GENERAL

# advanced materials and design for board level emi shielding

Published: September 19, 2026 | Index ID: #-

## Advanced Materials and Design for Board Level EMI Shielding

In today's hyper connected world, electronic devices are packed with high speed digital circuits, power electronics, and wireless transceivers that generate and are susceptible to electromagnetic interference (EMI). Even a small burst of noise can disrupt data integrity, trigger false alarms, or cause catastrophic failure in safety critical systems. As manufacturers push the limits of performance, the demand for effective board level EMI shielding has never been higher. Traditional copper foils and metal enclosures are often insufficient to meet the stringent requirements of modern applications such as automotive infotainment, aerospace avionics, 5G base stations, and medical implants.

Advanced materials—ranging from graphene based composites to silver nanowire films—offer unprecedented conductivity, weight savings, and design flexibility. Coupled with sophisticated design techniques, they enable designers to achieve superior attenuation, lower insertion loss, and tighter compliance with global EMI standards.

In this article, we dive deep into the world of advanced materials and design strategies that empower engineers to build robust board level EMI shields. We explore the science behind each material, practical integration methods, simulation workflows, and real world case studies that demonstrate the tangible benefits of adopting these cutting edge solutions.

## 1. Understanding EMI and Its Impact on Printed Circuit Boards

### 1.1 What Is Electromagnetic Interference?

EMI refers to unwanted electromagnetic energy that couples into electronic circuits and disrupts their normal operation. It can be categorized into:

- Conducted EMI – Noise traveling along power or signal traces.
- Radiated EMI – Electromagnetic waves emitted into free space.

Both types can cause bit errors, voltage spikes, and even permanent damage to sensitive components.

### 1.2 Why Board Level Shielding Matters

At the board level, EMI can:

- Introduce crosstalk between high speed data lines.
- Alter power supply ripple, affecting analog performance.
- Create electromagnetic compatibility (EMC) violations that hinder regulatory approval.

Shielding at the board level is often the first line of defense, providing a controlled electromagnetic environment before the signal reaches the external world.

## 2. Traditional Shielding Techniques and Their Limitations

### 2.1 Copper Foils and Ground Planes

Conventional PCB manufacturers rely on copper layers, ground planes, and vias to dampen EMI. While effective at

low frequencies, copper becomes lossy at gigahertz ranges, and thick copper layers add weight and cost.

### 2.2 Metal Enclosures and Faraday Cages

Metal housings can block radiated emissions but often introduce mechanical constraints, thermal challenges, and are not feasible for thin, flexible electronics.

### 2.3 Conductive Paints and Tapes

These solutions offer surface conductivity but suffer from poor adhesion, limited mechanical strength, and are difficult to apply uniformly on complex geometries.

## 3. The Need for Advanced Materials

As the frequency spectrum expands into the millimeter wave band and device densities increase, traditional shielding falls short. Advanced materials provide:

- Higher conductivity with lower weight.
- Mechanical flexibility for conformal shielding.
- Improved frequency response across wide bands.
- Ease of integration into existing PCB manufacturing flows.

By leveraging these properties, designers can achieve tighter EMI attenuation while keeping form factors small.

## 4. Categories of Advanced EMI Shielding Materials

### 4.1 Graphene Based Composites

Graphene, a single layer of carbon atoms arranged in a hexagonal lattice, boasts exceptional electrical conductivity and mechanical strength. When incorporated into polymer matrices, graphene composites provide:

- Conductivity up to 10,000 /S/m, far exceeding conventional polymer fillers.
- Flexibility for bending and folding applications.
- Low density (~1.8 /g/cm³), ideal for weight critical designs.

Typical applications include flexible EMI shielding films and graphene reinforced copper foils.

### 4.2 Carbon Nanotube (CNT) Composites

Single walled or multi walled CNTs create a percolation network that dramatically enhances conductivity in otherwise insulating polymers. CNT composites offer:

- Conductivity as high as 1,000 /S/m in lightweight films.
- Excellent thermal conductivity for heat dissipation.
- Scalable manufacturing via extrusion or spray coating.

They are often used in EMI shielding foils, coatings, and flexible interconnects.

### 4.3 Conductive Polymers

Polymers such as polyaniline, polypyrrole, and PEDOT:PSS can be doped to achieve conductivity between 10 and 1,000 /S/m. Their advantages include:

- Low cost and ease of processing.
- Good adhesion to a variety of substrates.
- Potential for inkjet or screen printing, enabling pattern specific shielding.

### 4.4 Silver Nanowire (AgNW) Networks

Silver nanowires form a transparent, conductive network when sprayed or spin coated onto substrates. Key benefits:

- Conductivity up to 20,000 /S/m.
- Transparency for display applications, allowing EMI shielding without obstructing optical paths.
- Excellent adhesion to flexible polymers.

### 4.5 Metallic Foams and Meshes

Lightweight metallic foams (e.g., aluminum or copper) and fine mesh grids provide high surface area for EMI attenuation while maintaining low density. They are ideal for:

- Enclosing high power components.
- Creating conformal shields around irregular shapes.
- Providing mechanical reinforcement.

### 4.6 Hybrid Composites and Layered Structures

Combining multiple materials—such as a graphene reinforced copper layer over a CNT polymer substrate—yields synergistic properties. Hybrid structures can:

- Maximize conductivity while minimizing weight.
- Tailor magnetic permeability for specific frequency ranges.
- Offer graded shielding performance across the board.

## 5. Design Considerations for Board Level EMI Shielding

### 5.1 Frequency Dependent Shielding Strategies

EMI attenuation varies with frequency. Designers should:

1. Low frequency (kHz–MHz): Use thick copper layers and ground planes to absorb conducted noise.
2. Mid frequency (MHz–GHz): Employ conductive polymers or CNT composites to provide continuous shielding.
3. High frequency (GHz–THz): Rely on graphene or silver nanowire networks for their superior skin depth performance.

### 5.2 Ground Plane Layout and Via Placement

Effective grounding reduces EMI pathways:

- Ensure a continuous, low impedance ground plane with minimal gaps.
- Use high density via stitching to connect ground planes across layers.
- Place vias near high speed traces to prevent radiated emissions.

### 5.3 Shielding Enclosure Design

When integrating a metallic enclosure:

- Design seams with overlapping joints and conductive gaskets to avoid gaps.
- Use magnetic shielding materials (e.g., Mu Metal) for low frequency magnetic fields.
- Incorporate feedthroughs with RF chokes or ferrite beads to block conducted EMI.

### 5.4 Material Compatibility and Adhesion

Advanced materials must bond reliably to PCB substrates:

- Pre treat surfaces with oxygen plasma or primer coatings.
- Select curing temperatures compatible with PCB stack up to avoid delamination.

- Test adhesion under thermal cycling to ensure long  term reliability.

### 5.5 Thermal Management Integration

Many advanced shielding materials also provide heat dissipation:

- Graphene and CNT composites have high thermal conductivity, helping to spread heat.
- Silver nanowire networks can act as heat spreaders while shielding EMI.
- Design the shield geometry to include heat  sink fins or thermal vias.

## 6. Integration Techniques

### 6.1 Laminated Composite Shielding

Layering a conductive composite film onto a copper foil creates a dual  function shield:

1. Apply a thin copper layer via standard PCB fabrication.
2. Laminate a graphene or CNT composite film on top, ensuring edge alignment.
3. Use an adhesive compatible with both materials and cure under controlled conditions.

### 6.2 Inkjet and Screen Printing Shield Patterns

Conductive inks (e.g., silver or carbon based) can be printed directly onto the board to form custom shielding geometries:

- Design patterns that cover high  noise zones while minimizing copper usage.
- Employ multi  layer printing to build up thickness without excessive weight.
- Post  print annealing improves conductivity and adhesion.

### 6.3 Conformal Coatings

Conformal EMI shielding coatings (e.g., epoxy  based composites) are sprayed or dip  coated onto the board surface:

- Provide uniform coverage over complex topographies.
- Enhance moisture resistance and mechanical protection.
- Allow for post  manufacturing application, ideal for retrofitting.

### 6.4 Hybrid Shielding Enclosures

Combining a lightweight metallic mesh with a conductive polymer film yields a lightweight yet effective shield:

- Mesh provides mechanical support and reduces weight.

**Tags: #advanced  #materials  #design  #board  #level  #shielding**