DESCRIPTION OF THE CHALLENGE

The challenge put forward by MAIER is titled: ***How can emerging technologies be integrated into the plastic injection process to improve the ambient lighting of the car interior and thus increase the safety of users?***

This challenge addresses the needs described below:

- How to design flexible printed electronics to be integrated into a decorated automotive plastic part with multiple functionalities?
- How to transform conventional rigid electronic technology into flexible electronic technology?
- How can electronics be integrated into MAIER's plastic injection process?
- How to provide a good balance between weight, space and cost for automotive components?

Background

The **electronic revolution** is bringing about an abrupt change in the automotive sector. The evolution and miniaturisation of electronic systems has meant that vehicle design has changed significantly since the 1970s, when the electronics in a vehicle were limited to the radio equipment, to today's vehicle in which electronic components are essential (drive systems, safety, detection) and represent **35% of the final price of the vehicle**. In addition, technological advances in electronics will shape and may even influence future vehicle designs and will undoubtedly lead to an evolution in the overall concept of vehicles. Thus, it is forecast that new developments and technologies will lead to the cost of integrated advanced electronic functionalities with respect to the total cost of the car reaching almost **50% of the final price of the vehicle by 2030**, as shown in the following picture:

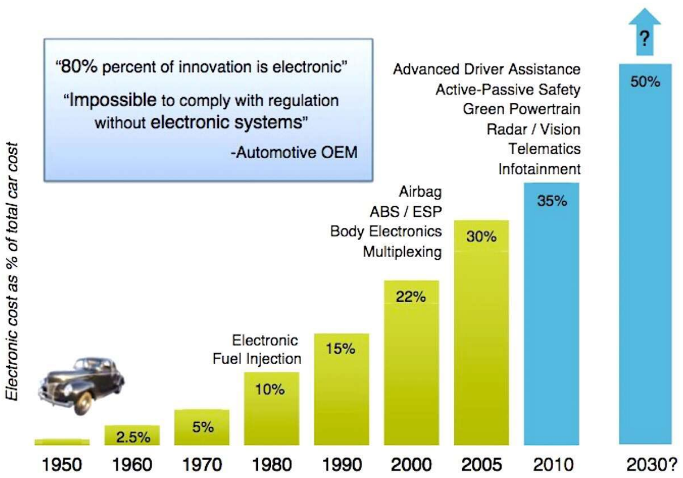


Figure 1: Evolution of the cost of electronics in the total cost of the vehicle

These expectations are based on the **market potential** of four distinct lines:

- **Infotainment**: vehicles are increasingly incorporating technologies related to **interactive entertainment**; functions such as video playback, mobile phone connectivity and interaction, Wi-Fi connections, etc.
- **Performance, fuel consumption and environmental sustainability**: this line is more oriented towards mechanics and the engine, such as engine control modules and start-stop functions, without forgetting the developments being made in hybrid and electric vehicles.
- **Active and passive safety**: solutions such as air-bag systems, automatic emergency connection in the event of collision, electronic traction control, electronic stability control, etc.
- **Aesthetics and comfort**: although solutions have been implemented along these lines, such as climate controls and noise cancellation, this is an area **yet to be explored and will be an important differentiating factor for the next generation of consumers**. In this sense, different OEMs have defined this line as a key trend for the future. Thus, they are focusing their attention on **concepts that bring aesthetics and comfort to their vehicles**. The vehicle's **interior lighting** concept stands out in this respect.

Within this last line, one of the technologies with the greatest potential is the evolution towards new concepts of **ambient lighting inside the vehicle**, in addition to traditional functional lighting. As an example, it is worth noting that, in recent years, some manufacturers are starting to **offer, in very limited series, interior ambient lighting as an additional feature of the vehicle**.

Interior ambient lighting is generally considered to be a purely aesthetic feature, which does not serve any inherent safety function of the vehicle. However, according to a study carried out by BMW and the *Lighting Engineering Group* of the Ilmenau University of Technology in Germany, **interior ambient lighting has the potential to enhance the safety of users**. In addition, the study demonstrated how interior ambient lighting can increase spatial perception, making the vehicle interior appear larger at night. Similarly, according to the study, interior ambient lighting can also reduce fatigue when driving a vehicle equipped with lighting at night. And also, according to the study, vehicle users believe that **ambient lighting in the vehicle interior increases the perceived quality** of the materials and the design of the car itself.

In fact, there are several specialised departments in reference centres (such as the Fraunhofer IAO) that **analyse its potential use to improve the travel experience** by means of colours as a stimulus for drivers and passengers, lighting systems that prevent dizziness and indisposition during journeys, or its potential use in autonomous vehicles as a means of interacting with the user to warn of dangers or the need to take control of the steering wheel again. In this way, it is expected that the future of vehicle interiors will be one of complete interaction between the user and the vehicle by means of a **smart ambient lighting system that accompanies the vehicle user and can adapt to different situations**.

In short, **advanced ambient lighting electronics will allow for greater integration in the way the user interacts with the vehicle**, not to mention providing an **aesthetic effect in the vehicle's interior**.

Figure 2: Interior ambient lighting

Therefore, the design of **interior ambient lighting** is becoming increasingly important, both from the **point of view of aesthetics and vehicle user comfort**.

As a clear symptom of this trend, it should be noted that **concept cars from the market's leading OEMs** already feature such ambient lighting systems:

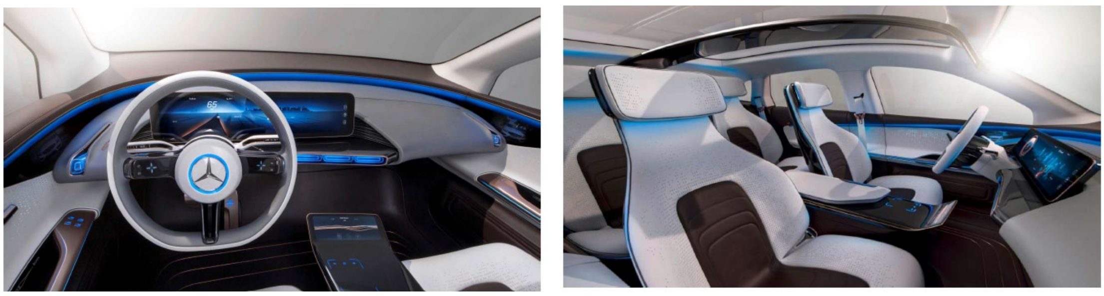


Figure 3: Mercedes EQ concept car

Figure 4: Audi AICON concept car

Figure 5: BMW Quant Concept F concept car

Figure 6: BMW Vision iNext concept car

Figure 7: Geely Ge11 concept car

Needs

There are three main requirements for the incorporation of electronic functionalities such as interior ambient lighting in the vehicle using conventional technologies:

- **Weight of the components.** Weight is becoming a critical factor in today's vehicles, in which electronics are increasingly present. Conventional electronics is based on the use of rigid PCBs with a thickness of 2-3mm and a certain weight. Traditional cabling is exceptionally heavy and bulky. Likewise, printed circuit boards are bulky and require a rigid support for mounting.

- **Space.** Conventional electronics components take up a lot of space (flat and rigid boards and wiring). In addition, the part where these conventional electronic components are assembled has a certain curvature, it is not flat, which leads to a loss of space.
- **Cost.** The assembly and mounting of conventional electronics in their environment involve a large number of operations that are normally carried out manually, which undoubtedly adds to the cost of the final product.

As an example, the following image shows the elements of conventional electronics that would be mounted on a real part (lower part of the image) with a high number of assemblies:

Figure 8: Conventional electronic elements for manual mounting and assembly on a real curved part.

Therefore, there is a need to transform conventional rigid electronics technology into electronics technology that provides a **good balance between weight, space and cost** for automotive components.

The great versatility and freedom in design offered by flexible printed electronics compared to conventional rigid electronics has led to a rethinking of the manufacturing processes for products and components. Thus, new technologies are emerging that are taking on a prominent role among the technological developments that different sectors, such as the automotive sector, are betting on and investing in. Among these emerging technologies, **IME (*In Mould***

***Electronics*)** technology, based on the combination of **flexible printed electronics and IMD (*In Mould Decoration*) technology**, stands out. Today, it is not a productive technology used in the automotive sector; however, it has **great potential** to replace conventional electronic components, as integrating **printed circuit boards and discrete electronic components within plastics** allows for design freedom that is totally disruptive to current technology. Thus, this technology allows:

- Achieving electronic functions in 3D contours.
- Parts with a thickness of less than 2 mm with electronic functionalities.
- Electromechanical interface.
- Monolithic manufacturing simplified to a single part, without the need for assembly operations on the production line.

In addition, IME technology provides a significant **reduction of the system's weight** (the flexible electronics have a reduced weight) as well as **design freedom** and the **speed of the IMD process**, where electronics assembly and injection moulding are available in a single operation. Therefore, **IME technology** shows the most promise in the **automotive sector** by offering the **capabilities of flexible and printed electronics in complete solutions**.

Thus, the emergence of EMI technology is expected to revolutionise this sector by allowing aesthetic finishes to be combined with functional elements in the same production cycle of the parts in question. In particular, the possibility of integrating **sensors and lighting devices into the surface of plastic parts has created a new trend in vehicle interior design**.

As mentioned above, *In Mould Electronics* (IME) is a technology that enables **transforming conventional thermoplastic parts into thermoplastic parts with smart surfaces by integrating printed circuit boards and electronic components into injected 3D parts** using consolidated industrial manufacturing techniques such as injection moulding. **IME technology research** is based on:

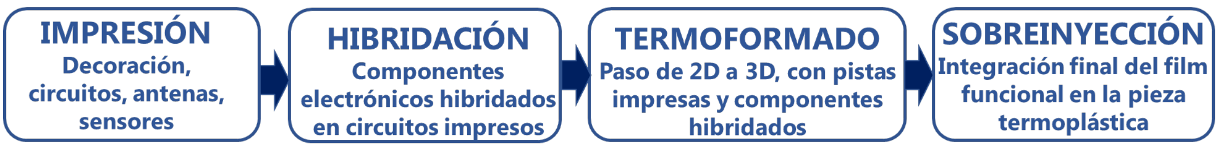


Figure 10: Basic stages of IME technology

IME technology, for which there is currently **no implementation in the automotive sector**, would meet the objectives set out, and is therefore proposed as a base technology that will allow electronic products to evolve towards greater integration. However, this technology is **not yet 100% developed** to the level of being able to contract it.
Currently, **these are stages that separately are industrially accessible and mature**, but the **interrelation between them in a single IME process is not consolidated** as a robust process where the lack of repeatability and compliance with requirements or specifications for the automotive market stand out. The **biggest gap** identified in this IME technology is **in the over-injection step** where the extreme conditions of temperature and pressure make it impossible to ensure the established requirements and repeatability of the function obtained.

Objectives

The ultimate goal for MAIER is to develop the technology that allows the integration of electronic elements into plastic components, to **develop vehicle interior parts with advanced lighting electronics and to be able to respond to the needs of the vehicle of the future**.

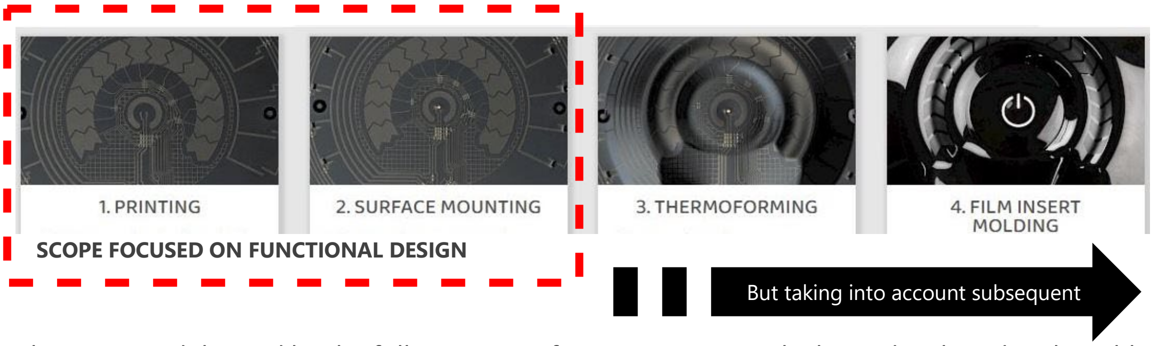
The overall objective of the development of this technology would be:

- To ensure that parts with advanced lighting electronics have the **ambient lighting functionality and aesthetic finish** required by the industry.
- The lighting should have a **decorative component, change its intensity** and **warmth** and be **compatible** with the **lighting of the entire vehicle interior**.
- The lighting should be **integrated for safety purposes** while driving (activated when the proximity sensors are triggered by the vehicle in front or in case of an alarm/warning on the dashboard…).
- To achieve an **electronic technology** that provides a **good balance between weight** (60% lighter than traditional PCB solutions), **space** (80% less bulky) and **cost** of its components for the automotive sector.
- To achieve totally disruptive **freedom of design** for interior parts with flexible electronics developed based on IME technology.
- To design **printed electronics and electronic materials** (inks, substrates, screens).
- To achieve **chemical compatibility between the flexible electronics and the thermoplastic material** of the injection moulded part so that there is **good adhesion** between them.
- To achieve **functional and decorative inks that support IME processes** with the geometry of the target part of the project.

- To ensure that the **components** can be used in the manufacturing processes by **injection moulding of thermoplastic parts**.

__Scope of the pilot project__

The required scope of the challenge would be defined by the company being able to **address the functional design of the film electronics**, but taking into consideration subsequent overmoulding processes:



This scope is delimited by the following specific requirements, which are developed in the table of requirements and characteristics for the design guide below:

- **Ability to define the design** of the film electronics (both the circuit and the specific components required).
- **Ability to define the IME process** that is **compatible with the overmoulding process** or, at least, that gives the keys for the definition and manufacture of the film for subsequent processes.
- **Proposals for a design guide** to **help define together with MAIER** the **new mould standards** to facilitate the overmoulding process without affecting the functionality of the electronic system.
- The aim is that the design can, in the future, be **implemented in specific products** inside the vehicle interior. A target part could be the interior surface on the centre console or a door trim in the car's interior.

Figure 9: Interior surface car

Figure 10: Car interior door trim

Table of requirements and characteristics for the design guide:

Variable	*Functional need*	*Weighting*
1. Film electronics design requirements	1.1. To achieve totally disruptive freedom of design for interior parts with flexible electronics developed based on IME technology.	Requirement
	1.2. Achieve an electronic technology that provides a good balance between weight (60% lighter than traditional PCB solutions), space (80% less bulky) and cost.	6
	1.3. Definition of electronic materials (inks, substrates, screens…) compatible with IME technologies,	9
	1.4. Ensure chemical compatibility with the thermoplastic material of the injected part.	9
	1.5. Ensure the functionality of the electronic system (prior to the injection process)	Requirement
	1.6. Consider the compatibility of the film electronics with other mechanical components used in the overmoulding process, such as moulds and injection moulding machinery.	6
2. Standard definition requirements for integration into moulds.	2.1. Mould design must consider requirements such as mould geometry, injection points, orientation and distribution itself of the material.	6
	2.2. Consideration must be given to the design of the film electronics to ensure that the	9

	mould allows for the correct insertion and positioning of the electronic components. This includes considerations such as the position and spacing of components, the orientation of boards and the selection of mounting materials.	
	2.3. The guide should address the characteristics of the materials used in the mould, such as hardness, resistance and thermal conductivity.	3
	2.4. The guide should include recommendations for mould and process validation and testing.	3

NEXT PHASES

The challenge focuses on the **development of an innovative design guide for film electronics, with the aim of making this technology compatible with injection moulding processes**. The goal is to achieve the integration of film electronics and injection technologies, ensuring that components function optimally and reliably before and after the process. To achieve this, it will be essential to establish **close collaboration with MAIER's engineering and production teams**, working together to identify and overcome technical challenges.

Once the challenge has been overcome with the defined scope, **more advanced stages, close to the production of embedded electronic systems**, **can be tackled**, allowing work on the entire process up to overmoulding. The **ultimate goal** is to **work hand in hand with MAIER throughout this process**, from design conception to implementation on the production line, ultimately ensuring compliance with the demanding requirements of the final product in the automotive sector. This partnership **will provide the opportunity to access product volumes in the automotive market** ranging from a minimum of **10,000 units per year** to **up to 200,000 units per year**, which would result in a significant boost and strengthening of the selected company's position in the sector.

It is crucial to highlight the **enormous potential of this technology** and its **applicability in a wide range of products** requiring embedded electronics systems **beyond the automotive sector**. Flexible film electronics can open up new market opportunities in industries such as **aerospace, medical, consumer goods and others**. The adoption of this technology in different sectors would allow the selected company to **access a broader spectrum of players**, driving growth and innovation in multiple fields, positioning the selected company among the leaders in the development of film electronics.

REFERENCES

1. The impact on vehicle cost resulting from greater automotive electronic content. Source: Freescale Semiconductor)
2. DVN, BMW's New Ambient Lighting; September 8, 2022. Source: www.drivingvisionnews.com/news/2022/09/08/bmws-new-ambient-lighting/