Structural Electronics for Automotive Interiors

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Abstract
This paper presents the results from a joined R&D project between two companies: Automotive Tier-1 and Technology Provider of structural electronics. The key benefits of structural electronics are three-dimensional shapes, reduced thickness and weight as well as simplified assembly. The purpose of this project has been to evaluate structural electronics for automotive interior use. The car interior application is a back-seat-control-panel. The structural electronics solution reduces thickness by 70% and weight by 50%. The back-seat-control-panel has been subjected to severe testing based on automotive OEM requirements. Environmental loads have been change of temperature, combination of high humidity and change of temperature as well as combination of UV light and high temperature. None of the components failed during reliability testing.

Introduction to Structural Electronics
Structural electronics enables design innovation by integrating electronic functions into three-dimensional injection molded plastic structures. Features, such as controls, sensors, illumination and communications, are embedded in thin 3D structures with plastic, wood and other surfaces.

The structures are light, thin and durable. In conventional use cases, such as an in-vehicle control panel, a single part replaces a multi-part conventional electronics structure and eliminates labor-intensive electro-mechanical assembly. The part also weighs less and is significantly thinner. The Technology Provider has demonstrated structural electronic designs with 70% weight and 90% thickness reduction when compared with conventional multi-part assemblies, Figure 1.

Introduction to Structural Electronics Manufacturing
A typical structural electronics solution consists of electronic film on the bottom carrying conductive inks, dielectrics, and surface mounted electronic components. On the top, there can be either surface film with decorations or a natural surface such as wood. Everything is injection molded to one-piece assembly. Figure 2 shows an illustration of materials in structural electronics design.

Figure 1. Structural electronics control panel design demonstrates 70% reduction in weight and 90% reduction in thickness when compared with conventional multi-part assembly.

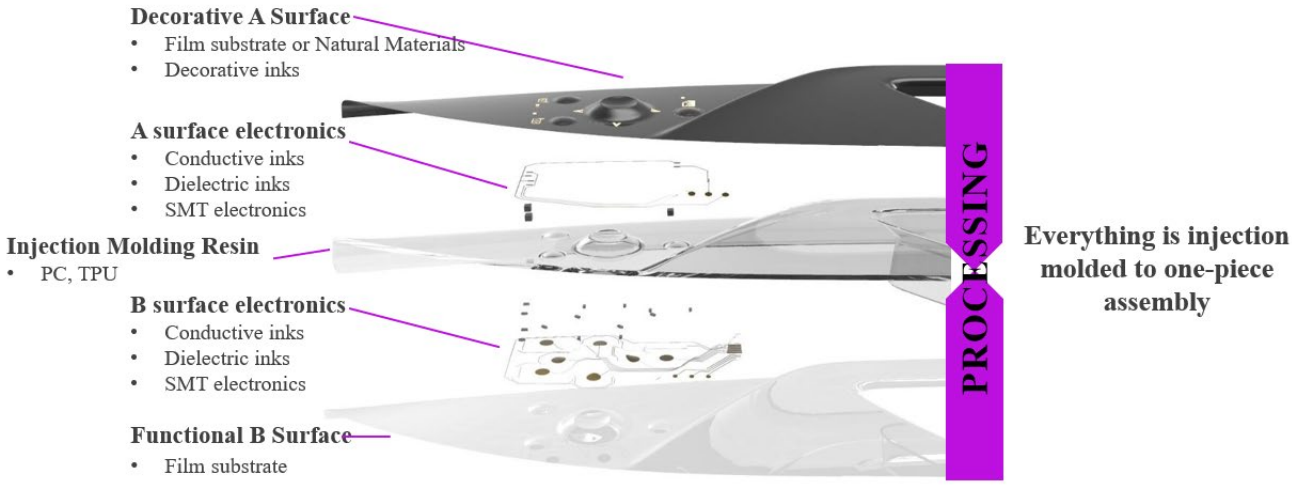

Figure 2. Illustration of materials in structural electronics design

Depending on the use case and functionality, structural electronics can also be one-film design. One-film design has an electric film on the back or front side of the part. When using only back-side-film, we create visual surface by post process on top of injection molded resin. When using only front-side-film, we print both graphics and electronics onto the same film.

The structural electronics design can be illustrated also as a material stack. Figure 3 shows an illustration of a material stack in a two-film design. Material stack is the combination of films, inks, electronic components, surface mounting adhesives and injection molding (IM) resin.

The core manufacturing processes for structural electronics are printing, surface mounting, forming and injection molding, Figure 4. Taken individually, these processes are mature and use standard equipment suitable for mass production. However, the standard processes are combined in a unique way during manufacturing.

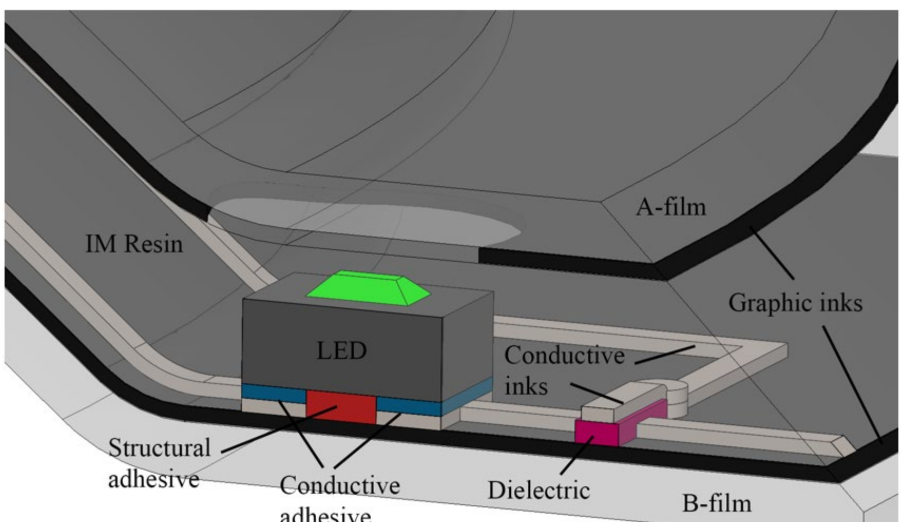

Figure 3. Illustration of a material stack in two-film design.

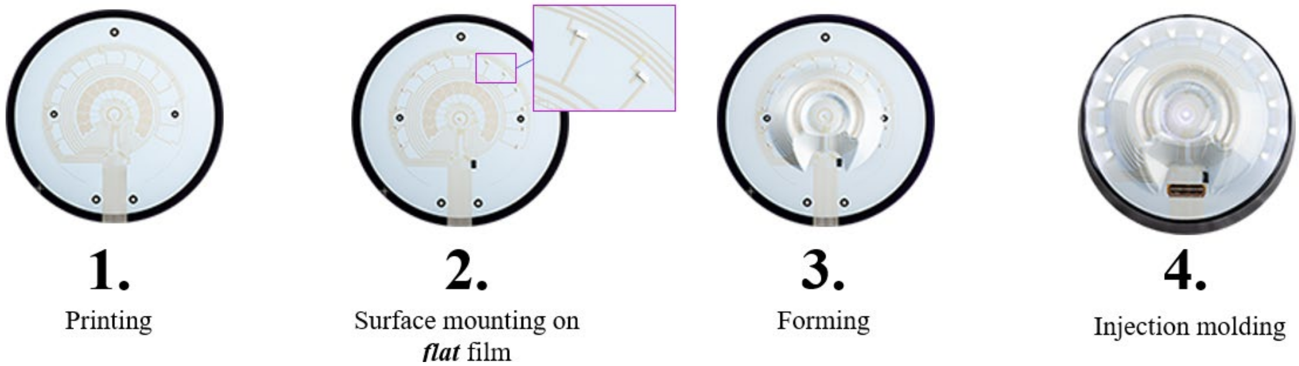

Figure 4. Core manufacturing processes for structural electronics

The first core manufacturing process is printing. The Technology Provider uses screen printing because it is suitable for mass-production and enables appropriate layer thickness (range of 10 µm). Electronics (functional inks) and decorations (graphic inks) are screen printed onto a plastic film or another suitable substrate material. Electronics are typically printed using silver (Ag) conductive inks and dielectric inks to insulate between layers of circuitry.

The second core process is surface mounting. Components are placed and bonded onto electronic films. Conductive and structural adhesives are used for electrical and mechanical bonding. The output is a two-dimensional film substrate with components.

The third core process is forming. Two-dimensional electric and decorative films are thermoformed into a three-dimensional shape and trimmed as needed. Outputs are 3D electric films with components and 3D decorative films. Forming is not used in conventional electronics manufacturing. During forming, component packages are subjected to elevated temperatures and pressures. The maximum temperature depends on the polymer film. Typically, it is below 150 °C. The maximum pressure is typically below 8 MPa (80 bar).

The fourth core manufacturing process is injection molding. Three-dimensional electric films and 3D decorative films are used as inserts in an injection molding tool. Resin, such as polycarbonate is injected between the films resulting in a single molded part. The output is a strong and durable structure, in which electronics are encapsulated within the molded plastic. Injection molding is not used in conventional electronics manufacturing, either. Some molding temperatures are higher than the peak temperature during reflow soldering of SAC solders. In addition, heat transfer from hot resin to electric films is through conduction. Thus, heat transfer to components and other materials is more efficient than during reflow soldering. Maximum pressures during injection molding are around 100 MPa (1000 Bar).

We give more detailed description of structural electronics manufacturing process in other publications [1, 2]. These references also outline requirements for components and surface mounting adhesives.

Back-Seat-Control-Panel Design

In this R&D project, the car interior application is a back-seat-control-panel, Figure 5. It controls a smart seat that has adjustable temperature and can even give a massage. This control-panel utilizes typical features in structural electronics, Table 1. The design is complex, and thus helps to understand the limitations of this technology.

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[1] Simula, T., Niskala, P., Heikkinen, M., Rusanen, O. Component Packages for IMSE (Injection Molded Structural Electronics). 2018. Proceedings of NordPac Annual Conference, Oulu; Finland, June 12-14, 5 p. Available at: https://tactotek.com/wp-content/uploads/2018/08/componentpackagesforimse_tactotek_v1.3_fortactotekweb.pdf

[2] Rusanen, O., Simula, T., Niskala, P., Lindholm, V., Heikkinen, M. 2019 Injection Molded Structural Electronics Brings Surfaces to Life. Proceedings of European Microelectronics Packaging Conference, Pisa; Italy, Sept 16-19, 7 p. Available at: https://tactotek.com/wp-content/uploads/2019/09/empc-presentation-for-tactotek-web_1939.pdf

The structural electronics solution is a two-film design. It integrates printed electronics and over 100 electronics components inside injection molded plastics. Most of the components are LEDs, either side- or top-emitting. The size of the solution is approximately 100x180 millimeters, and it is about 5 millimeters thick. The structural electronics solution reduces thickness by 70% and weight by 50%.

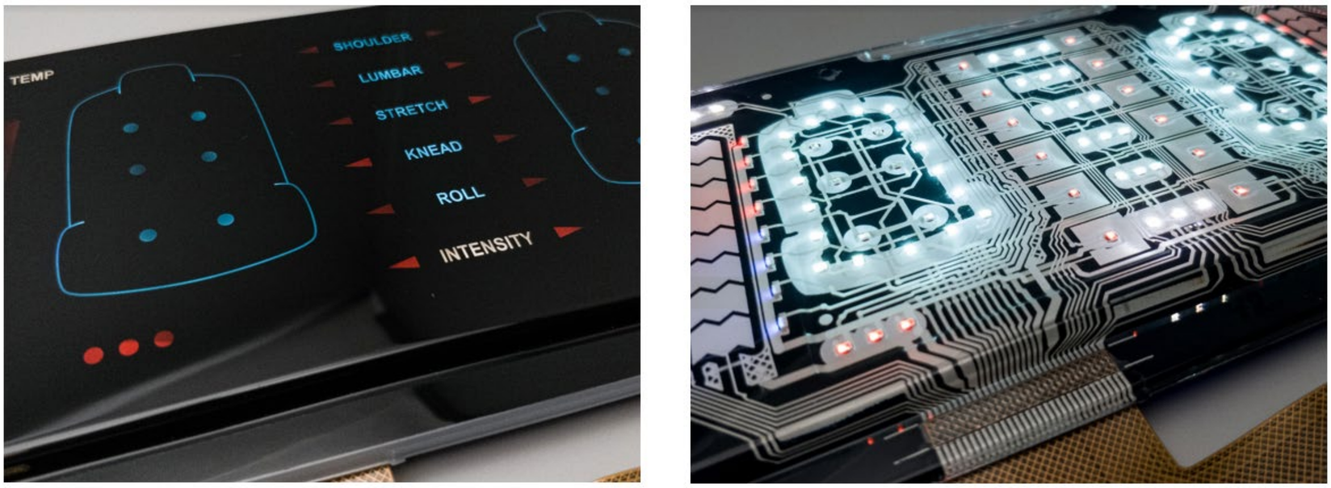

Figure 5. On the left: the back-seat-control-panel. On the right: the same panel with clear A-film and injection molding resin so that electric components are visible.

Table 1. Typical features in structural electronics and their utilization in back-seat-control-panel

Structural Electronics Feature	Utilization in back-seat-control-panel
Controls (with illumination)	12 capacitive buttons (12 blue dots) 2 capacitive sliders (with blue and red lights)
Illuminated icons and text	Blue and white texts Red arrows Blue and red sliders Blue contour line and massage dots
3D surface	Part internal structure has high curvatures, user interface has low curvatures. Figure 5 shows the user interface curvatures.

Results of Reliability Testing

The Automotive Tier-1 company subjected the back-seat-control-panel to severe testing based on automotive OEM requirements. Environmental loads were change of temperature, combination of high humidity and change of temperature as well as combination of UV light and high temperature. Figure 6 shows a summary of reliability testing. None of the components failed in the tests.

Two control-panels were also subjected to chemical substances: acetone and sugary drinks. The chemical substances did not cause any visible degradation on the control-panel surface.

Results of Analysis

In addition to reliability testing, it is important to analyze the components and materials. The following chapters explain the studies done by the LED and injection molding resin suppliers.

The LED supplier made an extensive study on their components after reliability testing. They did not find any abnormalities of optical and electrical characteristics. They concluded that LEDs are not impacted by structural electronics manufacturing processes.

The injection molding resin supplier made an extensive study on their material: a dispersive (i.e. milky) polycarbonate. They prepared samples and aged some of them in 105 °C for 500 hours. Then they measured the transmission spectrum for non-aged and aged samples. Figure 7 shows that the transmission spectrums are similar.

Thermal Shock

- Temperature cycling -40 °C … +85 °C.
- Modules are powered off.
- Test duration is 300 cycles.

624 LEDs were tested and none failed.

Damp Heat Cyclic with Frost

- 93%RH,
- There are two types of thermal cycles, +25 °C … +65 °C, and -10 °C … +25 °C.
- Modules are powered on.
- Test duration is 240 hours.

624 LEDs were tested and none failed.

Incremental Temperature Test

- Temperature is cycled at 10 °C steps, between -40 °C and +85 °C.
- Modules are powered on.
- Test duration is 240 hours

208 LEDs were tested and none failed.

UV Exposure Test

- UV irradiation is 1.4 W/m^2 at wavelength of 420 nm.
- UV irradiation raises chamber temperature to about 100 °C.
- Modules are powered off.
- Test duration is 150 hours.

624 LEDs were tested and none failed.

Figure 6. Summary of reliability testing

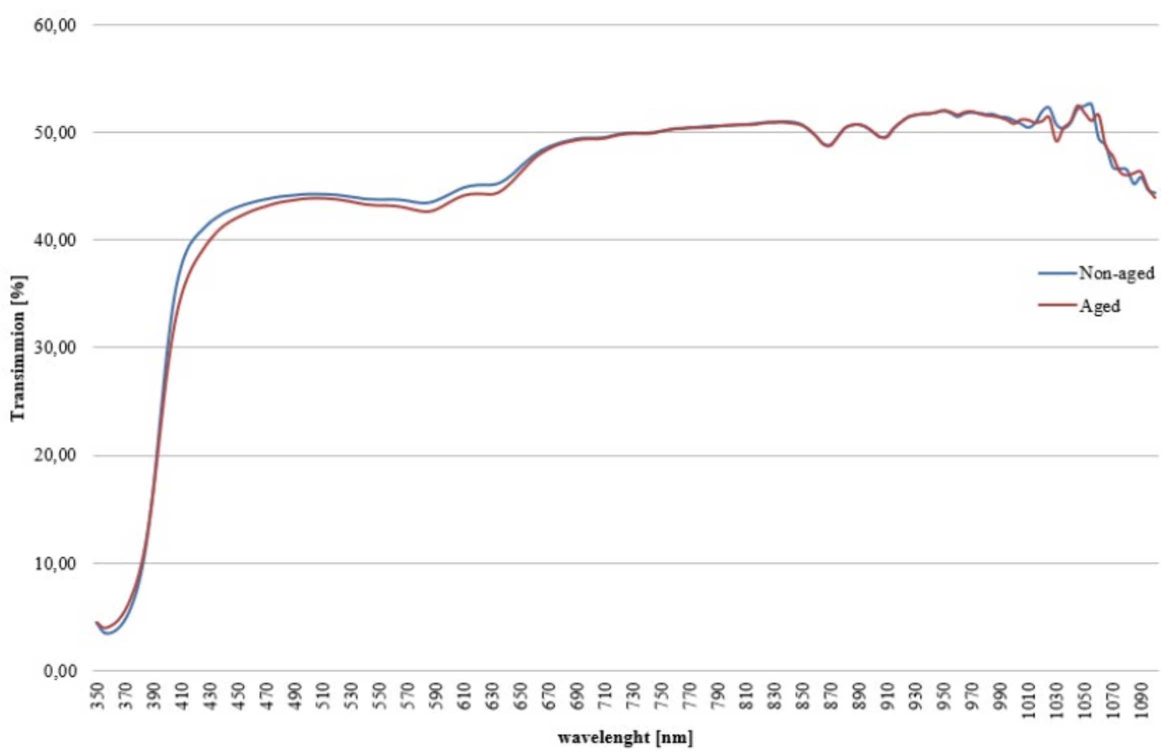

Figure 7. Transmission measurements for injection molding resin material, sample thickness is 3 mm[3]. The transmission spectrum is similar for non-aged and aged samples. Table 2 shows the relevant wavelengths for blue, red and white LEDs.

Table 2. LED 10% relative emission intensity range for blue, red and white light [4]

Color	LED 10% relative emission intensity (nm)
Blue	445–495
Red	610–780
White	430–670

Conclusions

The key benefits of structural electronics are three-dimensional shapes, reduced thickness and weight as well as simplified assembly. For the back-seat-control panel, the structural electronics solution reduces thickness by 70% and weight by 50%.

This control-panel has been subjected to severe reliability testing based on automotive OEM requirements. Environmental loads have been change of temperature, combination of high humidity and change of temperature as well as combination of UV light and high temperature. None of the components failed during reliability testing. Studies done by LED and injection molding suppliers did not show any adverse effects on LEDs or injection molding resin.

Acknowledgements

The authors thank the project teams at Faurecia and TactoTek for their important contribution in this work. We also thank Nichia and Covestro for their much-valued analysis on LEDs and injection molding resin.

[3] Covestro measurements for dispersive polycarbonate injection molding resin.

[4] Nichia specifications for relevant LEDs.