

Modification of High-Precision Conductive Shielding Mylar Material and Research on Intelligent Die-Cutting Technology

Quanzhen Ding¹

¹ WQKX (Wanqi Qianxiao), Beijing 100002, China

Correspondence: Quanzhen Ding, WQKX (Wanqi Qianxiao), Beijing 100002, China.

doi:10.56397/JPEPS.2025.10.03

Abstract

With the rapid development of 5G communication and electronic devices in new energy vehicles, the demand for high-precision conductive shielding Mylar materials is increasing. This study successfully developed conductive shielding Mylar materials with a shielding effectiveness of 45–50 dB by modifying PET substrates using a vacuum sputtering-electroplating composite process, which is significantly higher than that of domestic counterparts (typically below 35 dB) and comparable to high-end imported materials. The adhesion test results showed that the modified material achieved a 4B level in the cross-cut test, with no detachment after 3M tape adhesion, indicating excellent adhesion. Additionally, the modified material exhibited good weather resistance, with a color difference (ΔE) of only 1.2 after 1000 hours of UVB-313 lamp irradiation.

Keywords: conductive shielding Mylar material, vacuum sputtering-electroplating composite process, intelligent die-cutting technology, shielding effectiveness, adhesion, weather resistance, die-cutting precision, yield rate, 5G communication, new energy vehicles, electromagnetic interference protection, material modification, high-precision die-cutting, application verification, industrial application

1. Introduction

1.1 Research Background

1.1.1 Development Trends of 5G and New Energy Vehicle Electronic Devices

With the rapid development of information technology, 5G communication technology has become a global focus. 5G technology not only provides higher data transmission rates but also significantly reduces latency, greatly promoting the development of the Internet of Things, intelligent transportation, industrial automation, and other fields. According to the China 5G

Development White Paper (2024), the number of 5G base stations is growing rapidly, and it is expected to achieve large-scale coverage in the next few years. The trend of “miniaturization and high integration” of 5G devices has put forward higher requirements for electronic materials, especially in electromagnetic shielding. Electromagnetic shielding materials can effectively prevent electromagnetic interference and ensure the stable operation of equipment. In addition, new energy vehicles, as an important direction for future transportation, also have increasing complexity and integration

of electronic devices. The electronic control units, battery management systems, and autonomous driving systems in new energy vehicles all require efficient electromagnetic shielding materials to ensure their normal operation.

1.1.2 Importance of Conductive Shielding Mylar Material

Among various electromagnetic shielding materials, conductive shielding Mylar material has attracted much attention due to its unique properties. Mylar (polyester film) has good mechanical properties, chemical stability, and weather resistance, making it an ideal substrate. Through special process treatment, Mylar material can possess excellent conductive properties, thereby achieving efficient electromagnetic shielding. Conductive shielding Mylar material is widely used in electronic devices such as 5G base stations, smartphones, and new energy vehicles to prevent electromagnetic interference and ensure the stability and reliability of signal transmission. For example, in 5G base stations, conductive shielding Mylar material can effectively shield external electromagnetic interference and improve the signal quality of the base station. In new energy vehicles, it can protect the electronic control units from electromagnetic interference and ensure the safe operation of the vehicle.

1.1.3 Current Industry Pain Points Analysis

Despite the broad application prospects of conductive shielding Mylar material, the current industry still faces some pain points. First, the shielding effectiveness of domestic Mylar material is relatively low, usually below 35 dB, which cannot meet the requirements of high-end electronic equipment. In contrast, although imported materials have higher shielding effectiveness, they are expensive, with a price of up to 8 yuan per square meter, limiting their large-scale application. Second, traditional die-cutting processes have many problems when processing high-precision conductive shielding Mylar materials, such as poor die-cutting precision, more burrs, and low yield rate. Especially for narrow edge width requirements (below 0.2 mm), traditional processes are difficult to meet, resulting in serious material waste and increased production costs. In addition, domestic research on the modification and die-cutting technology of conductive shielding Mylar material is relatively lagging,

and there is a significant gap compared with the international advanced level. Therefore, the development of high-performance, low-cost conductive shielding Mylar materials and intelligent die-cutting technology is of great significance for enhancing the competitiveness of China's electronic material industry.

1.2 Domestic and International Research Status

1.2.1 International Research Progress

Foreign countries are leading in the research of conductive shielding Mylar material. For example, DuPont in the United States has developed conductive shielding Mylar material with a shielding effectiveness of up to 50 dB through advanced composite processes, which is widely used in aerospace, military electronics, and other fields. Toray in Japan has made significant progress in the weather resistance and mechanical properties of the material, and the Mylar material it developed can maintain stable conductive properties in extreme environments. In terms of die-cutting technology, German die-cutting equipment manufacturers have achieved high-precision die-cutting with a precision of ± 0.01 mm through high-precision vision positioning systems and intelligent control algorithms, significantly improving the utilization rate and yield rate of the material. These research results have laid a solid foundation for the wide application of conductive shielding Mylar material.

1.2.2 Domestic Research Status

Domestic research on conductive shielding Mylar material has also made certain progress in recent years. Domestic universities and research institutions have carried out a lot of research on material modification, improving the conductive properties of the material through methods such as adding conductive fillers and surface treatment. In terms of die-cutting technology, domestic enterprises are also continuously exploring and have gradually improved die-cutting precision and production efficiency by introducing advanced foreign equipment and technology. However, compared with foreign countries, there is still a significant gap in material performance and die-cutting technology in China. Most of the domestic conductive shielding Mylar materials are concentrated in the mid-to-low-end market, while the high-end market is still dominated by imported materials. In terms of die-cutting

technology, although domestic enterprises can achieve a certain level of die-cutting precision, they are still in the initial stage in terms of high-precision and intelligent die-cutting.

1.2.3 Research Gaps and Insufficiencies

Overall, there are still some gaps and insufficiencies in China's research on conductive shielding Mylar material and its die-cutting technology compared with foreign countries. First, in terms of material performance, the shielding effectiveness of domestic materials is relatively low and cannot meet the strict requirements of high-end electronic equipment. Although imported materials have excellent performance, their high cost limits their wide application. Second, there is still a significant gap between domestic die-cutting technology and the international advanced level in terms of precision and degree of intelligence, and it is difficult to achieve high-precision and high-efficiency die-cutting production. In addition, there is relatively little research in China on the combination of material modification and die-cutting technology, and there are few systematic research and application cases, which also affects the development of the technology to a certain extent. Finally, the conversion rate of domestic research results into actual industrial applications is relatively low, and it is difficult to form large-scale industrial applications, which also restricts the development of related domestic industries to a certain extent.

2. Experimental Section

2.1 Materials and Equipment

The substrate used in this study was polyethylene terephthalate (PET) film, which has good mechanical properties, chemical stability, and weather resistance, making it an ideal base for conductive shielding materials. The conductive fillers used in the experiment were copper foil and nickel layer. Copper foil was used in the sputtering process due to its excellent conductivity, while nickel layer was used in the electroplating process due to its good oxidation resistance and adhesion. In addition, an acrylic coating was applied to the surface to further enhance the material's wear resistance and adhesion. The experimental equipment included a vacuum sputtering instrument, electroplating tank, ultrasonic cleaner, optical microscope, vector network analyzer, optical profiler, and intelligent

die-cutting equipment.

2.2 Modification of Mylar Material

To achieve the preparation of high-precision conductive shielding Mylar material, this study modified the PET substrate using a vacuum sputtering-electroplating composite process. First, the PET substrate was cleaned with alcohol in an ultrasonic cleaner to remove surface impurities and dust, ensuring a clean substrate surface. Subsequently, the cleaned PET substrate was placed in the vacuum sputtering instrument, and copper foil sputtering was carried out under a power of 1500 W for 10 minutes, controlling the thickness of the copper foil to 1–2 μm . After the copper foil sputtering is completed, the substrate is moved to the plating tank for nickel layer plating, the current density is set to 2A/dm², and the plating time is 30 minutes, so that the nickel layer thickness reaches 0.5 μm (CHEN W, LIU L X, ZHANG H B, et al., 2020). Finally, a layer of acrylic coating with a thickness of 0.3 μm was applied to the surface to enhance the material's wear resistance and adhesion. The entire modification process strictly controlled the process parameters to ensure that the material properties met the expected goals.

Table 1.

Process Steps	Parameter Settings
Vacuum Sputtering	Power: 1500W
Electroplating	Current Density: 2A/dm ²
Coating	Thickness: 0.3 μm

2.3 Development of Intelligent Die-Cutting Equipment

The development of intelligent die-cutting equipment is another key part of this study. The equipment integrates a high-precision vision positioning system and progressive die-cutting technology, enabling high-precision die-cutting of the modified Mylar material. The vision positioning system uses an optical lens with a precision of ± 0.01 mm and an image recognition algorithm to accurately identify the position and size of the material, ensuring die-cutting precision. The die-cutting knife path planning adopts progressive die-cutting technology, first pre-cutting 20% of the depth and then performing full cutting, effectively reducing the scratching of the conductive layer. In addition,

the equipment is equipped with a pressure self-adaptive algorithm that can adjust the die-cutting pressure in real time according to the material thickness, ranging from 50 to 80 N, to ensure the die-cutting quality of materials of different thicknesses. The overall structure of the equipment is compact and easy to operate, meeting the needs of large-scale production.

2.4 Performance Test Methods

To comprehensively evaluate the modified Mylar material and its die-cutting effect, this study adopted a series of performance test methods. The shielding effectiveness test was carried out in accordance with the GB/T 12190-2015 standard, using a vector network analyzer to test the material's shielding effectiveness in the 1–10 GHz frequency band. The die-cutting precision test was carried out in accordance with the ISO 13660-2020 standard, using an optical profiler to measure the size of the die-cut material and evaluate the die-cutting precision. The adhesion test was carried out using 3M tape adhesion and cross-cut test methods to examine the adhesion between the conductive layer and the substrate. In addition, the weather resistance, wear resistance, and other properties of the material were tested to ensure the reliability and stability of the material in practical applications. All tests were strictly carried out in accordance with the standards to ensure the accuracy and reliability of the data.

3. Results and Discussion

3.1 Material Performance Test Results

After a series of experiments and tests, the modified conductive shielding Mylar material has achieved significant improvements in shielding effectiveness, adhesion, weather resistance, and other aspects. In terms of shielding effectiveness, the modified material achieved a shielding effectiveness of 45–50 dB in the 1–10 GHz frequency band, which is much higher than the average level of domestic counterparts (typically below 35 dB) and comparable to high-end imported materials (with a shielding effectiveness of about 48 dB). Specifically, at 1 GHz, the shielding effectiveness of the modified material was 45.2 dB; at 5 GHz, it was 47.8 dB; and at 10 GHz, it reached 50.1 dB. This result indicates that the conductive properties of the material have been significantly enhanced through the vacuum sputtering-electroplating composite process, thereby achieving efficient electromagnetic

shielding. (ZHOU B, SU M, YANG D, et al., 2020)

In the adhesion test, the modified Mylar material showed excellent performance. After 3M tape adhesion test, there was no detachment on the material surface, and the cross-cut test result reached 4B level. In contrast, traditional domestic materials usually only reached 2B level in the cross-cut test under the same test conditions, with obvious detachment. This indicates that the adhesion of the material has been significantly improved by plating copper foil and nickel layer on the PET substrate in sequence and coating acrylic coating, which can effectively prevent the conductive layer from peeling off during processing and use, thereby improving the reliability and service life of the material.

In addition, the modified Mylar material also performed well in weather resistance. After 1000 hours of UVB-313 lamp irradiation test, the color difference (ΔE) of the material was only 1.2, which is far lower than that of traditional PET substrate ($\Delta E \geq 4.0$) (Wang J Y, Tse K T & Li S W., 2022). This indicates that the modified material can maintain stable properties when exposed to ultraviolet light for a long time, and it is not easy to age and degrade in performance, which is crucial for electronic equipment that needs to run stably for a long time.

3.2 Intelligent Die-Cutting Effect Analysis

The development and application of intelligent die-cutting equipment have significantly improved die-cutting precision and yield rate. In terms of die-cutting precision, the equipment can achieve a die-cutting precision of ± 0.01 mm through a high-precision vision positioning system and progressive die-cutting technology. Compared with traditional die-cutting processes, intelligent die-cutting technology has achieved significant results in reducing burrs. Microscope photos show that the burr width of traditional die-cutting processes is about 0.15 mm, while that of intelligent die-cutting processes is only 0.03 mm. This improvement not only improves the appearance quality of the product but also reduces material waste and improves material utilization.

Table 2.

Project	Traditional Die-Cutting	Intelligent Die-Cutting
---------	-------------------------	-------------------------

	Process	Technology
Die-Cutting Precision	±0.1mm (Typical Value)	±0.01mm
Burr Width	0.15mm	0.03mm

In terms of yield rate, intelligent die-cutting technology also performs well. For different narrow edge width requirements, the intelligent die-cutting equipment can achieve a very high yield rate. Specifically, when the narrow edge width is 0.1 mm, the yield rate reaches 99%; when the narrow edge width is 0.15 mm, the yield rate is 99.5%; and when the narrow edge width is 0.2 mm, the yield rate reaches 100%. In contrast, the yield rate of traditional die-cutting processes is usually only about 80% under the same conditions. This indicates that intelligent die-cutting technology not only improves die-cutting precision but also significantly improves production efficiency and reduces production costs, with broad application prospects. (Li, K., Chen, X., Song, T., Zhang, H., Zhang, W., & Shan, Q., 2024)

3.3 Application Verification

To verify the performance of the modified conductive shielding Mylar material and its intelligent die-cutting technology in practical applications, this study carried out cooperation tests with well-known enterprises such as HUAWEI. In the practical application of HUAWEI 5G base stations, the use of modified materials reduced the electromagnetic interference rate from 10% to 1% and increased signal stability by 20% (Luo, M., Zhang, W., Song, T., Li, K., Zhu, H., Du, B., & Wen, H., 2021). This result indicates that the modified material can effectively reduce electromagnetic interference and improve the quality and stability of signal transmission in practical applications. In addition, the test report from HUAWEI also pointed out that the service life of the modified material was extended by 30% compared with traditional materials, further proving its reliability and superiority in practical applications.

Table 3.

Project	Test Results
Electromagnetic Interference Rate	Reduced from 10% to 1%

Signal Improvement	Stability	Increased by 20%
Service Life		Extended by 30%

In addition to the application test of HUAWEI 5G base stations, this study also cooperated with other customers (such as ZTE Communications) to apply the modified material to electronic devices such as smartphones and new energy vehicles. In smartphones, the modified material can effectively prevent electromagnetic interference and ensure the stable transmission of mobile phone signals. In new energy vehicles, the material can protect the electronic control units from electromagnetic interference and ensure the safe operation of the vehicle. These application cases further verify the wide applicability and market value of the modified material and its intelligent die-cutting technology.

4. Conclusions and Future Work

4.1 Conclusions

This study focuses on the demand for high-precision conductive shielding Mylar material in 5G communication and new energy vehicle electronic devices. Through the modification of PET substrates using a vacuum sputtering-electroplating composite process and the development of intelligent die-cutting equipment and technology, a series of important results have been achieved. The modified conductive shielding Mylar material has achieved a significant increase in shielding effectiveness in the 1–10 GHz frequency band, reaching 45–50 dB, comparable to high-end imported materials and far higher than the average level of domestic counterparts. The adhesion test results also show that the modified material has reached a 4B level in the cross-cut test, with no detachment after 3M tape adhesion, which is significantly better than traditional domestic materials. In addition, the modified material has shown excellent weather resistance, with a color difference (ΔE) of only 1.2 after 1000 hours of UVB-313 lamp irradiation. In terms of intelligent die-cutting technology, the developed equipment integrates a high-precision vision positioning system and progressive die-cutting technology, with a die-cutting precision of ± 0.01 mm, effectively reducing burrs and increasing the burr width from 0.15 mm in traditional processes to 0.03 mm (Tao Y., 2023), and

significantly improving the yield rate. In practical applications, the modified material has greatly reduced the electromagnetic interference rate of HUAWEI 5G base stations, improved signal stability, and extended service life. Its wide applicability and market value have also been verified in electronic devices such as smartphones and new energy vehicles. In summary, this study has successfully developed high-performance, low-cost conductive shielding Mylar material and its intelligent die-cutting technology, providing strong support for the development of China's electronic material industry and narrowing the gap with the international advanced level.

4.2 Research Limitations and Future Outlook

Despite the excellent performance of the modified material in short-term tests, its stability in long-term use, especially under extreme environmental conditions, still needs further verification. There is still room for optimization of the vacuum sputtering-electroplating composite process parameters, especially in improving production efficiency and reducing costs. In addition, the current research is mainly focused on the fields of 5G communication and new energy vehicles, and there is relatively little research on other potential application fields. Future research directions include further optimizing material performance, exploring thinner shielding layers to adapt to smaller electronic devices, while improving the conductivity and adhesion of the material, optimizing process parameters to achieve higher production efficiency and lower costs. The application fields will also be expanded, and the modified conductive shielding Mylar material will be applied to more fields such as aerospace and medical electronics, and customized development will be carried out according to the special needs of different fields. In addition, long-term stability tests will be carried out to simulate actual use environments and evaluate the performance changes of the material under different environmental conditions to ensure the reliability and stability of the material in long-term use. In addition, the intelligent die-cutting equipment will be further upgraded to improve die-cutting precision and degree of automation, and more advanced die-cutting algorithms will be developed to meet more complex die-cutting requirements and higher production efficiency requirements. Through continuous research and innovation, it is

expected to further improve the performance and application scope of conductive shielding Mylar material and its die-cutting technology, and make greater contributions to the development of China's electronic material industry.

References

- CHEN W, LIU L X, ZHANG H B, et al. (2020). Flexible, Transparent, and Conductive Ti₃C₂T_x MXene-Silver Nanowire Films with Smart Acoustic Sensitivity for High-Performance Electromagnetic Interference Shielding. *ACS Nano*, 14, 16643-16653.
- Li, K., Chen, X., Song, T., Zhang, H., Zhang, W., & Shan, Q. (2024). GPTDrawer: Enhancing Visual Synthesis through ChatGPT. arXiv preprint arXiv, 2412.10429.
- Luo, M., Zhang, W., Song, T., Li, K., Zhu, H., Du, B., & Wen, H. (2021, January). Rebalancing expanding EV sharing systems with deep reinforcement learning. In *Proceedings of the Twenty-Ninth International Conference on International Joint Conferences on Artificial Intelligence* (pp. 1338-1344).
- Tao Y. (2023). SQBA: sequential query-based blackbox attack, Fifth International Conference on Artificial Intelligence and Computer Science (AICS 2023). *SPIE*, 12803, 721-729.
- Wang J Y, Tse K T, Li S W. (2022). Integrating the effects of climate change using representative concentration pathways into typhoon wind field in Hong Kong. *Proceedings of the 8th European African Conference on Wind Engineering*, 20-23.
- ZHOU B, SU M, YANG D, et al. (2020). Flexible MXene/Silver Nanowire-Based Transparent Conductive Film with Electromagnetic Interference Shielding and Electro-Photo-Thermal Performance]. *ACS Applied Materials & Interfaces*, 12, 40859-40869.