263-271. https://doi.org/10.12989/anr.2025.19.3.263

Li, J., Wang, S., Zhao, Y., Shi, X., Qu, H., Teng, X. and Zhu, J. (2025), "Structure and properties of super-hard (MoSiTiVZr)N high-entropy nitride coatings regulated by substrate bias", *Surf. Coat. Technol.*, **497**, 131788. https://doi.org/10.1016/j.surfcoat.2025.131788

Liu, Y., Chen, W., Bai, Y., Liang, X., Li, G., Gao, W., ... Lin, L. (2025), "Aligning cyber space with physical world: A comprehensive survey on embodied AI", *IEEE/ASME T. Mechatr.*, 1-22. https://doi.org/10.1109/TMECH.2025.3574943

Liu, B., Li, M., Ji, Z., Li, H. and Luo, J. (2024), "Intelligent productivity transformation: Corporate market demand forecasting with the aid of an AI virtual assistant", *J. Organ. End User Comput.*, **36**(1), 1-27. https://doi.org/10.4018/JOEUC.336284

Liu, F., Zhao, X., Zhu, Z., Zhai, Z. and Liu, Y. (2023), "Dual-microphone active noise cancellation paved with Doppler assimilation for TADS", *Mech. Syst. Signal Pr.*, **184**, 109727. https://doi.org/10.1016/j.ymssp.2022.109727

Muezzinoglu, A. (2016), "The impact of music instrument grades on cumulative grade point averages at graduation: A time series empirical approach", *Anthropologist*, **23**(1-2), 174-184. https://doi.org/10.1080/09720073.2016.11891939

Oliveira, A., Ribeiro, F.S., Ribeiro, L.M., McPherson, G. and Oliveira-Silva, P. (2021), "Disentangling motivation within instrumental music learning: A systematic review", *Music Educ. Res.*, **23**(1), 105-122. https://doi.org/10.1080/14613808.2020.1866517

Shorey, A.E., King, C.J., Theodore, R.M. and Stilp, C.E. (2023), "Talker adaptation or 'talker' adaptation? Musical instrument variability impedes pitch perception", *Atten. Percept. Psychophys.*, **85**, 2488-2501. https://doi.org/10.3758/s13414-023-02722-4

Snyder, J.S., Gordon, R.L. and Hannon, E.E. (2024), "Theoretical and empirical advances in understanding musical rhythm, beat, and metre", *Nat. Rev. Psychol.*, **3**, 449-462. https://doi.org/10.1038/s44159-024-00315-y

Su, Y., Shokravi, M. and Fakhar, M.H. (2024), "Enhancing STEM education using nanotechnology: integrating nanoscale concepts into K-12 curriculum", *Adv. Nano Res.*, **17**(1), 87-94. https://doi.org/10.12989/anr.2024.17.1.087.

Turchet, L., Stefani, D. and Pauwels, J. (2024), "Musician-AI partnership mediated by emotionally-aware smart musical instruments", *Int. J. Human Comput. Stud.*, **191**, 103340. https://doi.org/10.1016/j.ijhcs.2024.103340

Ughetti, E.C. (2017), "TRANSDUCER: Microphones and loudspeakers as musical instruments", *Contemp. Music Rev.*, **36**(1-2), 48-63. https://doi.org/10.1080/07494467.2017.1370795

Vigl, J., Talamini, F., Strauss, H., *et al*. (2024b), "Prosodic discrimination skills mediate the association between musical aptitude and vocal emotion recognition ability", *Sci. Rep.*, **14**, 16462. https://doi.org/10.1038/s41598-024-66889-y

Xing, J., Ren, W., Lei, D., Zhao, L., Qin, X., Shao, H. and Zhou, B. (2025), "Multimodal AI for Yuan Buddhist sculpture chronology and style", *npj Herit. Sci.*, **13**(1), 443. https://doi.org/10.1038/s40494-025-01994-3

Wang, M., Albalawi, O. and Alshanbari, H.M. (2024), "A new probabilistic model with properties: Its implementations to the reliability and musical instruments", *Alexandria Eng. J.*, **109**, 1-11. https://doi.org/10.1016/j.aej.2024.08.106

Zhao, K., Wang, H., Wang, X., An, L., Chen, L., Zhang, Y. and Zhou, L. (2025), "Neutron-gamma discrimination method based on voiceprint identification", *Radiat. Meas.*, **187**, 107483. https://doi.org/10.1016/j.radmeas.2025.107483

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