TECHNICAL WHITE PAPER · MG TECH R&D · 2026

Heat-Free, Plastic-Based Nanostructured Protective Coating for Printed Circuit Boards: Technology, Performance and Reliability Considerations

Abstract

Printed circuit boards (PCBs) deployed in automotive, industrial, marine, outdoor and high-humidity environments are exposed to moisture, liquid water, ionic contamination, corrosion, thermal cycling and mechanical stress. These stressors degrade surface insulation resistance and drive failure mechanisms such as electrochemical migration, dendritic growth and corrosion. Protective (conformal) coatings are an established mitigation, and frameworks such as **IPC-CC-830** and **IEC 61086** define how they should be qualified. This paper describes a **heat-free, plastic-based, multi-layer protective coating** (MGCoat) that forms a reinforced, non-transparent layer at room temperature. Quantitative figures are stated as manufacturer specifications and observed performance; independent qualification under the cited frameworks is recommended for formal compliance.

Keywords: PCB reliability; conformal coating; protective coating; surface insulation resistance; electrochemical migration; IPC-CC-830; IEC 61086; immersion protection; heat-free application.

1. Introduction

Field reliability of electronics is governed by tolerance to environmental stress. As electronics move into under-hood automotive modules, outdoor sensors, marine equipment, LED systems, drones and motorcycle electronics, the PCB faces condensation, rain, wash-down, salt, dust, ionic residues, temperature excursions and vibration. Conformal coatings reduce these risks by forming a protective barrier on the board, helping preserve dielectric strength and long-term function [1], [4].

This paper presents a **plastic-based protective coating applied without heat**. Unlike very thin films that act mainly as a surface insulator, the system is engineered as a **reinforced, build-up layer** that combines environmental and mechanical protection, and defines a credible path to standards-based validation.

2. Failure Mechanisms of PCBs in Service

2.1 Moisture and ionic contamination. Adsorbed moisture with ionic residues (flux, salts, pollutants) lowers the **surface insulation resistance (SIR)** between conductors, enabling leakage currents that can shift bias points and cause malfunction [4], [5].

2.2 Electrochemical migration and dendrites. Under bias and humidity, metal ions migrate and re-deposit as conductive dendrites that bridge conductors, producing intermittent or hard shorts. Coatings that limit moisture films and ionic mobility suppress this.

2.3 Corrosion and CAF. Moisture and contamination corrode copper; internally, conductive anodic filamentation can form along the glass-resin interface. Both reduce service life, especially in fine-pitch designs.

2.4 Thermal and mechanical stress. Temperature cycling pumps humid air through enclosures, while handling, vibration and abrasion impose mechanical loads. A coating that adds **mechanical robustness after curing** addresses both.

3. Conformal Coatings: Function and Material Classes

Conformal coatings are thin polymeric layers conforming to the assembly. The common classes are **acrylic, silicone, polyurethane, epoxy and parylene**, each balancing moisture protection, mechanical and chemical resistance, temperature range and rework differently [1], [4]. In practice many market coatings are ultra-thin transparent films optimised for humidity and light contamination; they add limited mechanical protection and no optical concealment. This leaves a gap for applications needing water and humidity protection, mechanical reinforcement and design confidentiality together.

4. The MGCoat Coating System

4.1 Material concept. MGCoat Liquid PCB Plastic Coating is a **plastic-based, non-transparent protective coating** that cures at room temperature into a reinforced layer. It is designed to be **built up in multiple passes**, matching thickness and protection to the application, and supports **dipping, spraying and brushing** for both volume production and field repair.

4.2 Specifications. The following are manufacturer specifications and observed performance.

Base / finish	Plastic-based, non-transparent (white, black or grey)
Application method	Dipping, spraying or brushing
Application temperature	Heat-free, 15–45 °C (optimum 25–35 °C)
Initial dry (touch)	8–10 minutes
Full cure (max. strength)	12 hours
Thickness per pass	20–200 µm (normal grade 50–100 µm)
Recommended passes	2–4, ~10 min between passes
Coverage	≈ 1 L per 1 m² at 300–500 µm
Operating temperature (cured)	−55 °C to +90...110 °C
Reworkability	Removable with a dedicated solvent
Shelf life	5 years (sealed)

4.3 Application methodology and protection grades. Protection is specified as a number of passes for a target environment and operating voltage, with a short inter-pass dry. After coating, the assembly is visually inspected to confirm full, air-free coverage.

Environment	Voltage	Passes
Full water immersion	AC 220 V	**4**
Full water immersion	DC ≤ 24 V	**3**
Rain / splash resistant	AC 220 V	**2**
Rain / splash resistant	DC ≤ 24 V	**2**

5. Reliability Evaluation Framework

Performance should be judged against recognised frameworks, not a generic “waterproof” claim. **IPC-CC-830** specifies qualification and conformance for electrical insulating compounds on printed wiring assemblies [1]. **IEC 61086-1** defines and classifies coatings for loaded boards; **IEC 61086-3-1** sets material specifications for general-purpose, high-reliability and aerospace use [2], [3]. Representative methods include **surface insulation resistance** (IPC-TM-650 2.6.3 [5]), humidity and damp-heat, thermal cycling, adhesion, mechanical durability, contamination and salt-spray resistance, UV exposure, post-immersion functional testing and short-circuit verification.

Note on claims. Figures here are manufacturer specifications and in-house observed results — **not** third-party certification. Independent qualification under IPC-CC-830 / IEC 61086 is recommended where formal compliance is required.

6. Comparative Positioning

Relative to thin transparent films, the system is positioned as a reinforced plastic layer with combined protection. Key differentiators:

Attribute	Typical thin conformal film	MGCoat plastic-based coating
Curing	Often needs heat/UV or long cure	Heat-free, room temperature
Layer	Very thin surface film	Reinforced 20–200 µm, multi-layer
Mechanical protection	Limited	Hard, abrasion-resistant after cure
Water exposure	Humidity / light splash	Rain to full immersion (graded)
Optical	Transparent	Non-transparent (design concealment)
Application	Usually spray only	Dip / spray / brush
Rework	Varies	Solvent-removable

7. Limitations, Safety and Recommended Validation

Engineering honesty is part of credibility. The product is **plastic-based and, like most plastics, somewhat flammable in the liquid state** — the liquid must never be exposed to open flame; once cured it is a stable film that protects until exposed to heat above ~120 °C or a hard scratch (drill or cutting blade). Waterproofing **does not replace electrical-safety design**: voltage, current, creepage/clearance, connectors and user access must be evaluated separately. For deep immersion, the whole assembly must be sealed with no trapped air. Performance depends on correct surface preparation, masking and full, air-free coverage. For formal adoption, third-party testing under the cited standards and documented lot data are recommended.

8. Conclusion

A **heat-free, plastic-based, multi-layer coating** that is mechanically reinforced after curing, graded from rain resistance to full immersion, non-transparent for design protection and solvent-reworkable, offers a practical industrial route addressing environmental and mechanical stress together — a gap not fully covered by thin transparent films. Positioned within IPC-CC-830 and IEC 61086 frameworks and supported by documented testing, it suits automotive, industrial, marine, LED and unmanned-system electronics.

References

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5. IPC-TM-650, *Test Methods Manual* (e.g., Method 2.6.3, Surface Insulation Resistance), IPC.