Lamination Process for Flexible Electronics and LED Technology

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Flexible electronics are becoming increasingly important across the entire industry. Market analyses consistently promise economic growth for this revolutionary type of electronics. More and more groundbreaking new developments are being published, often preceded by many years of research and development work. Today, technical progress allows the integration of innovative concepts of flexible electronics into existing products. This enables the optimization of existing applications, but also the development of completely new product solutions. The automotive industry is considered an important pioneer for innovative technologies. Therefore, flexible electronics were used to make several future-oriented lighting and control concepts as well as new applications in the field of electromobility available in series production.

Flexible boards assembled with components are thinner and lighter than conventional solutions on rigid boards, which is why they save space and contribute to weight and therefore fuel reduction. But the versatility of flexible electronics also opens new opportunities for a wide range of lighting applications. Enormous flexibility and multifunctionality with minimal space requirements, innovative material combinations for PCBs (e.g., paper as PCB) and contemporary design possibilities for multidimensional light installations score points against conventional solutions on rigid PCBs. Flexible electronics enable a technological leap for artificial light and unusual lighting concepts in completely new dimensions.

Practical Problems

Novel manufacturing processes can be used to produce electronic assemblies and components that are noticeably light, thin, and extremely flexible. Unfortunately, problems often arise in practice. If an innovative development concept with the revolutionary nature of electronics is to make it from the initial idea to its implementation in the product, there are several hurdles to overcome.

First, the often technically complex electronic assemblies from the research must be made reliably reproducible in copious quantities for the industry. The path from a prototype to mass production can be tedious if the machine production processes must be repeatedly checked and adjusted if necessary.

An essential criterion for market maturity is the reliability and stability of the electronics. Compared to rigid modules, electronic devices on flexible substrates are quite fragile. They are very susceptible to damage due to the high sensitivity of the functional materials.

Handling problems may already occur during the assembly of the sensitive flexible units in the factory. In addition, various environmental influences can have a negative impact on the electronic components in use.

Proven Protection Methods for Electronics

Flexible materials equipped with different components for light and functionalities require reliable protection for a long service life. The lighting industry uses established technical methods to maintain the functionality of electronics under different operating conditions.

Basically, a distinction can be made between two methods of protection: Conformal coating and potting. Selecting the right type of protection against damaging external factors is difficult because it is an additional cost-relevant process in the production, which entails both strengths and weaknesses depending on the type and implementation. For an optimal result, the desired degree of protection for the electronics must already be kept in mind in the initial phase of design development.

Potting

Potting is the process of enclosing an entire PCB within its housing with liquid materials, often mixtures based on polyurethanes, silicones or epoxies. Potting can be done either manually or with a special machine. A potting compound with a material thickness >1 mm remains permanently as an integral part of the electronic unit. Thus, potting not only protects from external factors, but can also help conceal the intellectual property contained in the electronics.

PROS

- Good chemical resistance (epoxy)
- Good moisture resistance
- High electrical insulation
- High shock and vibration resistance
- High resistance to abrasion

CONS

- Material thickness reduces mechanical flexibility
- Resistance to abrasion may reduce flexibility
- Weight
- Big effect on optical transmission
- Difficult process whose success depends on many influences (humidity, temperature, sterility)

Coating

For the coating, special protective lacquers with a chemical composition often consisting of acrylic, polyurethane, silicone, epoxy or parylene are used. The protective coating with a material thickness <0.2 mm can be applied to the flexible boards using different methods: spray applications, vapour phase, dip applications, manually

with brushes, etc. The application can be carried out on the entire assembly or only selectively on the sensitive areas.

PROS

- Mechanical flexibility
- Very low material thickness
- Very low weight
- Little effect on optical transmission

CONS

- Weak chemical resistance
- Low moisture resistance
- Low electrical insulation
- No or little resistance to abrasion

Lamination Process: Strengths of Conventional Protection Methods Combined in a New Technology

Especially new markets and future-oriented applications with flexible PCBs demand high requirements that often cannot be optimally fulfilled with the established potting or coating methods. Depending on the application, a choice has to be made for one of the methods and disadvantageous factors have to be considered.

To enable an optimum of both established protection types, an innovative production process was recently established at the Lumitronix[1] factory to make the flexible electronic units more robust for challenging applications.

[1] https://b2b.lumitronix.com/en/

The Lamination Process Increases Mechanical Resistance

In the production line, flexible printed circuit boards equipped with components are laminated with several polymer materials that serve as a protective layer. Very large areas (W x L: 1 x 1.7 m) can be processed. Virtually "endless" products in a roll-to-roll manufacturing process are also conceivable in the future.

In the lamination process, the special plastic layers are applied to the front and back of the flexible PCB material by applying a high heat (temperature <250°C) and a high, consistent pressure. Depending on the intended use, the combination of the composite materials can be adjusted. The parts mounted on the flexible PCB are encapsulated, excluding almost all air residues in the composite material.

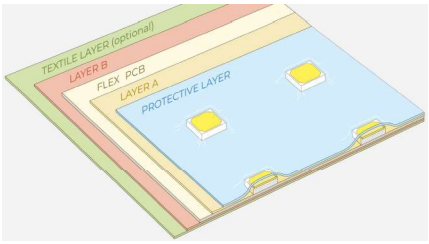

Figure 1: Schematic structure of a laminated LED module

After lamination, the mechanical resistance increases significantly and protects the electronics from physical stress, such as vibrations and shocks. Since only very thin layers are used (<0.6 mm per side), the flexibility of the module is still maintained. Depending on the PCB layout and the assembled components, a minimum bending radius <5 mm after lamination is still possible without causing the module to break.

The lamination can be exposed to temperature fluctuations. The protective layers can withstand continuous operation in an environment with temperatures of up to 120°C. However, electrical interference can also be safely repelled by the protective layers of the lamination. A high surface resistance ($10^{14}/cm^2$) and a high dielectric strength (>1 kV) are realized with the special plastics used.

The very thin layers of the lamination offer a high transparency of 92-94% on the top side, making the innovative technology perfect for complementing flexible assemblies with LEDs and/or optical sensors.

The photometric properties and light color of the components mounted on the flexible substrate are retained even under the protective coating. Compared to conventional protection methods, the shift in color temperature is only approx. 200 - 300 Kelvins. Since the material composite is highly resistant to UV radiation and at the same time offers high UV transmission, there is no yellowish effect even after prolonged use of the laminated assembly.

Securely Protected, Flexible Modules Withstand a Wide Variety of Environmental Influences

Moisture in the air or directly on an unprotected flexible assembly can impair the functionality of the electronics or even lead to failure. Moisture is considered the main cause of the often insidious corrosion processes, but various chemicals can also promote them. For example, so-called volatile organic compounds (VOCs) can reduce the performance and service life of LED-based lighting systems. Due to dust content and industrial pollution, the air con-

Figure 2: Example of a laminated flexible LED strip in operation.

tains countless particles and a wide variety of (non-visible) substances that endanger electronics in the form of positively or negatively charged ions. They can react with the processed materials, damage them or cause a short circuit. When used outdoors, the electronics are additionally stressed by the changing weather conditions with solar radiation, wind, or water. Furthermore, destructive damage can be caused by unwanted interference (encroachment) by users.

The innovative LumProtect® lamination technology provides reliable protection against a wide range of environmental influences while maintaining the functionality and flexibility of the electronic assembly.

The lamination provides protection against moisture, whereby the production process is aligned regarding the desired degree of protection. A very high level of protection in accordance with class IP67 can be achieved. Tests have shown that the special plastics used in the protective coatings are highly resistant to various chemicals and VOCs, which ensures the service life of the electronics both indoors and outdoors. Furthermore, the electronics are made robust against physical stress and can also largely ward off unauthorised tampering by humans.

Figure 3: Example of a laminated flexible LED strip.

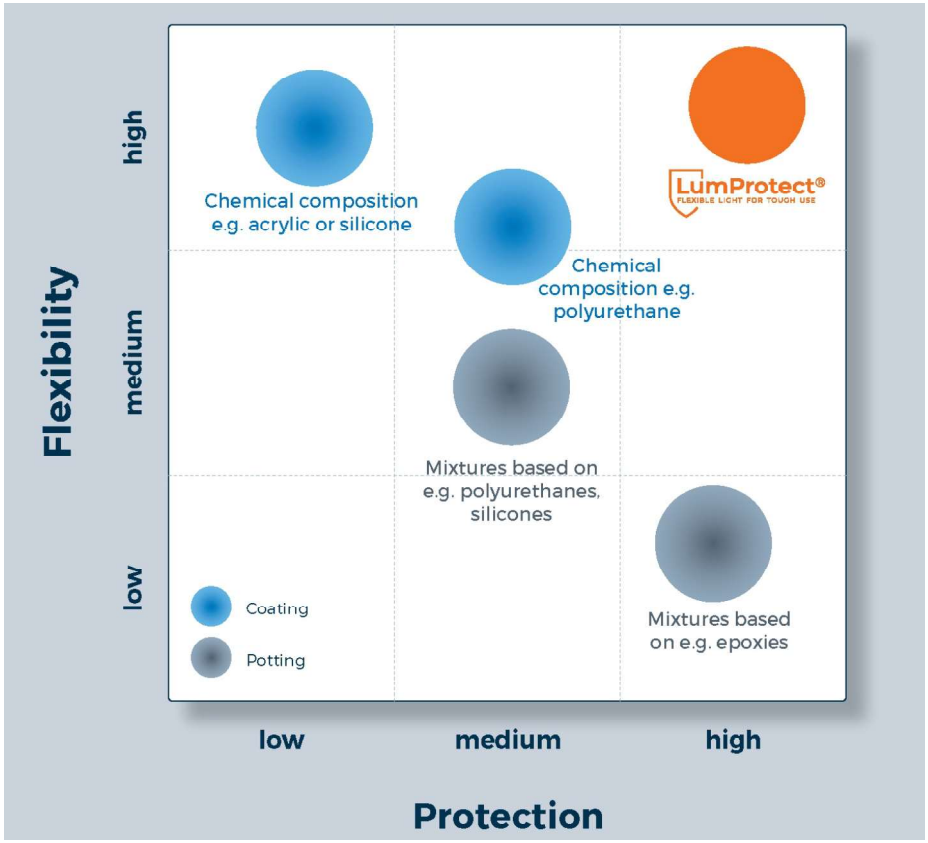

Figure 4: Comparison of coating, potting and laminated protection technologies.

Lamination

The lamination production method protects against humidity (IP67 possible), gases and dust, various chemicals, and physical stress and weather influences.

PROS

- Mechanical flexibility
- Very low material thickness
- High material transparency (92 – 94%)
- Little effect on optical transmission
- Very low weight
- Good chemical resistance
- Good moisture resistance
- High electrical strengths (>80 kV/mm, 4–5 V at 50 µm)
- High shock and vibration resistance
- High resistance to abrasion

CONS

- Limited by the maximum dimensions for components, parts with a height >2 mm are critical
- High process temperature can lead to restrictions in the selection of substrates
- Only for flex, so far, no suitable solution for rigid boards

Technology for Customized Solutions

Lumitronix offers the first laminated LED modules as standard products for common lighting applications, both surface modules and linear strips in different light colors. It is possible to laminate all existing flexible LED modules with LumProtect®.

The lamination technology further offers the possibilities for customization of certain technical parameters. By adapting the layers within the material composite, different designs and colors of lamination can be offered with a kind of textile. The upper layer always remains transparent but can be produced as a structured or smooth surface. Different connection and sealing options with cables, plugs, eyelets & crimp contacts allow easy integration of the laminated assembly into the system.

The current technical parameters of the lamination process are particularly oriented towards the requirements of the lighting industry. Since the production process is carried out 100% at the Lumitronix site, other adaptations for challenging applications can be realized together with customers within the scope of development projects. ■

