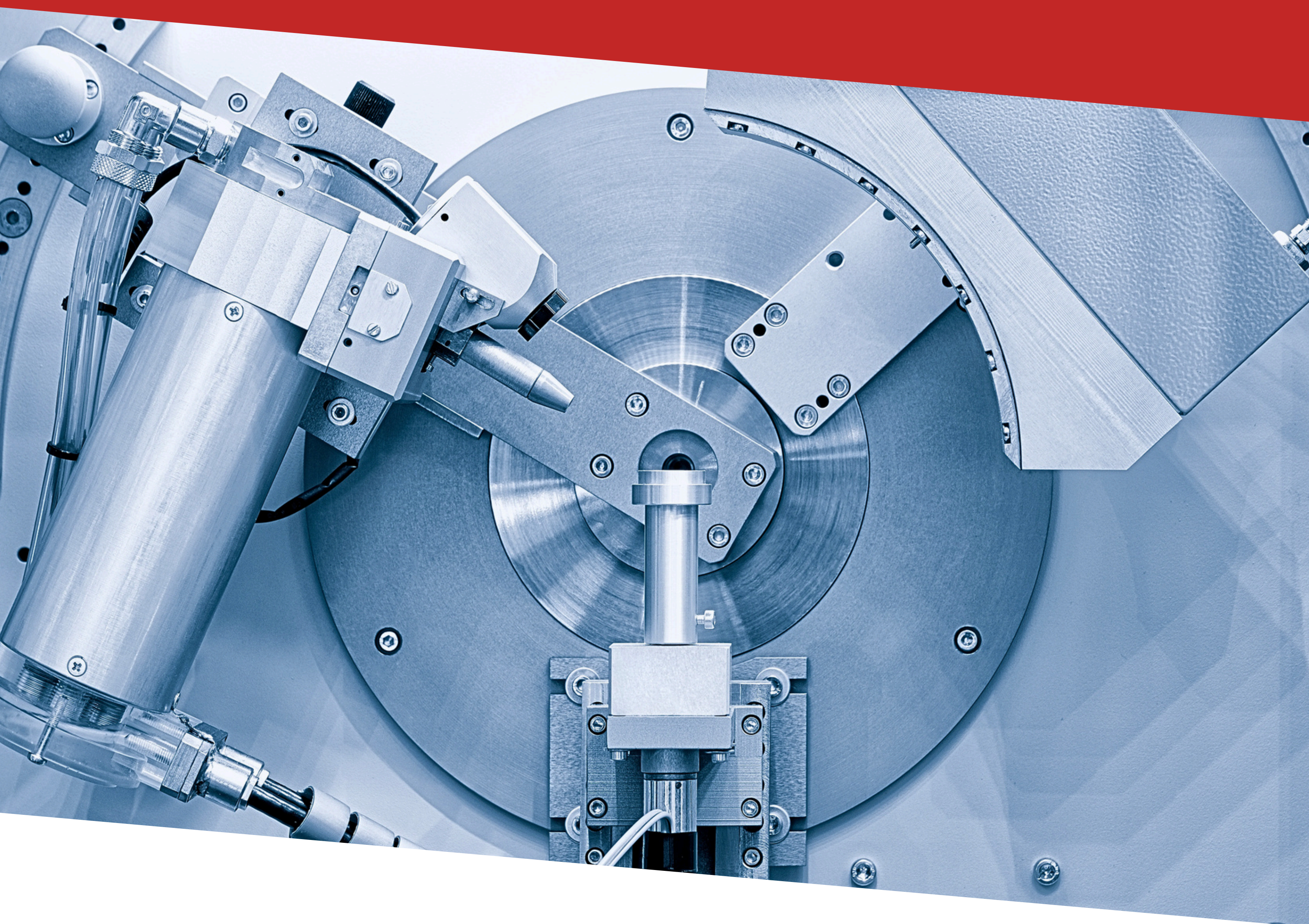
Industry Focus



Non-Destructive Testing

An exclusive collection featuring top-tier articles, visionary experts, and essential industry insights

AZO NETWORK sponsored by EVIDENT

TABLE OF CONTENTS

Foreword

Welcome to the latest edition of our Industry Focus eBook, where we delve into the constantly evolving **non-destructive testing (NDT) field.** NDT remains essential for ensuring safety, reliability, and performance as industries advance in material science, infrastructure maintenance, and energy storage. It does so without compromising the integrity of the structures and components being examined.

This eBook emphasizes how cutting-edge technologies, such as artificial intelligence, robotics, and advanced imaging techniques, are transforming the field of non-destructive testing (NDT). With AI-driven material diagnostics and the emergence of innovative ultrasonic and optical methods, the future of non-invasive testing is more precise and efficient than ever before.

Discover how **Harnessing AI and Machine Learning for Advanced Materials Testing** explores the impact of intelligent algorithms on the accuracy and efficiency of material inspections. In **Transforming Infrastructure Maintenance with AI-Driven Robotic Inspection**, we explore how autonomous systems revolutionize large-scale asset monitoring.

Meanwhile, emerging imaging solutions are paving the way for breakthroughs. **Research Reveals Printable Image Sensor for Non-Destructive Testing** introduces a novel approach to NDT imaging, while **Ultrasonic Imaging with Micro-Metalenses for Advanced Material Diagnostics** showcases the potential of next-generation acoustic imaging technologies.

As energy storage systems become more essential, ensuring battery health and longevity is critical. **Ultrasonic Techniques for Lithium-Ion Battery Diagnostics** examines the latest advancements in assessing battery performance and safety. Rounding out our discussion, **From Lasers to Lenses: The Role of Optical Science in NDT** highlights the invaluable contributions of optical technologies in enhancing precision and reliability across various NDT applications.

This collection of articles provides an insightful overview of the latest advancements shaping the future of non-destructive testing (NDT). It highlights the contributions of researchers, engineers, and innovators who continually push the boundaries of what is achievable in material diagnostics and structural evaluation.

As you delve into these insights, we hope you find inspiration in NDT's evolving capabilities and significant impact across various industries. Thank you for joining us on this journey into the future of testing and inspection.

The Editorial Team

AZO NETWORK

Harnessing AI and Machine Learning for Advanced Materials Testing

Materials testing is critical in product development and manufacturing across various industries. It ensures that products can withstand tough conditions in their intended applications.

Image Credit: Gorodenkoff/Shutterstock.com

Researchers and engineers evaluate the properties and behavior of materials used in buildings, bridges, airplanes, and other structures to ensure their safe, reliable, and efficient performance under various conditions.

In this regard, Artificial intelligence (AI) and machine learning (ML) are revolutionizing traditional testing methods, which can be time-consuming, expensive, and often limited in scope.[1, 2]

AI and Machine Learning in Materials Testing

Enhancing the Accuracy of Materials Testing with AI and ML

AI algorithms improve the accuracy and efficiency of materials testing by processing massive datasets, identifying complex patterns, and making precise predictions.

For instance, AI helps analyze vast amounts of data generated during testing, including sensor measurements, images, and historical records, identifying patterns and correlations within this data.[1, 2]

AI models can be trained to predict critical material properties, such as mechanical strength, fatigue resistance, and corrosion susceptibility, allowing researchers to optimize material selection for specific applications without extensive physical testing.[1, 2]

Similarly, repetitive tasks like data analysis and report generation can be automated using AI and ML, freeing researchers to focus on complex problem-solving and material design while significantly reducing time and costs.

Using AI to Predict Material Properties and Behaviors

AI models are being used to predict a material's yield strength, tensile strength, and ductility based on its composition and processing history.

For instance, a recent study explored AI to enhance non-destructive testing (NDT) methods for assessing the compressive strength of concrete. Traditional NDT methods like the rebound hammer (RH) and ultrasonic pulse velocity (UPV) tests often produce less accurate results than destructive testing.[3]

The study applied AI models, including adaptive neural fuzzy inference systems (ANFIS), support vector machines (SVM), and artificial neural networks (ANNs), to predict concrete strength more precisely. Analyzing data from 98 *in-situ* concrete samples, the AI models demonstrated significantly improved accuracy over conventional statistical methods.[3]

ML techniques can also analyze data from various testing methods, like tensile and fatigue testing, to predict material behavior under different stress conditions, enabling materials with tailored properties for specific applications.

Machine Learning in Developing NDT Methods

NDT is crucial for evaluating materials without causing damage. Machine learning algorithms can analyze complex images and signals generated by NDT methods like X-Ray radiography and ultrasonic testing to detect defects with higher accuracy and sensitivity than traditional methods.[3, 4]

Researchers are developing AI-powered systems to analyze acoustic emissions during stress testing to identify potential cracks or damage in materials. For instance, a 2019 study developed AI-powered systems to analyze acoustic emissions during stress testing of fiber-reinforced composite structures. They employed artificial neural networks to enhance the prediction of local stress exposure and failure in these materials.

The system predicted failure loads by detecting AE signals, which are ultrasonic stress waves released during internal displacements like crack growth. This approach allowed accurate prediction of structural integrity without the need for full-scale destructive testing, significantly reducing the time and costs associated with large-scale structural assessments.[5]

In another 2019 study, researchers explored the application of machine learning for NDT to detect hidden material damage using low-cost external sensors. The study involved a multi-domain simulation to evaluate various ML models and algorithms, including support vector machines, neural networks, and decision trees.[6]

The researchers demonstrated the effectiveness of these models in predicting internal damages from noisy sensor data by employing a mass-spring network to simulate the device under test.

While deep learning models are popular, they found that simpler ML techniques like decision trees and single-layer perceptrons can also provide robust and accurate predictions, sometimes more efficiently.

The study highlights the potential of integrating ML with inexpensive sensors for real-time structural health monitoring and damage detection.[6]

Companies Integrating AI in Materials Testing Systems

Several companies are integrating AI and ML into their materials testing systems. For example, Baker Hughes, an oilfield services company, utilizes AI to analyze data from downhole sensors, optimize drilling operations, and ensure well integrity.[7]

Similarly, Siemens Simcenter Culgi software uses machine learning to analyze past simulations and real-world data, allowing engineers to predict product performance quickly and accurately.[8, 9]

Integration Challenges and Solutions

AI and ML hold great potential for materials testing but also present challenges. Integrating AI with existing testing frameworks requires significant technological and methodological adaptations.

Training effective AI models require large amounts of high-quality data, and ensuring data accuracy is imperative since inaccurate data may generate false predictions. Understanding how AI models arrive at their predictions can also be difficult, necessitating interpretability to build trust in AI-driven materials testing.[2,10,11]

These challenges can be addressed through continuous research, standardized data format development, and collaboration between different disciplines.[10, 11]

Future Outlooks

AI is expected to play a significant role in material testing in the future. AI systems for real-time monitoring and predictive maintenance of materials in service can enable proactive interventions before failures occur. Additionally, integrating AI with Internet of Things (IoT) devices offers the potential for continuous, *in-situ* materials testing and monitoring.[10]

AI in materials testing will likely influence industry standards and testing methodologies, evolving them to incorporate AI-driven predictive models, leading to more efficient and accurate evaluation processes. This shift will enhance industries' ability to develop and deploy advanced materials.

References and Further Reading

1. Huang, G., Guo, Y., Chen, Y., Nie, Z. (2023). Application of machine learning in material synthesis and property prediction. *Materials*. doi.org/10.3390/ma16175977
2. Badini, S., Regondi, S., Pugliese, R. (2023). Unleashing the power of artificial intelligence in materials design. *Materials*. doi.org/10.3390/ma16175927
3. Ngo, TQL., Wang, YR., Chiang, DL. (2021). Applying artificial intelligence to improve on-site non-destructive concrete compressive strength tests. *Crystals*. doi.org/10.3390/cryst11101157
4. Yella, S., Dougherty, MS., Gupta, NK. (2006). Artificial intelligence techniques for the automatic interpretation of data from non-destructive testing. *Insight-Non-Destructive Testing and Condition Monitoring*. doi.org/10.1784/insi.2006.48.1.10
5. Sause, M. G., Schmitt, S., Hoeck, B., Monden, A. (2019). Acoustic emission based prediction of local stress exposure. *Composites Science and Technology*. doi.org/10.1016/j.compscitech.2019.02.004
6. Bosse, S., Lehmhus, D. (2019). Robust detection of hidden material damages using low-cost external sensors and Machine Learning. *Proceedings*. doi.org/10.3390/ecsa-6-

06567

7. Baker Hughes. (n.d). *Combining Baker Hughes energy technology expertise with C3 AI technology.* [Online] Baker Hughes. Available at: https://www.bakerhughes.com/bhc3#:~:text=BHC3%E2%84%A2 (Accessed on June 6, 2024)
8. Siemens (n.d). *AI in Simcenter Simulation*. [Online] Siemens. Available at: https://webinars.sw.siemens.com/en-US/ai-in-simcenter-simulation/ (Accessed on June 6, 2024)
9. Siemens (n.d). Simcenter Culgi software. [Online] Siemens. Available at: https://plm.sw.siemens.com/en-US/simcenter/fluids-thermal-simulation/culgi/ (Accessed on June 6, 2024)
10. Yazdani-Asrami, M., Sadeghi, A., Song, W., Madureira, A., Murta-Pina, J., Morandi, A., Parizh, M. (2022). Artificial intelligence methods for applied superconductivity: material, design, manufacturing, testing, operation, and condition monitoring. *Superconductor Science and Technology*. doi.org/10.1088/1361-6668/ac80d8
11. Himanen, L., Geurts, A., Foster, AS., Rinke, P. (2019). Data-driven materials science: status, challenges, and perspectives. *Advanced Science*. doi.org/10.1002/advs.201900808

How SA Recycling Improved Scrap Sorting Efficiency with Vanta™ Handheld XRF

SA Recycling is an organization at the forefront of the metal recycling and processing industry. This article looks at the company's use of Evident Scientific's Vanta™ handheld XRF analyzer at its facility in Montebello, California, and its impact on scrap sorting efficiency.

Image Credit: Evident Corporation (XRF / XRD)

The site's General Manager, Tog Valizada, discussed how the Vanta analyzer helps enable the accurate sorting of alloys and the identification of light elements throughout the facility.

Streamlining Scrap Sorting at SA Recycling

SA Recycling's facility in Montebello, California, processes approximately 3000 tons of ferrous scrap and 1.5 million pounds of nonferrous scrap every month. Several analyzers are used at this location, including one Vanta handheld XRF analyzer from Evident Scientific.

General Manager Tog Valizada of SA Recycling. Image Credit: Evident Corporation (XRF / XRD)

Tog highlights how the Vanta analyzer improves scrap sorting efficiency: *"The Vanta XRF analyzer is easy to use, and testing takes about three seconds. It's very quick. Our employees prefer that, especially when we're sorting through our alloys."*

Employees at the facility use the Vanta analyzer for receiving purposes daily. Tog reports that it is an important instrument on the buying side of the business when scrap is received and purchased.

In terms of shipping, the Vanta analyzer allows the organization's employees to read the light elements to confirm that scrap is shipped to the end user according to relevant specifications.

The instrument's SmartSort feature is a rapid sorting method for alloy analysis that automatically shortens or lengthens the test time depending on the material under analysis. This means that the Vanta analyzer tests until it has an exact match for a grade and determines whether to use one or two beams for the analysis.

This useful feature maintains accuracy and precision while saving time, even when light elements are present. For example, should the analyzer switch off testing in the first beam with light elements present in the grade, nominal chemistry will be displayed for any elements not analyzed via the second beam.

Tog elaborates on these benefits: *"Testing for light elements is important for us, and we leave the SmartSort feature on. That automatically lets us know if there's anything that shouldn't be in the chemistry. If something is not according to the spec, we can catch it during the processing, keep it, separate it, and make sure we don't ship it. It's very important and can save us a lot of money."*

SA Recycling must track back any material rejected at the mill, meaning that accurate sorting using the Vanta analyzer is key to saving on freight costs and the time and labor of sorting the materials a second time.

Benefits of Working with Evident Scientific

Tog also highlighted the advantages of Evident Scientific's local service and support, highlighting how these are key factors in the usefulness of the Vanta handheld XRF analyzer: *"One of the things I like, and why I prefer Vanta handheld XRF over other analyzers we're using, is having the relationship with the local rep who can help you,"*

These benefits all help contribute to a rapid return on investment (ROI) as Tog summarizes: *"The return on investment is very important. Before purchasing the Vanta XRF analyzer, we ran the numbers to make sure that with the money we're putting into the instrument, we'll be able to get it back in a short period of time."*

Acknowledgments

Produced from materials originally authored by Michelle Wright from Evident Scientific.

EVIDENT

This information has been sourced, reviewed and adapted from materials provided by Evident Corporation (XRF / XRD).

For more information on this source, please visit Evident Corporation (XRF / XRD).

Transforming Infrastructure Maintenance with AI-Driven Robotic Inspection

Inspecting the vast amount of infrastructure worldwide for potential faults is a time-consuming and costly process. With accelerating urban development, ensuring that buildings are safe is becoming increasingly complex and urgent.

Image Credit: Gorodenkoff/Shutterstock.com

AI, robotics, and other innovative Industry 4.0 technologies offer significant benefits in terms of time, efficiency, and cost savings for infrastructure maintenance. This article explores how AI-driven robotic inspection is transforming infrastructure inspection, monitoring, and maintenance.

How is Building Inspection Commonly Performed?

Regular inspection of structures for problems such as damage, stress cracking, and subsidence is crucial to ensure their safety. This process assesses the structural integrity of buildings, protecting the lives and livelihoods of residents and communities reliant upon them.

In the construction industry, several non-destructive testing (NDT) methods are employed for this critical purpose. NDT methods do not cause any harm to materials or structural components, making them vastly preferable to destructive methods. These types of inspection methods are also cost-effective and time-efficient.

Visual inspection is one of the most predominant types of NDT inspection methods in use today, and it is also one of the oldest. However, visual inspection only gives limited information on a building's structural soundness and cannot detect hidden defects such as corrosion, cracks, or voids.

Radiography testing uses X-Rays or gamma rays to reveal structural flaws, accurately detecting cracks, voids, and similar issues. However, interpreting the results of radiography testing is highly subjective. Eddy current testing is useful for conductive materials such as steel but cannot be applied to materials like concrete.

Ultrasonic testing is a highly effective NDT method for building inspection. It can detect poor-quality concrete, as acoustic waves travel more slowly through it than in high-quality concrete. Differences in transmission times can be interpreted to indicate the presence of structural flaws. However, in heavily reinforced concrete structures, interpreting ultrasonic testing results can be highly challenging.

Assessing the Magnitude of Infrastructure Challenges

Much of the world's infrastructure, including bridges, dams, and tunnels, is in need of inspection and repair. According to the American Society of Civil Engineers, in the US alone, before the Infrastructure Investment and Jobs Act—a bipartisan bill signed in 2021—there was an estimated backlog of repairs needed for the nation's bridges and roads, reaching $786 billion.

While NDT methods can provide valuable insights into the structural integrity of buildings and infrastructure, the challenges associated with standard inspection techniques in the construction industry underscore the necessity for innovative approaches that address many of the problems engineers face.

Utilizing AI-Driven Methods for Building Inspection

A multiscale robotic-driven approach to building inspection could significantly improve the efficiency of building inspection, ensuring that even minor defects do not become problematic in the future. Pre-screening structures to identify problem areas and continuously monitoring them would be an extremely powerful approach.

A research team at Drexel University has proposed an AI-driven robotic methodology for building inspection and defect monitoring. The proposed system employs precise, non-destructive laser scanning using robots, deep learning, and computer vision to detect even relatively minor faults within structures.

A high-resolution camera with stereo-depth capabilities feeds visual information to a convolutional neural network. Convolutional neural networks are currently employed in a plethora of applications across various industries, from facial recognition to detecting deepfake videos. This deep learning technology can identify even the finest discrepancies and patterns within data sets while interpreting data non-subjectively.

Convolutional neural networks and other AI-based deep learning and machine learning technologies require training on datasets. The neural networks employed in this system were trained on datasets comprising images of concrete structures and sample cracks. This allows the system to identify potential images of cracks within structures collected by the robots during laser scanning.

The neural network identifies regions of interest, which are then scanned by a robotic arm equipped with a line scanner, creating a three-dimensional digital image of the crack. At the same time, a LiDAR camera creates an image of the surrounding structure.

Both images are then stitched together to create a digital twin, which can be used to track crack growth in the structure between inspections. This provides engineers and building owners with crucial information, allowing them to better maintain the asset and repair any defects and damage before they pose a threat to life and livelihood.

Testing the System

The research team evaluated the proposed system's performance on a concrete slab with various defects. The results of this test demonstrated the system's high sensitivity and capability of detecting even the smallest fissures and cracks within a given structural component. Cracks less than a hundredth of a millimeter could be detected with high accuracy.

This AI-driven robotic inspection system comfortably outperforms current top-of-the-line cameras, sensors, and scanners, making it a potential building inspection tool that could overcome many of the challenges building managers and engineers face. This system would not completely negate the need for human inspectors, who would still retain the final call on maintenance.

Although this technology does not eliminate the need for human inspectors, it does reduce their workload, improving the overall performance and efficiency of routine building inspection, monitoring, and repair. It would also reduce potential oversight and mistakes caused by the subjective interpretation of datasets.

The Future

AI technologies, robotics, and automation are the future, set to revolutionize the performance of a plethora of critical tasks in multiple industries. The inspection and monitoring of the extensive global infrastructure and buildings for damage, which could lead to potentially fatal failures, stand to significantly benefit from the innovative technology developed by the research team at Drexel University.

The team intends to integrate the system into an uncrewed ground vehicle. This would create a highly efficient, comprehensive, autonomous inspection system. Real-world testing will be crucial in refining the system's capabilities and ensuring its robustness in the construction industry. According to the research team, collaboration with regulatory bodies and industry will be essential.

Other ongoing research methods are also being explored to provide innovative solutions for the construction industry and building inspection. These include drones, augmented reality, virtual reality, and cloud-based computing approaches. The future of automated AI- and Industry 4.0-driven building inspection is, therefore, a very exciting one.

References and Further Reading

Alamdari, A.G., Ebrahimkhanlou, A. (2024). A multi-scale robotic approach for precise crack measurement in concrete structures. *Automation in Construction.* doi.org/10.1016/j.autcon.2023.105215

Vital Building and Pest Inspections. (2023). *The Future of Building Inspections: Trends and Innovations.* [Online] Vital Building and Pest Inspections. Available at: https://vitalbuildinginspection.com.au/the-future-of-building-inspections-trends-and-innovations

World Construction Today. (2019). *5 Most Common Non-Destructive Testing Methods For Building Inspection*. [Online] World Construction Today. Available at: https://www.worldconstructiontoday.com/news/5-most-common-non-destructive-testing-methods-for-building-inspection/

Optimizing Automotive Components with Aluminum Coating Thickness Analysis

Every component plays a crucial role in the fast-paced world of automotive engineering, ensuring vehicles' performance, longevity, and safety.

Image Credit: Evident Corporation (XRF / XRD)

Aluminum is one of the most commonly used materials in automotive manufacturing. It is known for its material strength and light weight, with aluminum widely used to help create safer, lighter, and more fuel-efficient vehicles.

Aluminum is also an extremely versatile material. It is available in various alloys, each offering distinct mechanical properties, including good formability and a favorable strength-to-weight ratio.

Various properties make specific aluminum alloys more suited to specific automotive components, so a range of alloys will be used throughout the vehicle to ensure optimal performance.

Appropriate surface finishes and coatings also afford aluminum auto parts an additional layer of protection and performance, enhance the parts' aesthetic appeal, and offer corrosion protection, wear resistance, improved formability, and other environmental factors.

This also means that vehicle performance relies on using the most appropriate material and coating for each part.

Original equipment manufacturers (OEMs) follow a strict quality process, but automotive manufacturers must also confirm the integrity of any incoming materials from OEM suppliers to ensure quality control and assurance. This process includes verifying the coating thickness on aluminum OEM auto parts.

This article examines different types of aluminum finishes and coatings employed in the automotive industry, discussing each coating's economic and physical benefits. It also outlines an efficient quality control device suitable for measuring and analyzing aluminum coating thickness.

Types of Aluminum Finishes and Coatings for Automotive Components

Automotive components and parts employ several aluminum surface treatments and coating options.

Anodizing

Anodizing is a commonly employed surface treatment technique used with aluminum OEM auto parts. This technique involves creating an oxide layer on the part's surface, improving corrosion resistance while also allowing for various color options.

Anodized aluminum benefits from durability, improved hardness, and exceptional adhesion properties, making it an ideal treatment for wheels, exterior body panels, and other visible automotive components.

Non-Chromate Conversion Coatings

Non-chromate conversion coatings provide a useful protective layer on aluminum surfaces, improving their corrosion resistance while offering exceptional adhesion for subsequent paint applications.

Non-chromate conversion coatings are widely employed in critical applications such as aerospace parts and engine components.

A Ti/Zr coating (based on titanium and zirconium) remains one of the most popular examples of these coatings. This coating is achieved by spraying a chemical agent for a Ti/Zr treatment before rinsing and drying. Many automotive manufacturers have adopted this treatment because it improves the bonding durability of aluminum materials.

Powder Coating

Powder coating involves applying a dry powder to the part's surface. This powder is then cured to form a protective and decorative layer. The powder coating process offers excellent durability, chemical resistance, and a diverse array of color options.

Powder-coated aluminum parts can be found in various areas of a typical automobile, including interior trim and chassis components.

Electroplating

Electroplating involves depositing a metal layer onto an aluminum surface via an electrolytic cell. This technique improves corrosion resistance, affords parts a smooth finish, and can be used to achieve attractive decorative effects.

Electroplated aluminum parts are primarily found in exterior trims and decorative accents.

The widespread adoption of lightweight electric vehicles (EVs) has prompted a range of coating technology advances. Research and development efforts primarily focus on developing coatings offering improved corrosion resistance, durability, and beneficial weight-saving properties.

These developments include thin-film coatings, nano-coatings, and advanced composite coatings, offering improved protection while minimizing weight gain.

These innovations further the goal of minimizing overall vehicle weight while ensuring optimal protection and performance.

XRF Coating Thickness Measurement

Automotive engineers and manufacturers must ensure consistent quality while rigorously adhering to specifications. Accurately measuring surface coating thickness is a key aspect of quality control.

X-ray fluorescence (XRF) technology has emerged as a reliable and efficient solution in this field, even for samples with a complex shape.

XRF is a nondestructive analytical technique for measuring materials' elemental composition. It can also precisely determine coating thickness on aluminum surfaces without damaging the part under investigation.

A technician performs coating analysis using a handheld XRF analyzer. Image Credit: Evident Corporation (XRF / XRD)

XRF is a widely recognized technique offering an array of benefits to coating thickness measurements.

Non-Destructive Testing

XRF technology measures coating thickness without damaging the integrity and usability of aluminum OEM parts.

Accuracy and Precision

XRF analyzers offer accurate and repeatable coating thickness measurements, minimizing any risks of parts deviating from specifications.

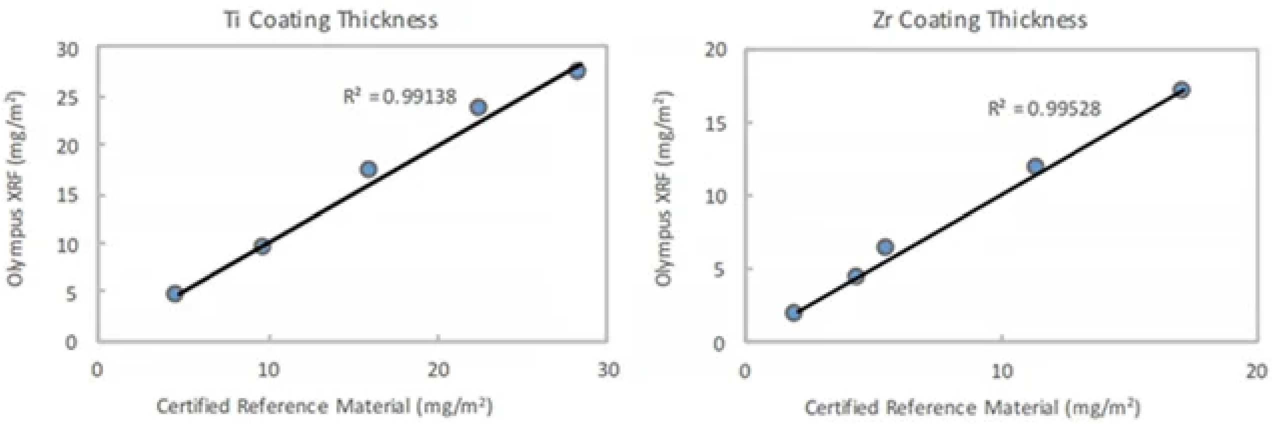


Image Credit: Evident Corporation (XRF / XRD)

Source: Evident Corporation (XRF / XRD)

Ti Coating Thickness	Zr Coating Thickness		
Lab	**XRF**	**Lab**	**XRF**
4.74	4.5262	1.94	1.6535
9.87	9.4366	4.47	4.1885
16.13	17.075	5.61	6.2165
22.67	23.5199	11.51	11.7935
28.36	27.2368	17.19	16.8635

The data shown here exhibits an excellent correlation between results acquired via a Vanta™ handheld XRF analyzer and the coating thickness reference materials for titanium (Ti) and zirconium (Zr).

Time and Cost Efficiency

XRF technology offers rapid measurements, resulting in minimal downtime and enhanced productivity. XRF also removes the need for destructive testing or complicated sample preparation, ultimately resulting in cost savings.

Versatility

XRF analyzers can measure diverse coatings, including conversion coatings and anodized layers. This makes XRF highly suited to various automotive applications.

In-Line XRF for Quality 4.0 in Automotive Manufacturing

Precise control over coating thickness may be required at the nanoscale, with 1 nanometer, or nm, equal to one billionth of a meter. The consistency of the measurement procedure is key to nano-thickness control, and manual control cannot always ensure an ideal procedure.

Evident Scientific offers an automatic in-line control system in alignment with Quality 4.0 practices. This system integrates a robot arm with an in-line XRF analyzer to analyze control points in real-time, ensuring 100% quality control of the surface treatment.

Confidence in Aluminum Coating Quality for Auto Parts

Surface finishes and coatings are indispensable for enhancing aluminum OEM parts' performance, protection, and visual appeal throughout the ever-evolving automotive industry.

Techniques such as anodizing, chromate conversion coatings, organic coatings, powder coating, and electroplating all serve distinct functions and contribute to the overall durability and functionality of various automotive components.

Automotive engineers must select the most appropriate surface treatment to ensure optimal longevity, performance, and customer satisfaction.

Surface treatment and quality control are closely linked when working with aluminum OEM parts in the automotive industry.

By staying at the forefront of advances in surface treatments and integrating cutting-edge technologies such as XRF, automotive engineers will continue to drive innovation, raise product performance, and succeed in this continually evolving and dynamic industry.

Acknowledgments

Produced from materials originally authored by Vladimir Vermus from Evident Scientific.

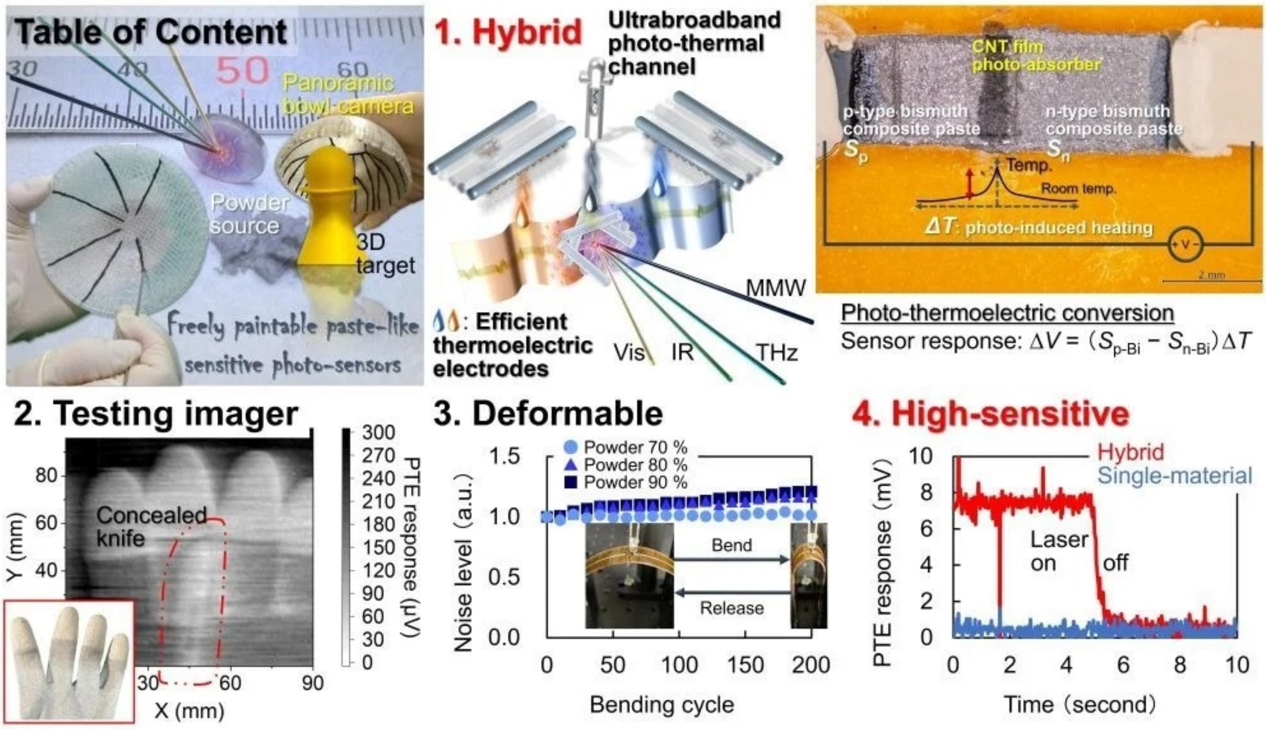
EVIDENT

This information has been sourced, reviewed and adapted from materials provided by Evident Corporation (XRF / XRD).

For more information on this source, please visit Evident Corporation (XRF / XRD).

Research Reveals Printable Image Sensor for Non-Destructive Testing

In a recent paper published in *Small Science*, a research group at Chuo University, Japan, led by Assistant Prof. Kou Li, developed an all-printable device fabrication strategy to overcome the technical constraints of multi-functional image sensor sheets for non-destructive inspections.



Graphical abstract. Image Credit: Chuo University

The device designs of photo-thermoelectric (PTE) sensors have mostly used a single material as the channel, even though these sensors may be appropriate for testing applications like non-destructive material identification in ultrabroad millimeter-wave (MMW)–infrared (IR) bands.

PTE sensors typically integrate photo-induced heating with related thermoelectric (TE) conversion. Using only one material channel limits device use by preventing the full utilization of its basic parameters.

Such critical circumstances are brought about by long-standing technical challenges in the field of PTE sensor design, where typical constituent materials show trends of the trade-off between photo-absorptance values (for heating) and the Seebeck coefficients (for TE conversion).

This study made the following important contributions to achieve this goal.

- Creating the PTE sensor structure using a highly efficient hybrid combination of carbon nanotube (CNT) film photo-thermal absorber channels and bismuth composite (Bicom) TE electrodes (Seebeck coefficient > 100 μV/K).
- Making the most of the aforementioned beneficial hybrid strategy, the sensor performs photo-detection operations with response intensities that are more than ten times greater than those of single-material PTE detectors (usually pn-junction CNT films), meeting the readable signal range criteria (> several millivolts) for the device coupling with portable circuit modules.
- By skillfully positioning Bicom powders with conductive solvents and surfactants as paste-like stable TE converting electrodes along the naturally ink-formed CNT film absorber, the hybrid PTE sensor can be designed into all-solution-processable fabrication configurations.
- Assuring optical stabilities against extreme environmental conditions (such as high temperatures and cyclic deformations) while achieving ultrabroad MMW–IR operations with the hybrid paste PTE device over conventional wideband detectors in comparable sensitivities (minimum noise equivalent power: 560 fWHz–1/2) to current narrowband sensors.
- Utilizing the advantages of the aforementioned optical features and paste-unique freely paintable device setups, the hybrid PTE sensor demonstrates functional non-destructive imaging inspections at high usability. For example, by creating an easy-to-handle panoramic bowl camera module, omnidirectional observations of a 3D target without a blind spot are demonstrated.

Journal Reference:

Matsuzaki, Y., *et al*. (2025) All-solution-processable hybrid photo-thermoelectric sensors with carbon nanotube absorbers and bismuth composite electrodes for non-destructive testing. *Small Science*. doi.org/10.1002/smsc.202400448

Source:

Chuo University

Ultrasonic Imaging with Micro-Metalenses for Advanced Material Diagnostics

In an article recently published in *Scientific Reports*, researchers from the USA and India explored advancements in ultrasonic imaging, focusing on achieving micron-scale resolution using bulk ultrasonics. They addressed key challenges in non-destructive testing and material diagnostics, particularly in industries where detecting microscopic defects is essential.

Image Credit: Funtay/Shutterstock.com

Advancement is Material Evaluation

Evaluating materials at greater depths with high resolution is crucial in fields such as high-energy physics, quantum materials, nuclear power generation, biomedical diagnostics, and aviation. Traditional methods, like radiographic (X-ray) testing, provide high resolution but have limited penetration in solids and involve ionizing radiation, making them costly and less practical for widespread use.

In contrast, ultrasound can penetrate thicker samples, is cost-effective, and is non-ionizing, making it ideal for rapid, large-scale diagnostics. However, conventional bulk ultrasound struggles with imaging microscopic defects due to longer wavelengths.

Techniques like scanning acoustic microscopy (SAM) offer higher resolution but are limited to surface imaging. Thus, achieving high-resolution imaging with low-frequency bulk ultrasonics could significantly improve deeper material diagnostics inside solids.

Developing Micro-Metalenses for Ultrasonic Imaging

The authors aimed to overcome the diffraction limit that restricts imaging resolution to half of the operating wavelength. They developed silicon-based, micro-fabricated metamaterial lenses with arrays of 10-micron square holes.

To enhance wave detection, a custom micro-focal laser with a sub-micron spot size was created, allowing for precise measurements. This setup combined laser technology with advanced signal processing to achieve micron-scale resolution of defects, focusing on identifying synthetic slit-type defects in silicon samples.

The experimental setup included an ultrasonic transmitter connected to a computer-controlled scanning stage, which held a tank with the samples and metalens. The transmitter was powered by a pulser, while a laser receiver detected displacements from the sample, converting these into ultrasonic signals for sub-wavelength imaging.

Micron-scale square holes were fabricated in silicon using Deep Reactive Ion Etching (DRIE), and a thin gold layer was added to enhance reflectivity for non-contact, laser-based detection. The metalens channels were also oxidized to make them hydrophilic, ensuring consistent water levels within the channels.

Key Findings and Insights

The study achieved a resolution of 50 microns using micro-fabricated metalenses. Line scans were conducted on silicon samples with synthetic slit defects, both with and without the micro-metalenses. The results confirmed that the hydrophilic properties of the metalens allowed ultrasonic waves to propagate and interact with the defects, which were detected by the micro-focal Laser Doppler Vibrometer (LDV).

Post-processing of the experimental data validated sub-wavelength resolution at the micron scale. A-scan data for ultrasonic inspection of slits spaced 50 microns apart showed defect separation down to this resolution in the bulk ultrasonic regime.

Additionally, a quantitative evaluation of the B-scan profile using metrics such as Peak-to-Side Lobe Ratio (PSLR), Signal-to-Noise Ratio (SNR), and Contrast Ratio (CR) revealed moderate contrast and clear defect visibility, indicating that while the main peak is stronger, the presence of side lobes remains notable.

Finite element (FE) simulations were performed to estimate the resolution limit of the micrometamaterial, confirming that resolution below the periodicity of the metalens was not achievable.

Practical Implications

Advancements in low-frequency ultrasound, combined with micro-fabricated holey metamaterials, show potential for fine imaging. This method is beneficial for detailed *in situ* analysis of electronic materials and devices, such as integrated circuits (ICs) and microelectromechanical systems (MEMS).

The research also has applications in Non-Destructive Evaluation (NDE) and biomedical imaging, where high-resolution imaging of complex structures is essential. Achieving high-resolution imaging at greater depths can improve diagnostics in various fields, including quantum materials, high-energy physics, nuclear power generation, aviation, and biomedical diagnostics.

Additionally, the non-ionizing and cost-effective nature of ultrasonic techniques makes them ideal for large-scale inspections, potentially replacing more expensive and hazardous electromagnetic methods.

Conclusion and Future Directions

In summary, micro-fabricated metalenses proved effective in achieving resolution with a 2.25 MHz commercially available bulk ultrasonic transducer. Their development offers a promising alternative to traditional imaging techniques, enabling high-resolution inspections at greater depths.

Future work should optimize the micro-metalens parameters and experimental setups, particularly in maintaining water levels within the channels and improving scanning speed. This research paves the way for advanced material diagnostics and imaging across multiple scientific and industrial fields.

Journal Reference

Chandran, L., *et al.* (2024). Micron-scale imaging using bulk ultrasonics. *Sci Rep*. DOI: 10.1038/s41598-024-72634-2, https://www.nature.com/articles/s41598-024-72634-2

What Are Olympic Gold Medals Made Of? The Surprising Answer

Olympic athletes continually break new records, push their physical limits, and do the unimaginable. Decorated Olympians will have amassed a collection of gold, silver, and bronze medals marking their success.

Image Credit: Evident Corporation (XRF / XRD)

This article examines whether Olympic medals are made of gold, silver, or bronze as their names imply.

The Composition of Olympic Gold Medals

Olympic gold medals primarily comprise silver with just a small percentage of gold. The International Olympic Committee (IOC) has developed specific rules around the design and production of Olympic medals, specifying their raw material composition as:

- First place (gold medal): This medal is primarily comprised of silver with a purity of at least 92.5%. These medals are plated with at least 6 grams of pure gold.
- Second place (silver medal): This medal is comprised of silver with a purity of at least 92.5%.
- Third place (bronze medal): This medal consists of bronze, an alloy composed primarily of copper and another metal such as zinc or tin.

These specifications reveal that Olympic gold medals' base material is silver, and that they are plated with over 6 grams of gold on their surface. The silver medals are composed of silver; however, and the bronze medals are comprised of bronze (a mixture of copper and another metal).

Determining Gold Content in Medals and Other Prized Items

Many other jewelry and souvenirs labeled as gold and silver are not pure gold and silver. It is especially important to identify their authenticity when trading these precious metals as commodities; X-ray fluorescence, also known as XRF, is a useful tool in this assessment.

XRF is a nondestructive analysis technique suitable for verifying precious metal content and karatage (gold purity) without damaging these extremely valuable objects.

The Vanta™ handheld XRF analyzer from Evident Scientific offers rapid, precise, and accurate on-the-spot elemental analysis of gold, silver, platinum, and other precious metals. Vanta analyzers are ideally suited to the determination of karat values for quality control and pricing in the trade or manufacture of gold or jewelry.

The Vanta analyzer benefits from a simple, accessible, and customizable user interface. Users with little or no experience can quickly master the instrument's operations with minimal training, with users able to download the results to rapidly produce a certificate.

Handheld XRF analysis of gold and jewelry. Image Credit: Evident Corporation (XRF / XRD)

Turning E-Waste into Treasure with 'Green' Medals

Medals awarded at the Tokyo 2020 Summer Olympics were composed of recycled electronic waste. An impressive amount of gold can be found in old home electronics; for example, there is 80x as much gold in 1 ton of cell phones as there is in some gold mines.

The Japanese Olympic Committee committed to reducing the Tokyo 2020 Summer Olympics' carbon footprint, innovating Olympic medal production by using recycled electronics to make 'green' medals.

The people of Japan were called upon to donate their used electronic products, with the required precious metals for the medals then extracted from this e-waste.

The initiative was well received, with many people engaging. As a result, 18,000 collection boxes were placed throughout the country, and 90% of Japan's local authorities participated.

The recycling initiative collected 78,985 tons of discarded gadgets over 2 years, including over 6 million used cell phones. Other donated devices included digital cameras, laptops, and handheld gaming devices.

Collection of cell phones for recycling. Image Credit: Evident Corporation (XRF / XRD)

The collected devices yielded 32 kg (70.5 lb) of pure gold, 3500 kg (7716 lb) of pure silver, and 2200 kg (4850 lb) of pure copper.

This provided enough recycled materials to create all 5,000 medals, marking a first for the Olympic Games and a major step forward in the global movement to make sporting events more sustainable.

Elemental Analysis of Electronic Waste and Other Scrap

Vanta XRF analyzers can rapidly and accurately sort recycled electronic waste and other scrap. The advanced instruments can reliably identify the majority of alloys and pure metals in just 1-2 seconds.

The analyzer can also provide users with detailed information on a material's chemical composition, facilitating the quick and precise identification of pure metal and alloy grades.

A technician uses the Vanta XRF analyzer to quickly analyze precious metals found in automotive catalyst scrap. Image Credit: Evident Corporation (XRF / XRD)

The Vanta analyzer is a versatile tool for scrap recycling and precious metals testing. It can perform a variety of tests.

It can be used to sort heavy alloys based on the relatively low contents of silicon and aluminum elements.

It is also possible to analyze motherboards' electronic components, identify electronic components containing precious metals (gold, silver, palladium, etc.), evaluate copper content in fine materials, and sort and identify toxic substances and lead-containing solders.

The instrument can also rapidly sort lead-containing glass and glass-ceramic products from recycling lines or detect toxic elements in materials.

The Vanta analyzer is suitable for analyzing automotive catalyst scrap containing precious metals such as platinum, palladium, and rhodium.

It can also be used in furnace and melt operations, monitoring the chemical composition of slags as they melt to control quality and predict the life of a furnace or to sort and evaluate recovered slags from a range of melt operations.

Acknowledgments

Produced from materials originally authored by Sihan Tan from Evident Scientific.

EVIDENT

This information has been sourced, reviewed and adapted from materials provided by Evident Corporation (XRF / XRD).

For more information on this source, please visit Evident Corporation (XRF / XRD).

Ultrasonic Techniques for Lithium-Ion Battery Diagnostics

The widespread adoption of Li-ion batteries, especially in the automotive industry, can be attributed to their high energy density, long cycle life, and decreasing cost. However, potential risks such as thermal runaway and spontaneous ignition remain a concern. This has driven the need for new, cost-effective diagnostic techniques to monitor battery performance and durability.

Image Credit: IM Imagery/Shutterstock.com

Among the various diagnostic methods, ultrasonic techniques have emerged as a promising non-destructive testing (NDT) approach for lithium-ion battery diagnostics. These techniques enable real-time monitoring of the battery's internal state, defect detection, and overall health assessment without causing damage or disruption, facilitating timely interventions and optimized management strategies.[1,2]

Principles of Ultrasonic Diagnostics

Ultrasonic diagnostics uses ultrasonic transducers to generate, propagate, and detect ultrasonic waves, typically in the 0.1 to 15 MHz range. These waves are transmitted into the material under inspection.

As the waves encounter boundaries between different materials, defects, or variations in density or porosity, a portion of the energy is reflected (pulse-echo) or received by a secondary transducer (through transmission). These ultrasonic waves carry valuable information about the material's internal characteristics, which can be analyzed to gain insights into its condition.[3]

Interaction of Ultrasonic Waves with Battery Materials

Factors such as material properties, density, and porosity influence the interaction of ultrasonic waves with battery materials. In lithium-ion batteries, wave propagation can be described using theories like Biot's theory for fluid-saturated porous media or the slurry model for electrode coatings.

A key parameter analyzed is the time-of-flight (ToF), representing the time it takes for an ultrasonic wave to travel through the material and return as an echo. By measuring the ToF and correlating it with known material properties, researchers can detect defects, density changes, or variations in the battery's internal structure.

Additionally, the amplitude and frequency of reflected or transmitted waves provide information about the material's characteristics, with changes indicating alterations in the battery components' mechanical properties linked to electrochemical processes during charging and discharging cycles.[4]

Applications in Lithium-Ion Batteries

Ultrasonic techniques have numerous applications in lithium-ion battery diagnostics, offering unique capabilities and insights that complement and extend traditional diagnostic methods.

Detecting Internal Defects and Degradation

One of the primary applications of ultrasonic techniques in battery diagnostics is the detection of internal defects and signs of degradation.

Ultrasonic tomography, a specialized ultrasonic technique, has proven valuable for studying metal defect detection in lithium-ion batteries. This method involves emitting ultrasonic waves into the battery samples and analyzing the reflected or transmitted waves.

These signals help create tomographic images of the internal battery structure, allowing researchers to visualize and analyze defects without damaging the battery. This capability is particularly valuable for quality control and identifying potential safety hazards that could lead to thermal runaway or other catastrophic failures.[5]

Monitoring State of Charge (SoC) and State of Health (SoH)

Ultrasonic analysis for SoC monitoring involves tracking changes in ultrasonic waveforms corresponding to the battery's charging and discharging states. This method relies on measuring the ToF of ultrasonic waves, which varies with the battery's mechanical properties during cycling.

Changes in signal amplitude during the charge/discharge cycle indicate structural changes, enabling SoC determination and over-discharge detection without complex algorithms or additional hardware. This approach can also monitor the battery's SoH, providing insights into its overall condition, enabling early detection of cell damage, aiding in battery refurbishment, identifying faulty cells, and estimating the remaining useful life.

Monitoring Solid-Electrolyte Interphase (SEI) Formation

The formation and evolution of the SEI layer play are crucial for lithium-ion battery performance and longevity. Ultrasonic techniques can be employed to monitor this process by analyzing changes in the acoustic properties of the electrode during cycling.

As the SEI layer evolves, its mechanical properties change, altering the propagation of ultrasonic waves. By correlating these changes with electrochemical measurements, researchers can gain valuable insights into the SEI formation process and its impact on battery performance.[7]

Diagnosing Electrodes

Spatially resolved ultrasound acoustic measurements provide a powerful diagnostic tool for analyzing the condition of lithium-ion battery electrodes. By performing ultrasonic measurements at multiple locations across the battery's surface and over the full operating voltage range, signal intensity and ToF changes can be correlated with the lithiation/delithiation processes and the associated density and structural changes occurring within the individual anode and cathode layers.

This method also provides information about electrode expansion behavior. It can identify regions where expansion is inhibited due to factors like current collector geometry, offering an economical and high-resolution diagnostic capability to monitor internal structural evolution in operando.[2]

Advantages and Limitations

Ultrasonic techniques offer several advantages for lithium-ion battery diagnostics, including non-destructive and non-invasive monitoring, early degradation detection, real-time monitoring, and high spatial resolution. These capabilities enable continuous battery health assessment, proactive maintenance, and targeted diagnostics, enhancing battery lifespan and performance.

However, challenges such as complex signal interpretation, susceptibility to external interference, limited penetration depth, and potential equipment requirements may arise.

Despite these challenges, the benefits of early degradation detection and improved performance often outweigh the drawbacks, especially in critical applications prioritizing battery safety and longevity.[8]

Future Outlook

Ultrasonic techniques for lithium-ion battery diagnostics have significant potential to enhance battery systems' safety, efficiency, and reliability. Advancements in transducer technology, signal processing, and machine learning are expected to improve their accuracy and reliability further.

Developing portable and cost-effective ultrasonic diagnostic systems could also lead to widespread use in applications such as electric vehicles and stationary energy storage, enabling real-time monitoring and predictive maintenance.

While challenges remain, ongoing research aims to enhance ultrasonic diagnostics, contributing to developing more efficient and safer lithium-ion batteries.[8]

References and Further Reading

1. Webster, M., Frankforter, E., Juarez, P. (2023, April). Evaluation of ultrasonic battery inspection techniques. In *Non-destructive Characterization and Monitoring of Advanced Materials, Aerospace, Civil Infrastructure, and Transportation XVII*. doi.org/10.1117/12.2656667
2. Robinson, JB., Maier, M., Alster, G., Compton, T., Brett, DJ., Shearing, PR. (2019). Spatially resolved ultrasound diagnostics of Li-ion battery electrodes. *Physical Chemistry Chemical Physics*. doi.org/10.1039/C8CP07098A
3. Chacón, XCA., Laureti, S., Ricci, M., Cappuccino, G. (2023). A Review of Non-Destructive

Techniques for Lithium-Ion Battery Performance Analysis. *World Electric Vehicle Journal*. doi.org/10.3390/wevj14110305

4. Gold, L., Herzog, T., Schubert, F., Heuer, H., Giffin, G. A. (2023). Ultrasound Propagation in Lithium-Ion Battery Cell Materials: Basis for Developing Monitoring and Imaging Methods. *Energy Technology*. doi.org/10.1002/ente.202200861
5. Yi, M., Jiang, F., Lu, L., Hou, S., Ren, J., Han, X., Huang, L. (2021). Ultrasonic tomography study of metal defect detection in lithium-ion battery. *Frontiers in Energy Research*. doi.org/10.3389/fenrg.2021.806929
6. Davies, G., Knehr, KW., Van Tassell, B., Hodson, T., Biswas, S., Hsieh, AG., Steingart, DA. (2017). State of charge and state of health estimation using electrochemical acoustic time of flight analysis. *Journal of The Electrochemical Society*. doi.org/10.1149/2.1411712jes
7. Bommier, C., Chang, W., Li, J., Biswas, S., Davies, G., Nanda, J., & Steingart, D. (2020). Operando acoustic monitoring of SEI formation and long-term cycling in NMC/SiGr composite pouch cells. *Journal of The Electrochemical Society*. doi.org/10.1149/1945-7111/ab68d6
8. Wang, Q., Song, D., Lin, X., Wu, H., & Shen, H. (2024). Application of machine learning in ultrasonic diagnostics for prismatic lithium-ion battery degradation evaluation. *Frontiers in Energy Research*. doi.org/10.3389/fenrg.2024.1379408

From Lasers to Lenses: The Role of Optical Science in NDT

Non-Destructive Testing (NDT) refers to a collection of methods designed to evaluate the properties of materials, components, or systems without causing damage, ensuring the tested objects remain fully intact and functional.[1]

Image Credit: MR.Zanis/Shutterstock.com

Advancements in optical science have greatly refined NDT methods. Tools such as lasers, lenses, and optical fibers offer non-contact, highly sensitive solutions that are resistant to electromagnetic interference.

For example, optical fiber-based NDT uses sensors like Fiber Bragg Gratings (FBG) to detect and transmit light signals. These sensors measure strain, temperature, and vibration, making them suitable for real-time monitoring of critical structures, including bridges, pipelines, and aircraft.[2-3]

Laser-Based Methods

Laser Ultrasonics

Laser ultrasonics is a method for generating and detecting ultrasonic waves in materials without physical contact. The process relies on a pulsed laser that causes rapid localized heating through the thermoelastic effect, leading to thermal expansion and the generation of elastic waves. These waves propagate through the material, reflecting or scattering at boundaries, defects, or internal structures.

A second laser, typically coupled with an interferometer, measures the surface displacements caused by these waves, enabling precise mapping of subsurface features.

This method is effective for inspecting complex materials and structures where traditional contact-based techniques may not be practical.[4] In aerospace, laser ultrasonics is used to identify internal cracks, delaminations, and other subsurface defects in aircraft fuselages, wings, and engine parts. It is also applied in manufacturing to verify the integrity of welds, composites, and metal structures during production.[5]

Laser ultrasonics is particularly useful for inspecting high-temperature or moving parts without interrupting functionality. While it provides high precision in detecting subsurface flaws, challenges include the high cost of equipment, the complexity of the setup, and the need for skilled operators to interpret data accurately.[4,5]

Laser Shearography

Laser shearography is an advanced NDT method that uses lasers and interferometric techniques to detect and analyze surface deformations and defects.

The process starts by illuminating a material's surface with coherent laser light, creating a speckle pattern that reflects surface irregularities. A shearing device splits the image into two slightly displaced versions, which are combined into an interferometric speckle pattern.

When the material is stressed—through thermal, acoustic, or vacuum loading—surface deformations alter the speckle pattern. These changes, caused by the interference of coherent light, result in phase differences in the interferogram. These phase changes correspond to displacement gradients on the surface, enabling the detection of defects such as delaminations, cracks, and disbonds.[4]

Compared to traditional interferometric methods like Electronic Speckle Pattern Interferometry (ESPI), shearography is less sensitive to external vibrations and motion, making it better suited for industrial environments and fieldwork.

Applications include inspecting composite structures, turbine blades, and aircraft tires in aerospace, as well as detecting defects in electronic components and semiconductor wafers in manufacturing. It is also used in the rubber industry to identify tire delaminations and in art preservation to analyze wooden panel paintings.[6]

The advantages of laser shearography include its ability to provide fast, full-field measurements and its resistance to external vibrations, making it effective for use in environments where conditions may involve movement, high noise levels, or unstable surfaces.[6]

However, the technique does have limitations. The setup is costly and complex, requiring skilled operators and appropriate excitation methods to identify defects accurately. Additionally, shearography only measures surface strain, so it is less effective at detecting bulk internal defects.[4,6]

Lens-Based Methods

Optical Coherence Tomography

Optical Coherence Tomography (OCT) is a non-invasive imaging technique that uses light waves to produce high-resolution, cross-sectional, and 3D images of an object's internal structure.

OCT operates on the principle of low-coherence interferometry, where light from a broadband source is split into two paths: one directed at the sample and the other at a reference mirror. When reflected light from both paths combines, it creates an interference pattern that reveals structural details. With resolutions ranging from 2.6 to 10 micrometers, OCT is well-suited for detecting minute defects or anomalies.[7,8]

Compared to traditional NDT methods like ultrasound, OCT offers faster imaging, enabling real-time or near-real-time inspections that improve productivity. Its non-contact nature is particularly useful for inspecting delicate materials, such as medical devices and electronic components, as it ensures the integrity of the object is preserved during the inspection process.[7]

OCT has applications across multiple industries. In the medical device sector, it ensures the structural integrity of implants like stents and prosthetics and detects defects in biomaterials. In display and panel manufacturing, OCT evaluates LCD and OLED screens, identifying imperfections at the pixel level.[8] It is also used in aviation and automotive manufacturing to inspect turbine blades, engine parts, and composites for structural abnormalities.[8]

While OCT offers high-resolution imaging and rapid inspection capabilities, it is limited by its shallow penetration depth compared to ultrasound and the high cost of equipment.[7,8]

Visual Inspection with High-Resolution Lenses

Visual inspection remains one of the simplest and most commonly used NDT methods. It is often enhanced with high-resolution lenses and optical tools. Devices such as magnifiers, microscopes, borescopes, and endoscopes improve the ability to detect surface defects.

Depending on the application, inspections are performed either by direct visual observation or through specialized optical devices. High-resolution lenses allow for detailed examinations of small flaws and hard-to-reach areas, making this method both versatile and cost-effective.[4, 9]

Construction and chemical manufacturing industries rely heavily on visual inspection to ensure quality control and maintain safety standards. Borescopes are frequently used in construction to inspect masonry arch bridges for structural integrity.

Similarly, in the chemical industry, visual inspection helps evaluate combustion chambers, pressure vessels, and furnaces for signs of wear or damage. This method is also effective for assessing coatings, seals, and weld roots, providing a simple yet valuable approach to quality assurance.[9]

The advantages of visual inspection include its affordability, speed, and simplicity, making it ideal for quick assessments and initial screenings. However, it is limited by its inability to detect subsurface defects, reliance on surface cleanliness, and the subjective nature of analysis, which can impact accuracy.[9,10]

The Future of NDT

The potential for future innovations in optical NDT methods is vast. Advances in laser technology, imaging systems, and data processing are expected to further enhance the resolution, speed, and automation of these techniques.

The incorporation of artificial intelligence and machine learning could further refine defect detection and analysis, providing faster, more accurate, and consistent results.[11] These developments will improve safety, operational efficiency, and quality assurance in various industries.

To learn more about these advancements and their applications, explore the following resources:

- Optical Coherence Tomography (OCT) in medical imaging: Capabilities and key applications
- Methodologies for Non-Destructive Testing of Paint Layers
- Non-Destructive Testing in Construction
- What Non-Destructive Testing Techniques are Used in the Aviation Industry?
- Non-Destructive Testing Techniques Used in the Oil and Gas Industry
- Can Machine Learning be used in Non-Destructive Testing?

References and Further readings

1. Kumpati, R.; Skarka, W.; Ontipuli, SK. (2021). Current Trends in Integration of Nondestructive Testing Methods for Engineered Materials Testing. *Sensors.* https://www.mdpi.com/1424-8220/21/18/6175

2. Hassani, S.; Dackermann, U. (2023). A Systematic Review of Advanced Sensor Technologies for Non-Destructive Testing and Structural Health Monitoring. *Sensors.* https://pubmed.ncbi.nlm.nih.gov/36850802/

3. Liu, L.; Zhang, H.; Jiao, F.; Zhu, L.; Zhang, X. (2023). Review of Optical Detection Technologies for Inner-Wall Surface Defects. *Optics & Laser Technology.* https://www.sciencedirect.com/science/article/abs/pii/S0030399223002062

4. Kroworz, A.; Katunin, A. (2018). Non-Destructive Testing of Structures Using Optical and Other Methods: A Review. *Structural Durability & Health Monitoring.* https://www.techscience.com/sdhm/v12n1/28695

5. Jodhani, J.; Handa, A.; Gautam, A. (2023). Rana, R., Ultrasonic Non-Destructive Evaluation of Composites: A Review. *Materials Today: Proceedings.* https://www.sciencedirect.com/science/article/abs/pii/S2214785322074296

6. Gupta, M.; Khan, MA.; Butola, R.; Singari, RM. (2022). Advances in Applications of Non-Destructive Testing (Ndt): A Review. *Advances in Materials and Processing Technologies.* https://www.tandfonline.com/doi/full/10.1080/2374068X.2021.1909332

7. Aumann, S.; Donner, S.; Fischer, J.; Müller, F. (2019). Optical Coherence Tomography (Oct): Principle and Technical Realization. *High resolution imaging in microscopy and ophthalmology: new frontiers in biomedical optics*. https://pubmed.ncbi.nlm.nih.gov/32091846/

8. Heise, B.; Hannesschlaeger, G.; Leiss-Holzinger, E.; Peham, L.; Zorin, I. (2020). Optical Coherence Tomography in Nondestructive Testing. *Optics and Photonics for Advanced Dimensional Metrology*. https://doi.org/10.1117/12.2556832

9. Kumar, A.; Arnold, W. (2022). High Resolution in Non-Destructive Testing: A Review. *Journal of Applied Physics*. https://pubs.aip.org/aip/jap/article/132/10/100901/2837323/High-resolution-in-non-destructive-testing-A

10. Zhong, S.; Nsengiyumva, W. (2022). Visual Testing for Fiber-Reinforced Composite Materials. *Nondestructive Testing and Evaluation of Fiber-Reinforced Composite Structures*. https://link.springer.com/book/10.1007/978-981-19-0848-4

11. Sunil, P.; Chandu, P.; Vivek, D. (2024). A Review: Non-Destructive Testing (Ndt) Techniques, Applications and Futureprospects. *Journal of Science & Technology (JST).* https://jst.org.in/index.php/pub/article/view/35