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1. Executive summary

The project addresses the development of two demonstrators integrated on flexible substrate including communication, control, sensor, intelligence, energy harvesting, light emitters and storage. They are a light-emitting autonomous info-panel and an autonomous taillight for automotive purpose. The outcome will be implemented in heterogeneous mass-manufacturing processes based on the integration of both printing and laminating technologies, which facilitates considerably lower fabrication cost than today's solutions. The complexity of expected prototypes will be improved, starting from a simple device to a more complex in terms of integration level, functionalities, processes, components, materials, applications.

- **Info panel:** the final demonstrator has been successfully manufactured. The prototype is a parking indicator composed by an alphanumeric and bi-chromatic (red and green) variable LEDs matrix showing a 4 letter words (FREE/FULL) integrated in a plastic substrate. The prototype has been characterised with optical and thermal cycles in order to follow the current regulations.

- **Lighting:** the final demonstrator has been successfully manufactured. The final demonstrator is a flexible HMSL and a RCL composed by signal lamp function (as RCL different functions as direction, stop, reverse signal and brake indicators) that respects all the specifications and the regulations of the automotive sector. The LEDs matrix, batteries, PV cells and electronics on plastic foil.

2. Project context and objectives

Within PRIAM the consortium will aim at transforming lighting systems from passive to active and able to work autonomously for more than 15 hours. The benefits for the population is straightforward increasing security, comfort and energy saving with a minimum cost to transform the existing infrastructure in that the existing panels will only need to be covered with the novel thin film signs. The project addresses the development of two new product families:

- Light-emitting autonomous road signs
- Autonomous car signals and tail lights

2.1. The Road-signs and taillights market situation

In 1968, the European countries signed the Vienna Convention on Road Traffic treaty, with the aim of standardizing traffic regulations in participating countries in order to facilitate international road traffic, to increase road safety and standardise the road signs. Amendments, including new provisions regarding the legibility of signs, priority at roundabouts and new signs to improve safety in tunnels were adopted in 2003. The principle of the European traffic sign standard is that shapes and colours are to be used for indicating same purposes. The convention however specifies a difference between motorways and ordinary roads. The Vienna Convention and the United Nations Convention on Road Traffic standardize the lighting systems for cars in terms of colours, functions and emission intensity; generally, but with some global and regional exceptions, lamps facing rearward must emit red light, lamps facing sideward and all turn signals must emit amber light, lamps facing frontward must emit white or selective yellow light, and no other colours are permitted except on emergency vehicles. Although some solutions of autonomous illuminated signals already exist on the road, these are a simply assembly of different components and not a real integration into a single system. Consequently the multi-functionality is allowed by incorporation, and not integration, of components such as lamps modules, rigid PV cells or lighting systems. A roadmap for signalling is shown in the Figure 1.

Figure 1 - Signalling Roadmap

The rear lighting systems must present different information translated into five lights functions: Rear position lamps and stop lamps (only red light and may be combined with the vehicle's brake lamps producing brighter red light), Centre High Mount Stop Lamp (from 1986, red rear turn signals identical in appearance to brake lamps and no flash are permitted), Reversing lamps (white light and amber permitted). An example to reduce the overall dimensions of taillight systems have been proposed in 2009 by CRF integrating LED dice into an array of micro-optical elements, serving at the same time as a package for the light sources and to perform specific optical functions. The advantages of this approach are: control of light distribution, reduce thickness (from 15 cm to 2 cm), design flexibility and stylistic appearance. The evolution proposed within PRIAM consists on the integration of communication sub-system, energy harvesting and storage sub-systems. As for the road-signs, the PRIAM activities will be focused on short-midterm technologies to force market penetration within next years. The technology roadmap of the proposed taillight systems is shown in Figure 2

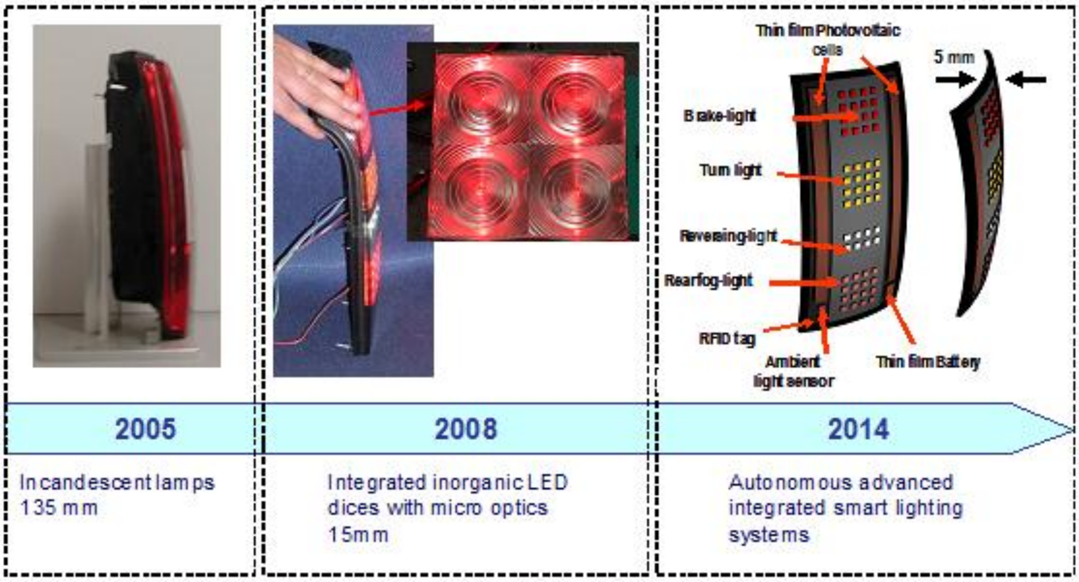


Figure 2 - Car rear lighting system Roadmap

2.2. PRIAM objectives

The integrated systems, as aimed in the PRIAM, integrate the following components in a single plastic foil:

- A solar cell
- A thin film battery
- Solid state light sources
- A sensor of ambient light detection
- A Radio Frequency (RF) communication element and
- An energy management processing unit.

These targeted systems comprise the founding elements of the PRIAM technology: the advanced integration of heterogeneous functionalities by homogenous processes. The development of the two new products is proposed by an evolutionary manufacturing approach based on roll-to-roll. That is at first the consortium will start with the advanced integration of existing functionalities, here named Building Blocks (BBs), on a flexible plastic substrate by using the synergy of different technologies such as lamination, printing, attaching, bonding, encapsulation and UV curing.

To get the expected outcomes the PRIAM project has been mainly oriented to pursue two aims:

A. Demonstrators based on the integration of heterogeneous Building Blocks (BBs).

Development of new devices concerning intelligent signalling based on flexible alfa-numeric letters (ASCII code) and autonomous lighting modules thought:

- selection and assembly of high performance BBs for their integration on the substrate (Photovoltaic film, battery, photodiode, LEDs, processing unit, RF link).
- preparation of the substrates and printing of the basic electrical and connection circuits.
- integration of all BBs into the substrate by homogeneous one step technologies (lamination/interconnect) such as lamination/bonding and printing.
- Development of the embedded algorithm to manage energy harvesting, storage and flow amongst the BBs for maximum autonomy of the device.

The autonomous and intelligent device, based on targeted integration, get benefits in comfort, security and energy saving.

B. Foil lamination/interconnection manufacturing processes.

Enhancement of a reliable technique combining printing and the roll-to-roll process enable the integration of BBs (such as batteries, electrical connections, RF, light sources, PV thin film cell and antenna) on a single foil integrating a processing unit managing the energetic flows.

- Combine lamination, printing (ink-jet and screen), bonding and encapsulation to integrate different functionalities on either a flexible or rigid foil.
- Transfer the developed approaches to a roll-to-roll platform. The use of a roll-to-roll process assures high throughput processing and production flexibility. The roll-to-roll approach will consider sophisticated methods for process control and characterisation such as electrical tests, optical measurements, thickness measurement and coating uniformity.
- Preliminary design of new production lines and upgrading of existing ones.
- Selection and optimization of suitable materials (inks) to print basic electrical circuits and connections on flexible substrate, for bonding (conductive epoxies and pastes) and laminating (adhesives) technologies
- Stimulate the development of new substrates and functional materials for future standardisation evolution of the technology consisting of all functions directly printed on same foil.
- Enabling high volume production of the two prototypes
- Enabling integration of other micro-fabricated modules

The major innovations are to provide new production concepts of plastic foil based devices with advanced integration of different functionalities. The existing technologies, based on a roll-to-roll concept, have been first adapted and upgraded to reach the PRIAM objectives. High throughput of roll-to-roll concepts, combined with bonding, lamination and printing processing will reduce the manufacturing cost compared to standard batch processing and patterning up to 50%. As already anticipated the crucial aspect is to master materials, BBs and process techniques to manufacture compact, efficient, robust and low cost multifunctional devices.

2.3. The PRIAM demonstrators

The main objective of PRIAM is the development of demonstrators as new autonomous road signals and lighting modules (taillight), integrating heterogeneous functionalities on plastic foils. Specifically the project addresses the development of two prototypes integrating on a flexible substrate: energy harvesting and storage, communication, control, sensor to measure light intensity, intelligence and light emitters.

Table 1 shows list an overview on specifications of BBs and overall devices of two proposed demonstrators, as at the beginning of the project.

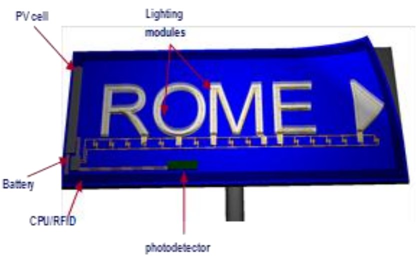
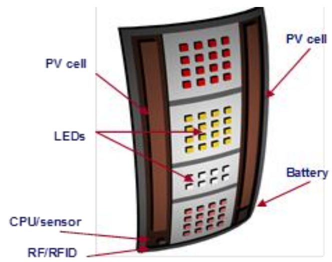
	Signalling *Flexible multifunctional road-signs or signboards including light emitting alfa-numeric letters, batteries, RF, PV cell, photodiode and CPUs*	**Lighting** *Conformable lighting module for interior lighting or taillight including LEDs, photovoltaic, batteries, photodiode, RF link and CPUs*
		
Building Blocks	– Light emitting module: array of 82 LEDs with efficiency above 30 lm/W and integrating a light guide. Colours: green and red – flexible PV cells (Silicon) with efficiency >10% – rechargeable batteries with high energy density capability: lithium-ion based batteries (energy density >100 Wh/kg, specific power > 5 mW/cm2, cyclability >10000) – standard silicon based photodiode for light sensing – RF module for wireless connection – CPU for optimal energy management	– Light emitting module: array of 32 LEDs with efficiency above 30 lm/W and integrating a light guide.Colours: yellow and red – flexible PV cells (Silicon) with efficiency >10% – rechargeable batteries with high energy density capability: lithium-ion based batteries (energy density > 100 Wh/kg, specific power > 5 mW/cm2, cyclability >10000) – standard silicon based photodiode for light sensing – RF or IR module for wireless connection – CPU for optimal power management
Demonstrators	– dimension of demonstrators ▪ Size range: 170 – 750 mm ▪ Shape: squared/rectangular ▪ Thickness:< 5 mm – Luminance: 5 – 15 cd/m^2 – Driving voltage: 12V – Autonomy: 15 h – Lifetime: >15000h – Production costs range: 50 - 100€/m^2	– dimension of demonstrators ▪ Size range: 20 – 50 mm ▪ Shape: squared/rectangular (2D bended) ▪ Thickness: 5 mm – Luminance: 5 – 15 cd/m^2 – Driving voltage: 12V – Autonomy: 15 h – Lifetime: >10000h – Production costs range: 30-50€ per a typical single taillight (5 functions). Small signal lights or autonomous CHMSL could potentially be produced at below 10€.

Table 1 – Demonstrators developed within PRIAM

2.4. PRIAM consortium

PRIAM has ambitious purpose of developing innovative demonstrators, improving existing manufacturing processes. To reach this goal a clear distribution of competences and responsibilities has been required in the frame of the project plan. At this purpose each partners has been in charge for each owner competences and based on their particular pre-existing expertise.

The consortium is composed 7 partners with interdisciplinary expertise to give emphasis to both development of demonstrators and basic understanding of the processes and materials as well. To assuring this exhaustive coverage of all R&D knowledge', National Research Institutes, SMEs and an Industry have been involved.

The role, activities, competences, expertise, as established in the frame of PRIAM are following reported

Participant no.	Participant organisation name	Type	Role in the project
1 coordinator	**CRF**	RES	Project coordination. Design and layout of electronic Building Block (BB). Ink-jet and screen printing processes for single BB manufacturing. Main processor encoding and development of communication protocol. Final assessment of devices demonstrators in terms of validation for automotive market sector. Exploitation towards automotive supply chain and other areas of transportation.
2	**CEA**	RES	Development of suitable bendable/flexible secondary batteries (Li-ion based). Lamination and encapsulation of the batteries. Improvement of lamination phases within converging technologies. Development of charging module and energy BB including bendable PV supply.
3	**VTT**	RES	Roll-to-roll, Roll-to-Sheet and Sheet-to-Sheet lines management. Main substrates investigation, analysis, manufacturing. Packaging of final demonstrators. Bonding processes for single chips (e.g. LEDs) or overall BB. Proof-of-concept production line and upgrading of existing production line
4	**microTEC**	SME	Process development for polymer microstructuring (RMPD® and 3D-CSP) technologies. Supply of packaging and assembly product solutions. Business and demonstrator development with expertise in integration technologies.
5	**CRP**	IND	Production line for COB, COF, COG matrices. Attaching of

			rigid components onto plastic foils. Lighting BB development. Cooperation with the taillight division of Automotive Lighting for the automotive application. Final assessment of devices demonstrators. LED systems (taillight) pre-productions.
6	**AXMC**	SME	Ink-jet processes and inks development. Development of inks for metal bonding and electrical circuitry printing. Improvement of ink-jet printing within converging technologies. Development of suitable curing methods for easy and fast processes.
7	**SOLARI**	SME	Final assessment of road sign devices in terms of general characterization (e.g. optical, lifetime, endurance, compatibility tests). Info panel demonstrators manufacturing.

Presence of leading industrial partners (CRF, CRP), committed to transferring technology from the academic to the industrial level (mainly towards automotive sector), has guaranteed an efficient exploitation of the results. Then participation of national research institutions (CEA, VTT) has assured the development of a substantial knowledge base on micro & nanotechnologies to be disseminated upon completion of the project. Finally PRIAM has strongly promoted the participation of SME through the direct involvement of them. AXMC has provided materials (inks) and ink-jet expertise for printing, microTEC has improved packaging and assembly product solutions and finally SOLARI has delivered info panel demonstrators, assuring real interest for the market in main PRIAM's outcomes.

3. S&T results/foregrounds description

The S&T results herein summarized are organized in two different sections in according with the main objectives:

1. Demonstrators: Development of innovative autonomous road-signs and automotive taillight systems with low power consumption and reduced geometries
2. Processes and materials: Upgrading existing printing technologies (ink-jet and as alternative screen printing) together with attaching, packaging, lamination and bonding in order to manufacture building blocks (electrical circuitry, RF, RFID, batteries…) for integrated systems. For this purpose enhancement of existing equipments and production lines will be carried out.

3.1 SWOT analysis

A SWOT analysis has been herein reported for integrated systems as lighting modules for generic market interest. At present the opportunities for such devices within automotive field are for novel lighting components indeed.

A key trend in the development of modern vehicles is that, in general, we are moving to a more multimedia-driven cars and that contents them self are evolving. We are witnessing a convergence of infotainment, entertainment, data acquisition, safety sensor, networking and connections devices. These developments will tend to force the car makers towards introduction of new technologies and to drive people's awareness of the novel technology they are using. Many different technological barriers stated within automotive sectors. Some barriers are regarding the volume of devices, the insufficient response time of most of the technical solutions as well as the harsh environment of testing as lifetime and temperature cycles.

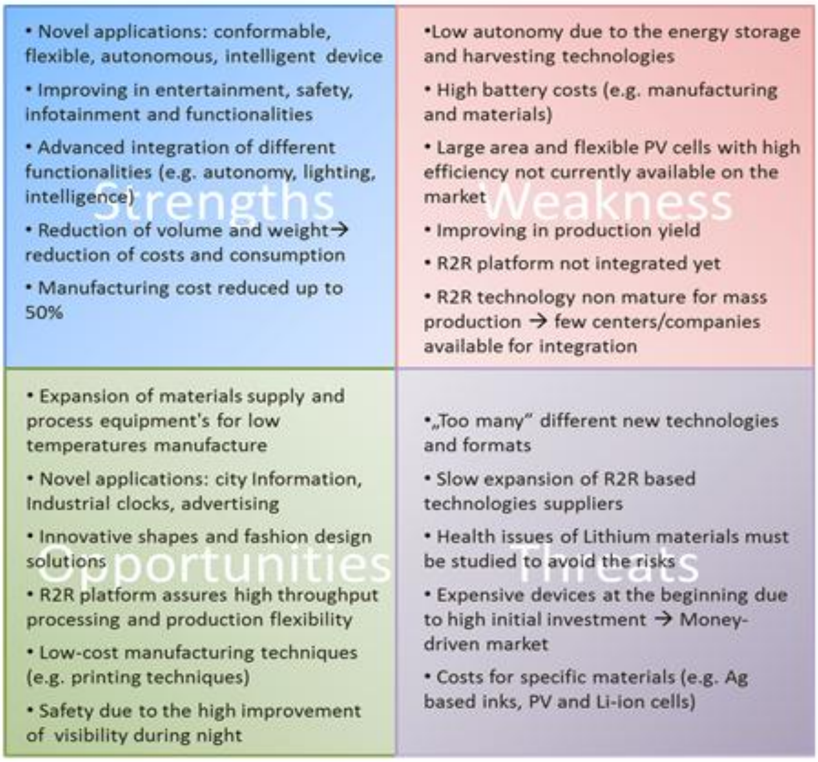


Figure 3 - SWOT analysis of PRIAM outcomes

The huge energy savings can be realized when replacing the current incandescent and discharge lamps by more efficient lighting devices. If an efficiency of 150 lm/W is assumed (predicted for ca. 2015) about 30% of the electrical energy used for general lighting purposes could be saved. It is estimated that by 2025 SSL could reduce the global amount of electricity used for lighting by 50% Innovative lightings and displays will save energy, which will lead to less material usage, less energy consumption, less radiation exposure and, after all, a lot less electronic waste. In these ways, the use of photonics can save energy compared to traditional manufacturing processes. Application of chip LEDs leads to improvement of safety, by embedding of lighting, reducing of energy consumption, reducing in volume and materials waste. Main challenges for application within automotive sector of Lighting technologies are to scale up the existing technologies to robust and efficient large area displays. A SWOT (Strength-Weakness-Opportunities-Threats) analysis is reported within Figure 3.

3.2 Demonstrators

In the following tables the main achieved features for each demonstrator and the developed technologies have been summarised, comparing them with the specifications defined at the beginning of the project. The comparison is done for final demonstrators.

INFO PANEL MODULE	At the beginning of the project	At the end of the project	Notes

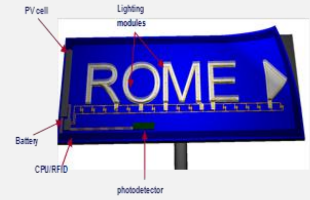
			-
Overall dimension	Size range: 170 – 750 mm	144 X 2550 mm (folded 144 x 1275 mm)	The final demos is longer (length +550 mm). It is well in weight. Improvement in size is due by the use of suitable PV cells and batteries.
Dimension of Lighting BB	--	70x80mm Effective LEDs matrix 120x144mm substrate	The final lighting BB (matrix and substrate) is bigger respect to specification in order to match the size of batteries and electronic BB
Shape	Squared/rectangular	Rectangular (2D bended)	No
Thickness	< 5 mm	5mm	No
Luminance	5 – 15 cd/m2	Preliminary tests was made on red LEDs and the result of 8500cd/m^2 @20mA it is enough to satisfy the regulation.	No for Red LEDs
Colour	--	Test performed on LEDs confirm the satisfaction of the regulation.	No
Viewing angle	--	Test performed on optical solution shown a viewing angle of 30° that correspond at B6 class of the regulation	Reduction of viewing angle class from B7 to B6
Contrast ratio	--	Actually R3 ratio is not reached due to the transparent substrate without antireflection systems.	--
Mechanical tests	--	--	--
Storage Temp and operating temp	--	Components of lighting BB, Electronic BB, and PV cells has been selected to reach the specifications, battery operating temperature range is not enough to satisfy the requirements	Actually maximum operating temperature 55°C
Driving voltage	12 V	3.7 V (output voltage)	A boost and a charge pump have been integrated to match suitable output voltage
Autonomy	15 h	10 h (stable capacity at 100% of power consumption)	No
Lifetime	>15,000 h	To be evaluated by final tests	No
Production costs range	50 - 100€/m2	Three different solutions have been evaluated: 1. PRIAM sol. cost is 30% more than actual product. 2. Not autonomous solution but with PRIAM tech for lighting BB cost is 30% less than actual product 3. Autonomous solution with standard batteries cost is almost equal to actual product	The cost of the 3 solutions is greater than 100€/m^2 .

Table 2 - Info Panel (as parking status signage) developed within PRIAM

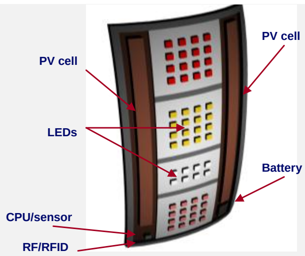
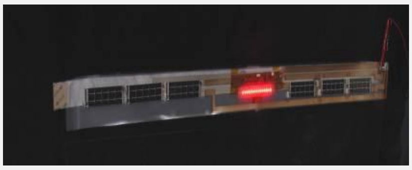
CAR TAILLIGHT	At the beginning of the project	At the end of the project	Notes
			-
Overall dimension	20 – 50 mm	HMSL: 35 X 2400 mm (folded 35 x 1200 mm) RCL: 1200 X 100 mm	The final demos is longer (length +1150 mm). It is well in weight. Improvement in size is due by the use of suitable PV cells and batteries.
Shape	Squared/rectangular (2D ended)	Rectangular	No
Thickness	< 5 mm	5mm	No
Luminance	5 – 15 cd/m2	To be evaluated by final tests	-
Light intensity	HMSL: min 25 Cd on axis RCL: Position: min 5 Cd on axis Stop: min 60 Cd on axis Turn: min 60 Cd on axis	HMSL: 46 Cd on axis RCL: to be evaluated by final tests.	
Driving voltage	12V	3.7 V (output voltage)	A boost and a charge pump have been integrated to match suitable output voltage
Autonomy	15 h	5 h (stable capacity at average power consumption of 0.4W)	Lower autonomy is due limited capacity of the batteries. This is present also considering average power consumption of 0.4W.
Lifetime	>10000h	to be evaluated by final tests	No
Production costs range	30-50€ per a typical single taillight (5 functions). Small signal lights or autonomous CHMSL could potentially be produced at below 10€.	HMSL: 18 €	The estimated cost for HMSL in case of mass production is higher.

Table 3 - Car taillight, both HMSL and RCL developed within PRIAM

3.2.1 Road-signs

LEDs-based Info-Panels or Road Signs, are devices which display information using LEDs sources. These devices are normally used in highways or roads to give information to the users about traffic, accident, street indications. Additionally the info panels could be applied in parking, building, stations and other environments with always the final aims to get information or enhance the figures visibility. For all the environments the panels have to be resistant to climatic and pollutions conditions to assure high visibility at variable wheatear conditions (sun and night shine).

In all the road signs, the active surface (emitting area for info data) is composed by LEDs arrays. Such modules are printed circuit boards with suitable electrical circuitry which allow to display an ordered pattern of pixels, allowing the info data collection. The LEDs array configurations determine three different kinds of panels: alphanumeric panels, semi-graphics panels and full graphic panels. In particular the road sings which display only alphanumeric messages are typically monochromatic whereas graphic and semi-graphic panels are not monochromatic but full-colour or mixed colour in function of the particular application. Full colour panels are obtained by mixing three different colour: red, green and blue: sometimes the white colour is added. A Road Sign for highway application, as Variable Message Signs or Graphic Signs shown in Figure 4, generally requires higher electrical consumption and higher mechanical dimensions compared to road signs used in specific applications such as parking or street name indicators, timetable displays etc…

Figure 4 - VMS panel and graphic display

Within PRIAM road signs devices which will be applied in specific road applications as park indicators will be investigated and manufactured.

Till now the parking indicators make use of a backlighting panel where the source is represented by fluorescent lamps (neon or CFL). The state of art is represented by backlighting by LEDs Edge-Light technology, as used for the backlighting of new generation of thin LCD televisions. In all of previous cases the symbols represented in the panel (such as arrows, parking names, alphanumeric sings) are painted on a plastic foil and a monochromatic LEDs matrix is used to get out the required message or information. As example the number of free parking places is shown in Figure 5.

Figure 5 - Parking and street indicators

Due to above described architecture, actual parking indicators have some disadvantages mainly concerning mechanical and sizing aspect as:

- High mechanical size to content all the electronics necessary to supply LEDs
- High weight
- High obstruction in particular environmental conditions
- Mechanical assembly issues
- High cabling costs to allow the connection to electrical network
- High cabling costs to allow the updating of the data
- High Energy consumption
- High Maintenance costs

PRIAM technology is really attractive for all mentioned applications because it allows many benefits such as cost reduction due to the saving in installation, maintenance, power consumption and finally weight and mechanical size reduction which lead to materials decrease.

Figure 6 and Figure 7 show different views of parking indicator manufactured in Solari di Udine. It easy to see the not autonomous indicators devices with large dimensions. Another aspect to take into account is that these devices has been made with several objects (plastic foil, metal case, Printed Circuit Boards, power supply unit, etc…) and not with an only one plastic foil with all electronic parts integrated, and this has a bad impact on the cost of production because all the final assembly process is manual. The integrated electronics allow the manufacture of parking indicators (or in general road sign) composed only by a single plastic foil where the info's are simply displayed on by a variable LEDs matrix integrated on the same plastic substrate.

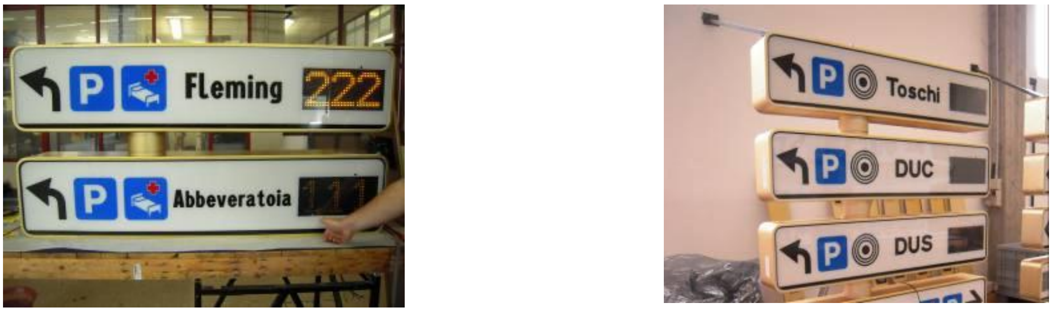


Figure 6 - Parking indicators printed and LEDs

Figure 7- Parking indicators mechanical dimensions

3.2.2 Taillights

Using LEDs for automotive lighting is already state of the art. Compared to conventional incandescent bulbs, the main advantages of LEDs are their high lifetime (up to 100.000 hours), their low energy consumption due to the efficient conversion of electrical power into optical power and the small depth of the modules. LEDs also offer a vast variety of fascinating innovative styling possibilities.

	LEDs	Bulbs
Consumption	4 W	25 W
Thickness	50 mm	150 mm
Lifetime	50.000 h	1.000 h
Reliability	No service required	15 bulb replacements
Switch-on-time	1 ms	200 ms

Figure 8 - comparison between standard bulbs and LED version of taillight

Figure 9 - Increased safety when braking (AL courtesy)

Moreover, the switch-on-time is very short. This provides a safety benefit to following vehicles in situations requiring fast braking response. First applications of LED technology go back to the first half of the nineties with the development of central high mounted stop lamps (CHMSL) with LEDs in 5 mm package. In the meantime, all functions can be equipped with LEDs. These functions are:

- high mounted stop lamp, tail light, fog light, turn indicator, break light and back up light for rear lamps;
- low beam, high beam, day time running light and turn indicator for front lamps.

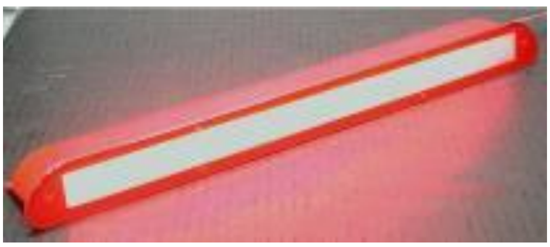


Figure 10 - High mounted stop lamp

Figure 11 - rear combination lamp

Figure 12 - full LED rear lamp

Figure 13 - full LED Headlamp

LED's technology permits to realize thin rear lamps with high reliability and low energy consumption. Modern stylistic choices include rear lamps with new three-dimensional shapes. In this moment, automotive lighting sector, uses rigid-flexible printed circuit boards mounted on a plastic support that fits the 3D surfaces with a stepped structure. This technology has high production costs and high number of breaking parts due to manual assembling.

PRIAM technology will allow the production of flexible and very thin rear lamps that can be easily adapted to the new car body shapes. Another aspect to take into account is that actual rear lamps are not autonomous from energetic point of view and so they contribute to the fuel consumption and consequently to the air pollution. PRIAM technology for automotive rear lamps allow to realize a product truly autonomous with several main benefits:

- Production and installation cost reduction
- No fuel consumption
- Conformability to new car body shapes
- Integration of different functionalities (ambient light adaptability, wireless communication with the car body computer)
- Further reduction of fuel consumption thanks to the lower weight of the device
- Conformability to new car body shapes
- Cabling costs elimination thanks to the wireless communication with the car body computer: Wireless communication could be used to communicate with others vehicles or with road signs

3.3 System partioning

The system architecture partitioning takes in account these data and integrates the interconnections, dependencies and associations between all selected functionalities. Crude scheme of the system partitioning is described in Figure 14.

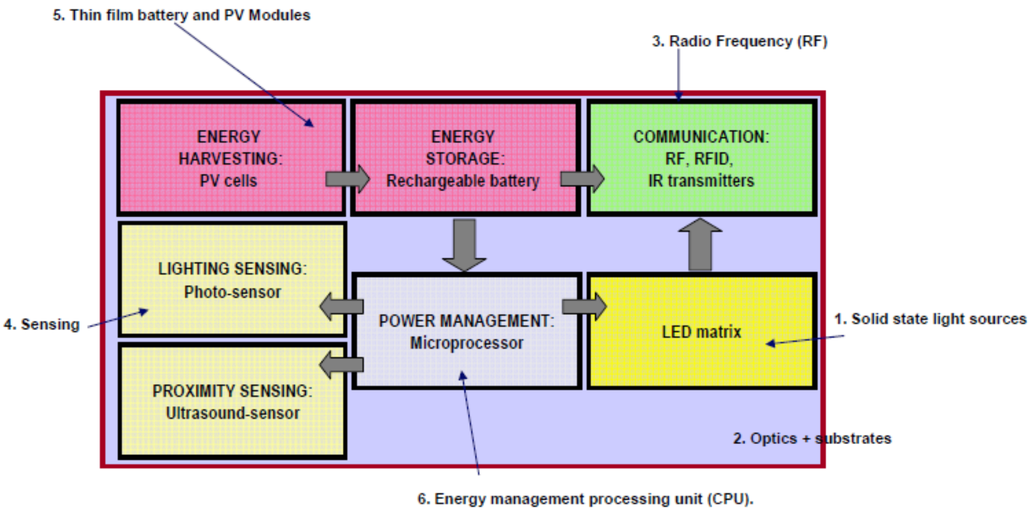


Figure 14 - Crude scheme of system architecture partitioning

In order to follow the project timetable and the activities flow, two prototypes (one at the end of second year and one at the end of the project) have been proposed. The complexity of such prototypes will be raised, starting from a simple device to a more complex in terms of integration level, functionalities, processes, components, materials, applications.

- Info panel: a first demonstrator, month 24, has been an alphanumeric and monochromatic variable LEDs matrix integrated in a plastic substrate. The second one, month 36, has been an extension of the first demonstrators, showing a 4 letters words, in order to create the variable necessaries to be used in the parking indicator.
- Lighting: a first demonstrator, M24, has been a high-mounted stop lamp that cannot meet all the project expectations but it will be fundamental to test and validate the processes, the materials and the various components. Final demonstrator has been a flexible Rear Combination Lamp (RCL) that will respect all the specifications and the regulations of the automotive sector.

The parking status indicator is an assembly of 4 LED-letters info panels whose architecture is shown in Figure 15. Specifications of selected sub-components are the same than those of the demonstrator previously presented. Thus, the system architecture partitioning is identical. Moreover, a micro CPU will be added with the aim to manage the whole of the device.

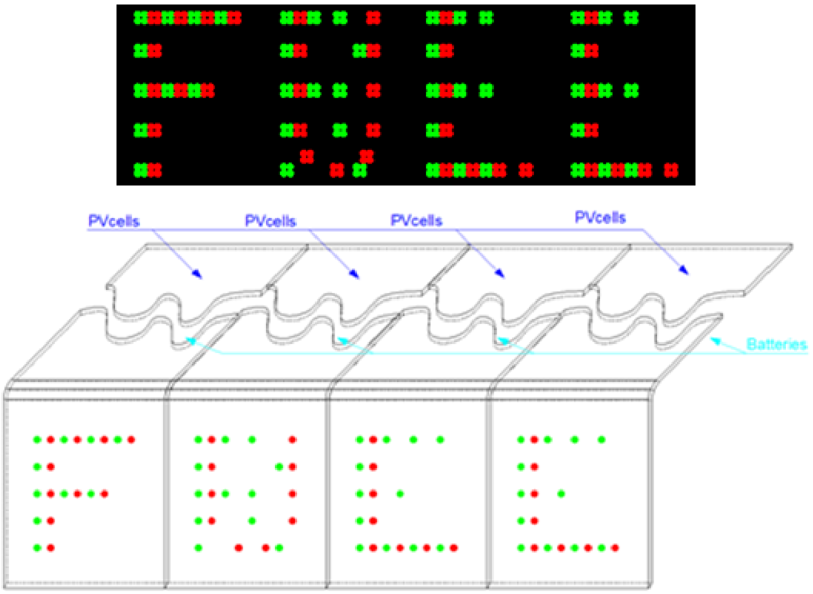


Figure 15 - architecture of the parking status indicator

Considering the BBs assembly on one unique layer of the backplane, architecture partitioning of the LED-letter info panel is schematized in Figure 16. According to the placement of the LED matrix and the electronics components, two versions are suggested. Electrical lines as well as the plastic substrate must be foldable to avoid power cuts. In addition, the electrical lines between the battery, the CPU and the LED drivers are more extended, expecting a more complex electrical scheme.

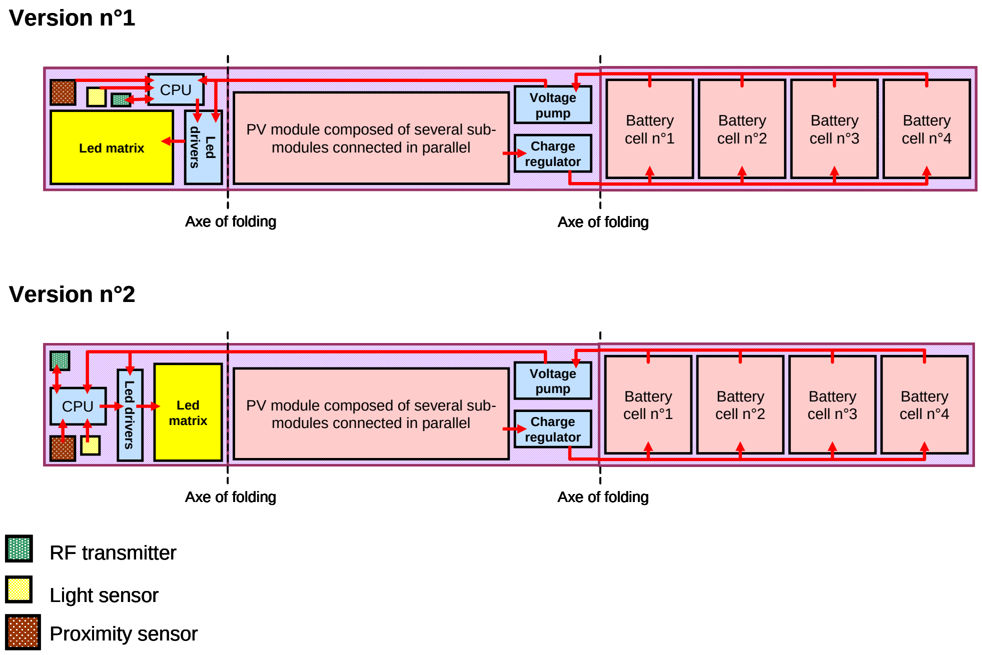


Figure 16 - architecture partitioning of the LED-letter info panel in of one-layer manufacturing process

According to the characteristics of selected sub-components, specific architecture of the high mounted stop lamp has been suggested (Figure 16). As the LED-letters info panel, the high mounted stop lamp will be composed of two layers: the first layer on the top of the backplane will include the LEDs, the electronic components and the PV module while the second layer on the bottom of the backplane will be dedicated to the battery with its 4 cells. The total dimension of the high mounted stop lamp demonstrator is 1200 x 30mm and its thickness is 1 mm.

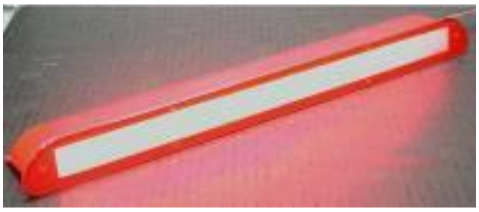


Figure 17 - architecture of the high mounted stop lamp

As previously reported, the system architecture partitioning depends on the adaptability of the manufacturing process, based on a Roll-to-Roll concept, to assembly the BBs on two layers or on one layer of the backplane.

Considering the BBs assembling on only one layer of the backplane, the architecture partitioning of the high mounted stop lamp is schematized in Figure 18.

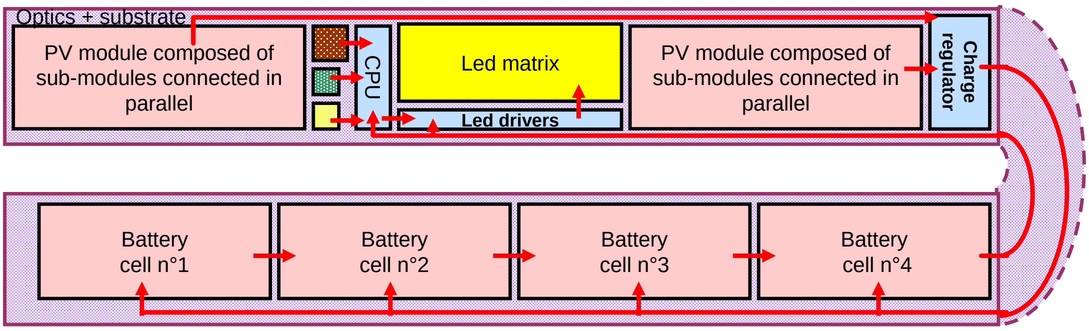


Figure 18 - architecture partitioning of the high mounted stop lamp in one-side manufacturing process

Electrical lines as well as the plastic substrate must be foldable to avoid power cuts.

According to the characteristics of the selected sub-components, the specific architecture of the rear combination lamp is schematized in Figure 19. The total dimensions of the rear combination lamp is 1500 x 160mm and its thickness is 1mm.

Figure 19 - architecture of the rear combination lamp

The architecture partitioning of the rear combination lamp is shown in Figure 20, according to the BBs assembling on one layer. The system partitioning is similar than those of the LED-letters info panel, except for the battery.

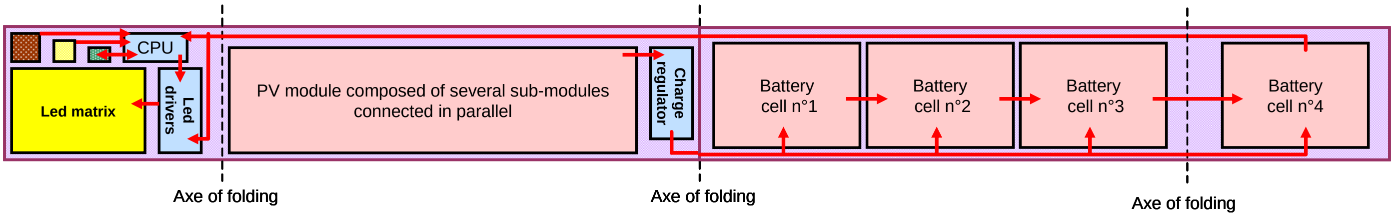


Figure 20 - architecture partitioning of the rear combination lamp in one-side manufacturing process

3.3 Suitable Materials

The two demonstrators will be constituted of several elements named Building Blocks (BB). A plastic backplane represents the element to maintain and interconnect all the other building blocks. Onto the backplane a battery set and a certain number of PV modules for the energy scavenging, a power management BB, a lighting BB with LEDs and micro-optics will be assembled.

The final specifications for sub-components and BBs are summarized in the bill of materials. The following tables report the main characteristics of each building block.

BB name	Material	Main characteristics	Interconnection
Plastic backplane	PET or PC	Screen printed conductors and pads for BBs connections.	Plastic backplane have the conductors and pads for the different interconnections between the other BBs.
Lighting BB	PET or PC	10 red and 10 green LED dice assembled by anisotropic conductive adhesive flip-chip technology. Plastic foil with micro-optics glued to the substrates. The focal distance is obtained using spacers.	Connected to the Power management electronics BB via backplane
	RMPD material	3D-CSP module with con for light dispersion and cooling solution	Connected to backplane with elec. and thermo. conductive glue
Power management electronics BB	PI	Microcontroller, switching LED driver, and other SMD passive components assembled in SMT technology.	Connected to batteries, Lighting BB and to the light and distance sensors via backplane
Batteries (4 pieces)	PET or PC	Li-ion Thin Film Battery	4 Batteries connected in parallel to PV modules and to the Power management via backplane
PV modules (8 pieces)	PET or PC	Amorphous Silicon PV modules	8 PV modules connected in parallel to the Power management via backplane

Table 4 - Info panel

BB name	Material	Main characteristics	Interconnection
Plastic backplane	PET or PC	Screen printed conductors and pads for BBs connections.	Plastic backplane has conductors and pads for the different

			interconnections between the other BBs.
Lighting BB	PET or PC	16 red LED dice assembled by anisotropic conductive adhesive flip-chip technology. Plastic foil with micro-optics glued to the substrates. The focal distance is obtained using spacers.	Connected to the Power management electronics BB
	RMPD material	3D-CSP module with con for light dispersion and cooling solution	Connected to backplane with elec. and thermo. conductive glue
Power management electronics BB	PI	Microcontroller, linear LED driver, and other SMD passive components assembled in SMT technology.	Connected to batteries, Lighting BB and to the light and distance sensors.
Batteries (4 pieces)	PET or PC	Li-ion Thin Film Batteries	4 Batteries connected in parallel to PV modules and to the Power management
PV modules (6 pieces)	PET or PC	amorphous Silicon PV modules	2 stacks connected in series of 3 PV modules connected in parallel to the Power management

Table 5 - Automotive high mounted stop lamp

3.3 System design

For both demonstrators, i.e., the High Mounted Stop Lamp as well as the Info Panel, all data have been collected and represented in 3D-CAD designs to give a detailed description of the demonstrators. From single elements like bare die LEDS up to subsystems and final product, everything is fully described. As software tool SolidWorks. has been used The level of detail is also required to produce samples by a Rapid Prototyping approach. The following pictures illustrate examples of the first Letter of the traffic lamp and the automotive High Mounted Stop Lamp 3D models.

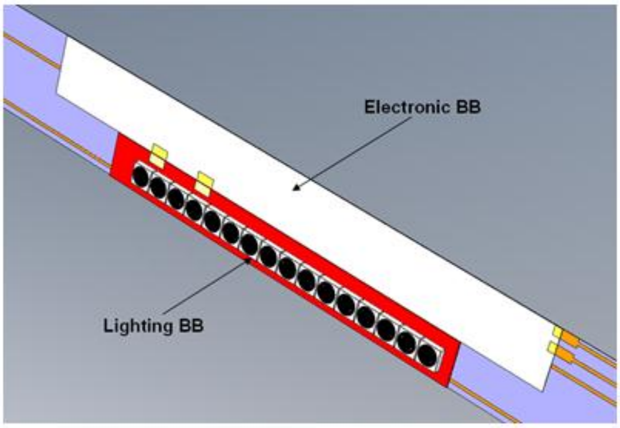


Figure 21 - detail of HMSL Lighting BB

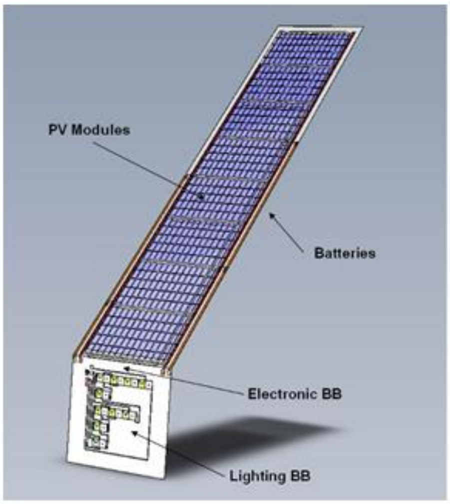


Figure 22 - 3D Model of the Info panel letter

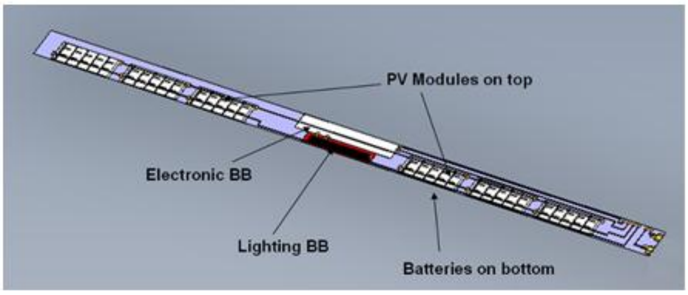


Figure 23 - 3D Model of the HMSL

3.3 Processes

Inorganic LEDs are experiencing some of the most rapid market growth of their lifetime. By using InGaAlP material (first introduced by Toshiba) with metallorganic chemical vapour deposition (MOCVD) as the growth process, combined with efficient delivery of generated light and efficient use of injected current, some of the brightest, most efficient and most reliable LEDs are now available. Within PRIAM SMD LEDs and chip LEDs will be integrated using the production line enabling COB (chip on board), COF (chip on flex), COG (chip on glass) technologies for assembly of LEDs matrices on large area (10x8 inches with unit per hours max= 3600) on suitable substrates. This production line will be improved and adapted to fit with PRIAM objectives.

Printed batteries (Thin and flexible batteries) are now being used in products as diverse as power sources for RFID, and for cosmetic applications. Although they are available for discontinuous use today, they will be constantly improved in capacity, enabling continuous use. Inorganic materials are generally used for the anodes and cathodes and improvements in terms of inks development are expected to allow a fully printed battery assembling. Solid or gel state lithium batteries will be considered within PRIAM with high degree of integration by use of polymer electrolytes materials which presents improved health and safety properties respect to liquid ones. The advantage of this approach is that it now enables batteries to be fabricated at high speed on roll-to-roll machinery similar to modern web-fed printing presses that join the various layers that make up the battery in a continuous run process.

Photovoltaic power generation has grown by an average of 40% per year and is expected to continue to grow strongly in the future. Several companies (e.g. PowerFilms, Konarka, G24i) are claiming to be ready for the mass production of flexible and high efficiency cells suitable for the easy integration in the PRIAM concept. Several issues including increased module efficiencies, improved encapsulation, enhancement in reliability of cells and modules, especially in outdoor applications and greater manufacturing yields and throughput (including the use of flexible substrates and roll-to-roll processing) should be overcome by industry manufacturing optimization and will be constantly followed within the project in order to select the most appropriate technology.

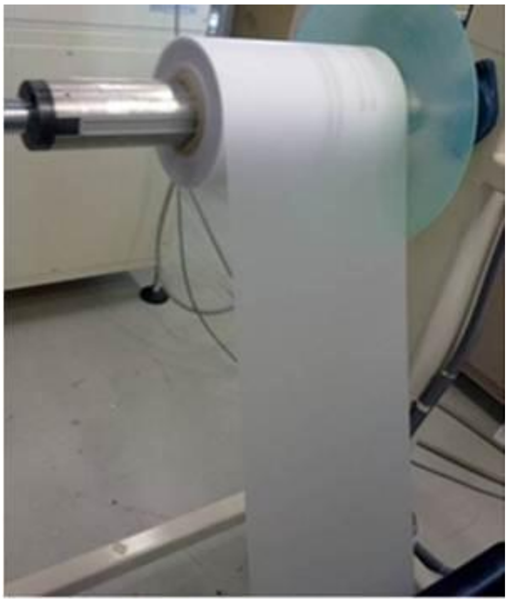
In the realization of control **circuitry** silicon technology is still often the only alternative. For thin flexible substrates however thinned silicon chips can be utilized so that the flexibility of the substrate can be maintained in the final assembly. The electrical interconnections between the chip and the substrate need however special consideration and they are often bottle neck in the final assembly of the system. The interconnections between silicon chip and polymer based flexible substrate are key issues in producing smart cards and RFID tags. There are currently two competing approaches, direct and indirect assembly, in the manufacturing of RFID tags. In direct assembly, the bumps of a chip are positioned and placed directly onto the antenna connections by means of flip chip technology.

3.3.1 Substrate manufacturing

The typical circumference of the rotary screen cylinder is 400 mm, which sets the limitation to the length of the circuitry layout. Therefore, the standard process available limits the backplane layout to a size of 300 x 400 mm. In order to be able to produce the long backplane wiring is required. The backplanes for the demonstrators were printed with flat-bed screen printing with roll-to-roll capability available in the facilities of a commercial supplier (see

Figure 24). The basic process is the same as in sheet-to-sheet screen printing but the substrate can be handled in roll-to-roll continuous WEB handling. Four printings were required for printing the large areas of the backplanes.

Figure depicts the roll of printed backplanes. The first curing of the conductors was at room temperature for approximately 10 days. In order to increase the conductivity a further curing at 90°C for 2 h was employed. Then it shows the substrates after spraying of a silicone protective layer on the substrate surfaces. Before spraying the contact areas were covered with Kapton tape. The silicone was dried for one day at room temperature followed by a treatment at 90°C for 24 h.



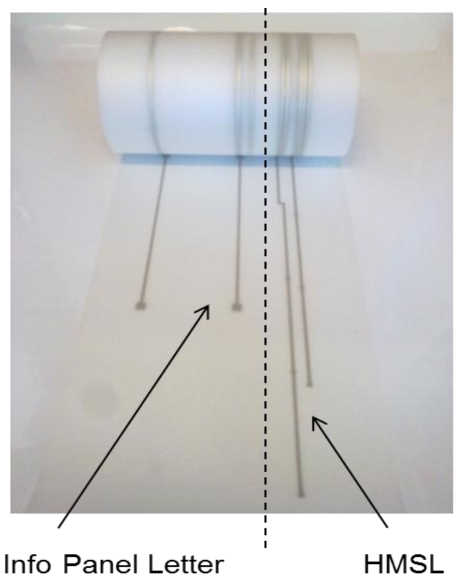


Figure 24 - R2R flat bed screen printed backplane PC roll and backplanes of Info Panel and HMSL

3.3.1 LED chips bonding

The main drivers in order to choose a particular mounting process are the substrate type and the chip structure. Two different process technologies have been selected for LED chips bonding and connection: Flip Chip On Board technology with anisotropic conductive adhesives and 3D-RMPD technology (microTEC owner).

Technology	Die Bonding	Electrical Connection	Chip structure
Flip chip on board	Anisotropic conductive adhesive	Anisotropic conductive adhesive	Top-top / bottom-bottom contacts
3D-RMPD	Thermal conductive adhesive	Vias + Conductive ink	Top-top contacts

In the anisotropic conductive adhesive bonding, the electrical contacts are limited in only one direction (Z). These adhesives are available as paste or film materials. Several commercial anisotropic conductive adhesives have been evaluated. Considering the characteristics, the data and the trials as well, it has been concluded that bonding of both green and red LEDs on Lighting BB will be flip chip bonded to the substrates using suitable ACA adhesive.

Additionally the 3D-CSP based packaging solution for the bare LED dies, with this solution being suitable for integration into a R2R process, has been evaluated and tested. The 3D-CSP technologies are used to build real microsystems, embedding all components needed in smallest space, but offer an appropriate interface to the outside suitable for many requirements. The 3D-CSP technologies are patented, details on the technology and design rules are offered for download on the microTEC (website www.microtec-d.com). Concept, solution and advantages are described below on the next three figures.

The lighting BB for the final demo - the layout of which is depicted in Figure 25 - has a total of 82 LED chips, of which 36 were red and 46 green LEDs. In addition there are 21 resistors. The size of the substrate is 120 mm x 290 mm.

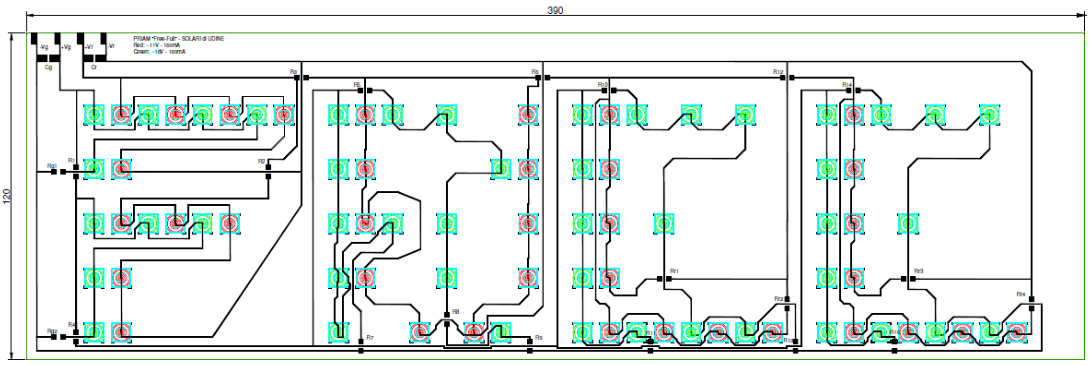


Figure 25 - The FULL/FREE lighting demo

The substrate was manufactured using R2R rotary screen printing with silver conductive paste for making the conductors. Rotary screen printing was used in making the backplanes. The process is a push-through process where ink is pushed through a fine fabric screen made of plastic or metal threads. The non-image areas of the screen are covered with a photopolymer stencil that determines the printed image. The screen has a cylinder shape and the stationary squeegee and ink are located inside the cylinder. As the screen cylinder rotates, the squeegee forces ink out of the screen apertures onto the substrate. Figure 26 shows part of a manufactured web.

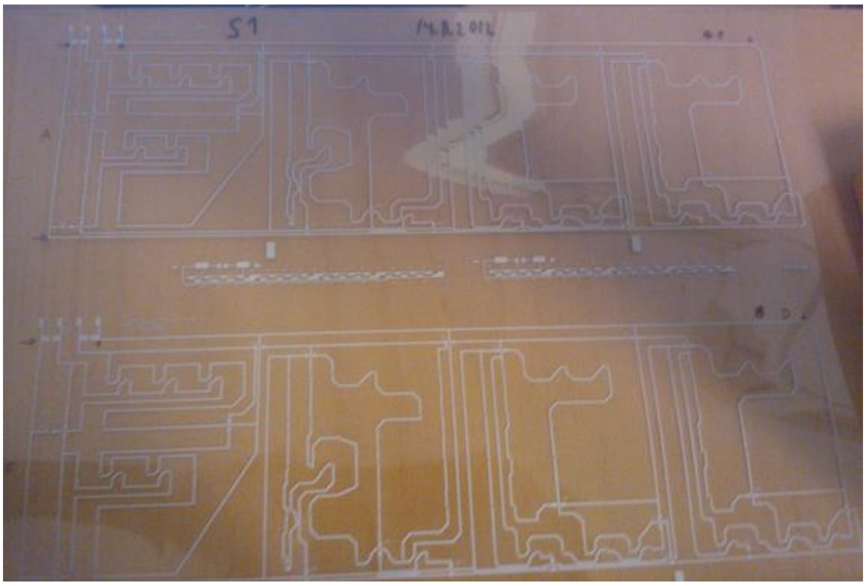


Figure 26 - Printed web with two FULL/FREE substrates and two RCL substrates between them.

The assembly and bonding of the components was performed with the EVO 2200 R2R bonding machine installation (see Figure 27).

Figure 27 - Datacon EVO 2200 R2R bonding machine

For the electrical interconnection of the components to the substrate thermode bonding was used. Key bonding process parameters in thermode bonding are temperature, bonding time, pressure and adhesive volume. Adhesive was dispensed to the contact area of the components, the LED components were picked from wafers, and the resistors were picked from waffle packs. LEDs were placed onto the substrate with contact areas facing the respective areas on the substrate. Each chip was pressed with a heated tool to transfer energy to cure the dispensed adhesive between the contact areas. The resistors were bonded using isotropic conductive adhesive (ICA). In Figure 28 FREE –word lighted with green LEDs is shown.

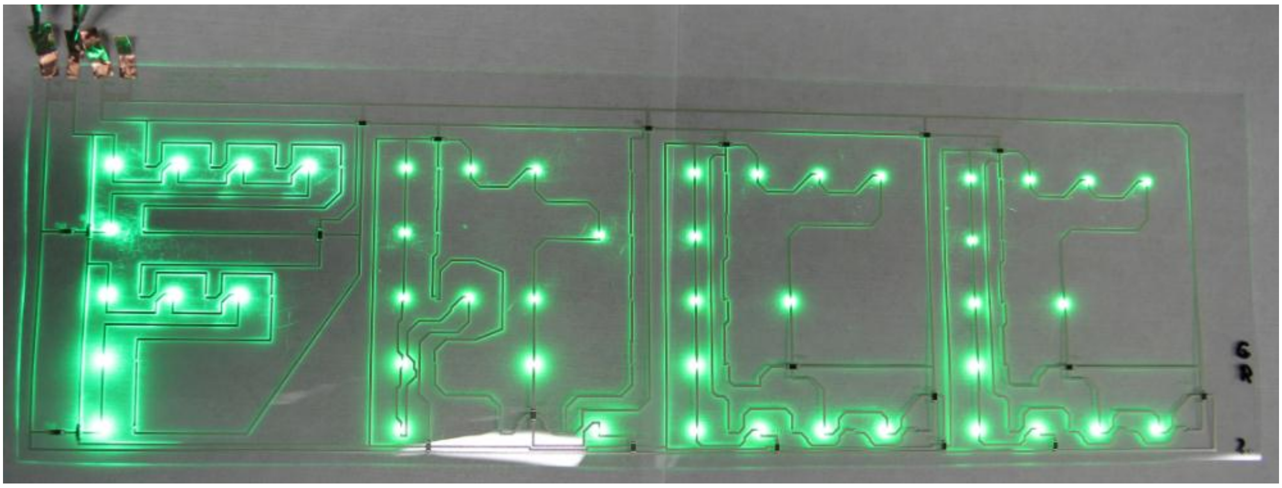


Figure 28 - Green LEDs lighting the FREE -word

3.3.1.1 New photonic sintering process

Sintering is a process for making the solid form from the metal powder form usually by heating them but below the melting point. The nanoparticles have a lower melting temperature than bulk materials so lower temperature is also required to sinter them. Nevertheless the temperature above 200°C used for typical heating process of sintering silver nanoparticles, but this is too high for most polymer substrates. Therefore some different sintering methods, has been developed e.g laser or pulsed light.

In this purpose, the speedlight – studio flash lamp was used to photonic (or flash) sintering. The energy was delivered in the form of light pulses – 1200 J per pulse. The pulse duration was about 250 μs. This type of lamp provides a broad spectrum of light from deep UV to IR.

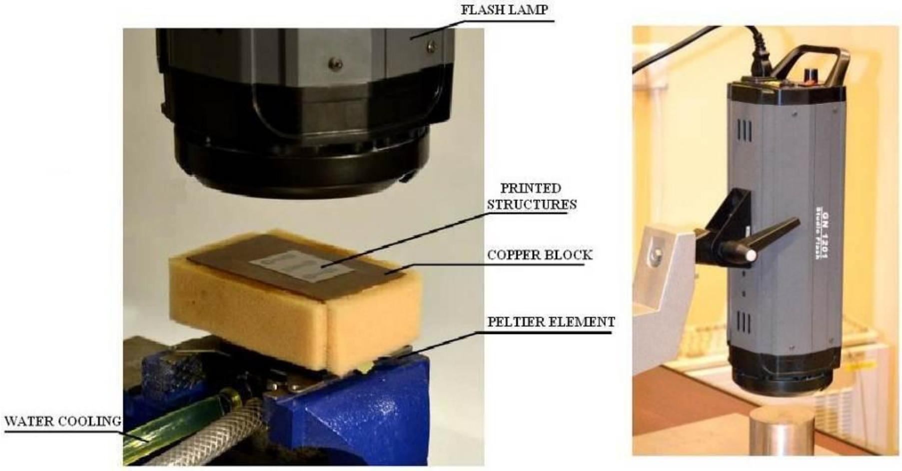


Figure 29. Experimental setup for photonic sintering process

Flash sintering is very cheap and efficient method. We obtained satisfactory results, reducing sintering time up to 1 second. (Fig. 15)

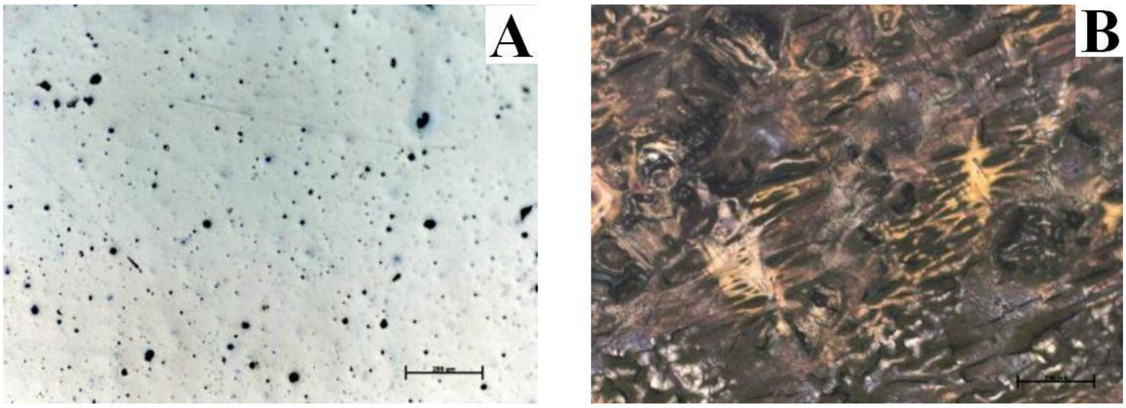
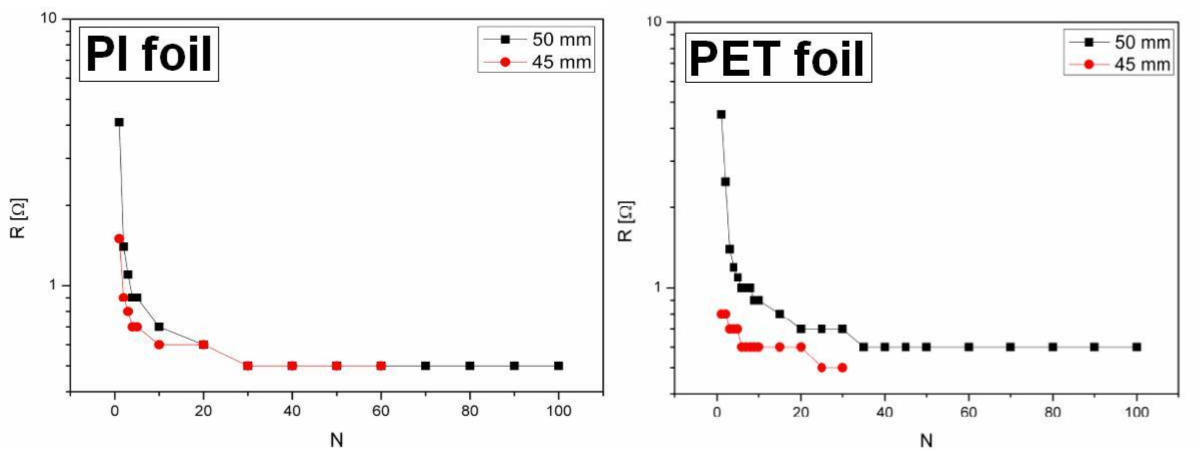


Figure 30. Printed structures before - A (200 MΩhm) and after - B (0,8 Ωhm) flesh photonic sintering process

Samples has been treated by flash lamp with function of distance between plastic substrate and source of light and a number of flash pulses up to stable of resistance value (Fig. 17).



The studies showed that flash sintering is very prospective method in flexible electronics.

3.3.2 Electronic Building Block

The only method who allows high yields, high performance in term of adhesion, thermal and electrical conduction is standard tin soldering. The assembly and manufacturing of electronic BB will be so strongly depended on issues concerning the attachment of standard IC components on flexible board. Due to this limitation we develop custom design of electronic on flex polyimide substrate who allows treatment at high temperature (>300 °C).

Concerning the Electronic BB, connectors pads and FPC (Flexible Printed Circuit) connectors are bonded on PA substrates. All the selected connectors (as Molex FPC connector (8 pins) to FFC (Flexible Flat Cable) and Molex FPC connector (4 pins) to FFC (Flexible Flat Cable for transceiver) are in line with selected design.

Electronic BBs wiring was implemented on Polyimide foil using silver inks and rotary screen printing. For the assembly of SMD components there are two possibilities: the electronic parts are assembled in the same roll to roll line or the electronic BBs are separated from the printed roll to sheets and assembled in sheet to sheet technology. The only method which allows high yields, high performance in term of adhesion, thermal and electrical conduction is standard SMT technology. For the assembly of SMD components in Roll to Roll line, special P&P machine and reflow oven have to be introduced. These machines are based on standard architecture but implements handling systems compatible with roll to roll technology.

Figure 31 - R2R SMT line – Courtesy of Automated Assembly Corporation

Electronic BB sheets can be assembled also in standard SMT lines adopting particular fixture for the handling. These fixtures have a sticky layer on the top surface (assist tape) and permitted to maintain the foils during the three stages of the SMT process: screen printing of the solder paste, components placing and reflow.

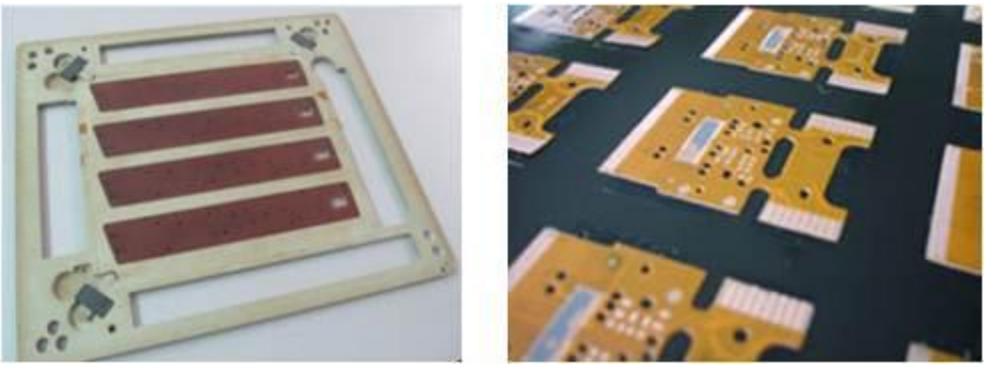


Figure 32 - example of flexible PCBs mounted on adhesive fixtures

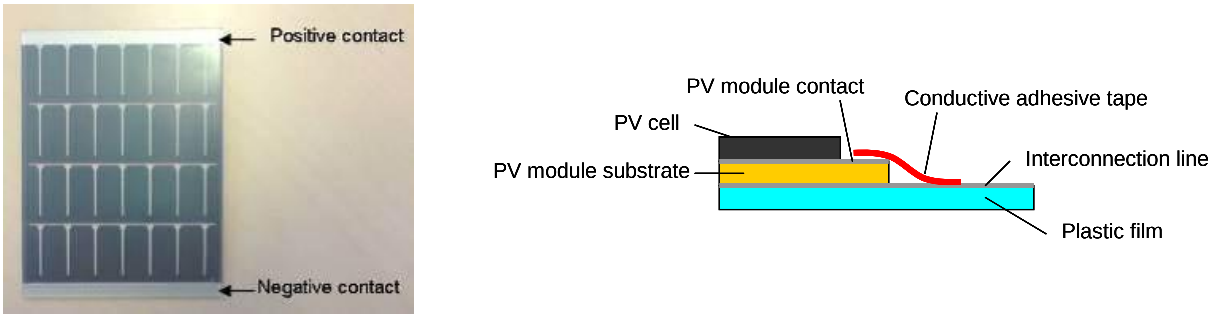
The electronic BBs for the preliminary demonstrators were manufactured in the SMT line available in CRP. They were laminated in a second step on the main backplane.

Figure 33 - CRP pilot line.

3.3.3. PV Modules

For the PV modules attachment on the polymer films (PC or PET according to the final selection), adhesives like glues or adhesive tapes were considered. Taking in account the nature of the PowerFilm PV module substrate based on polyimide, a benchmarking study on adhesives adapted to the polymer-to-polymer bonding have been undertaken.

For the PV module interconnection, the envisaged solution is to use an electrically conductive adhesive transfer tape for better facilities due to the PV module snap contacts positioning (on the PV module top layer).



PowerFilm PV module (top layer) *PV module connection by means of conductive adhesive tape*

Figure 34 - PV module and connection

After assessment if was selected that the solar cells will be laminated onto the backplane using double-face adhesive tape. For electrical connections, copper foil stripes soldered onto the contact pads of PVs, will be used to contact to the backplane using ACA and overnight curing at room temperature.

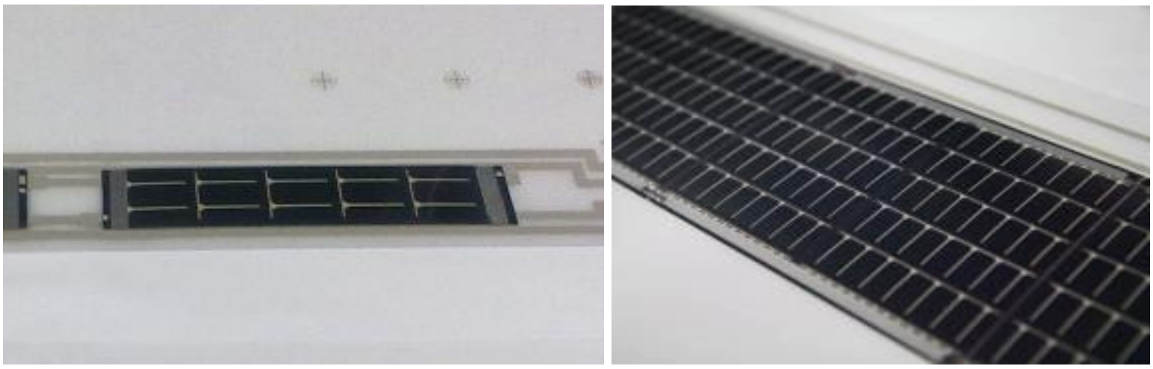


Figure 35 - HMSL solar cell assembly (left) and info panel solar cell assembly (right)

The battery and the PV module assembly onto the backplane was expected to be performed by lamination process. In this view, battery lamination trials have been undertaken in order to firstly define the lamination parameters which seem to be relevant for the process and secondly prove the feasibility of this process. The battery lamination was realized in two steps: the first step consisted in bonding the adhesive onto the battery and the second step concerned the attachment of the battery onto the backplane.

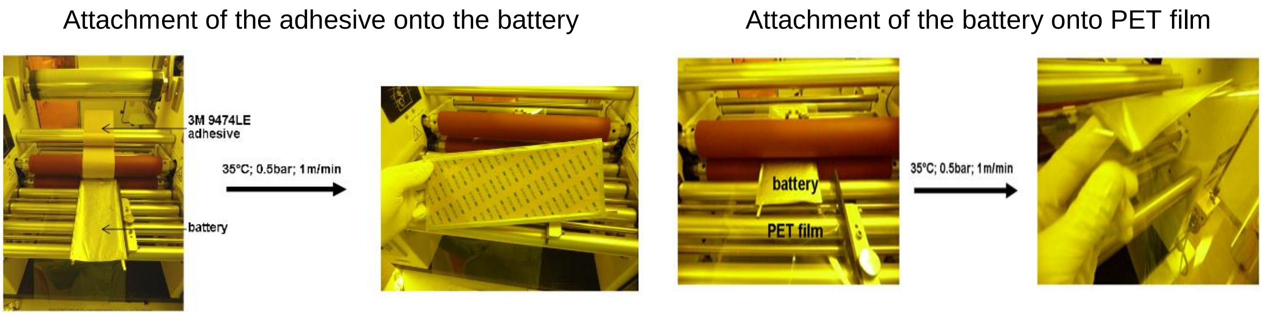


Figure 36 - Battery lamination trials

For electrical connections copper foil stripes soldered onto the contact pads of PVs were used to contact to the backplane. One step lamination process could be envisaged with specific equipment based on co-lamination concept. In this case the adhesive is sandwiched between the substrate and the battery and then laminated. This concept can be adaptable to the PV module too.

3.3.4 Building blocks Interconnection

Electrically Conductive Adhesive Transfer Tape (Pressure Sensitive Adhesive –PSA-) with anisotropic electrical conductivity has been used to get electrical connection in flexible circuit interconnection applications, or grounding application between the various types of substrates. For PRIAM purpose electrically conductive tape is selected as best option offering good adhesion between PC and Kapton® sheet.

Following materials and process were chosen for the battery and Lighting BB integration on system backplane:

- Batteries: Laminated onto the backplane using, electrical contacts with ICA
- Lighting BBs: Optics attached using UV curable optically clear adhesive

- BBs attached to the backplane using double-face adhesive, electrical contacts with copper stripes using ICA adhesives.

Following figures show the results of the attachment and interconnections of batteries on the main backplane (the same for the PV cells) and optics (Info Panel and HMSL respectively) within the lighting BB.

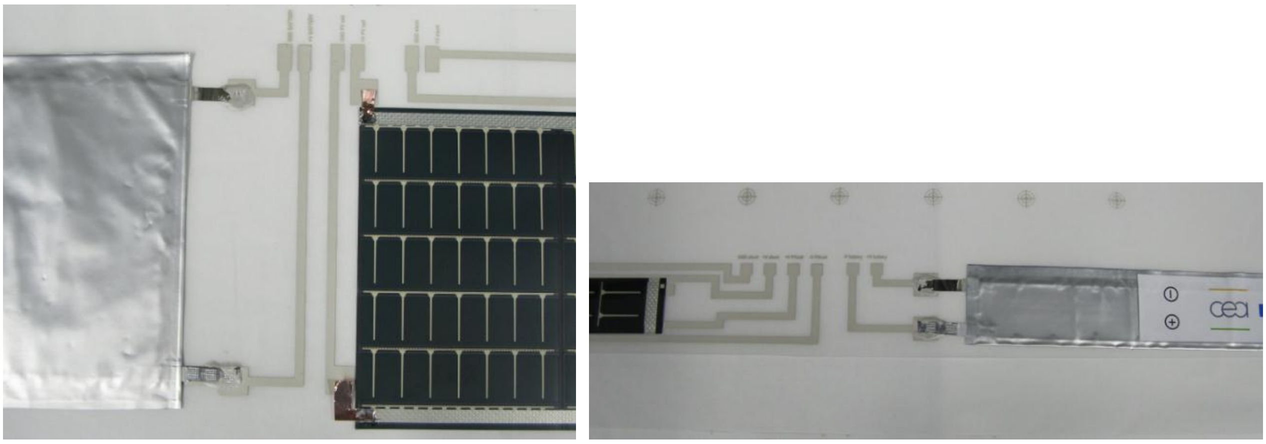


Figure 37 - HMSL battery assembly (left) and Info Panel battery assembly (right)

Figure 38 - HMSL lighting BB assembly

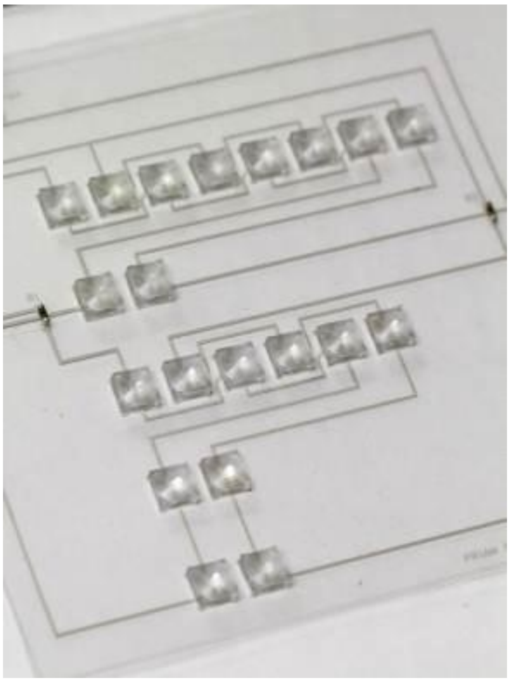


Figure 39 - Info Panel lighting BB assembly

Building blocks onto the backplanes were attached using ICA which could be cured at room temperature (overnight curing was employed). BBs were mechanically attached to the backplane using double-face adhesive, and electrical contacts were made with copper stripes using the ICA adhesive. Pictures of the info and HMSL panel with components attached are shown in Figure 40, and Figure 41, respectively.

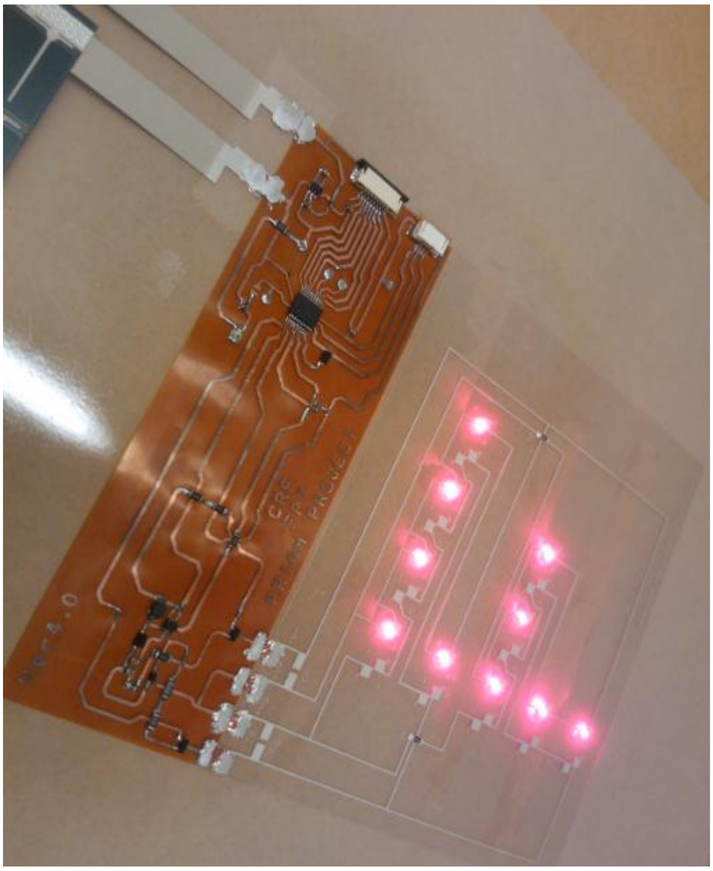


Figure 40 - Partial view of the info panel backplane with electronic and lighting BBs assembled

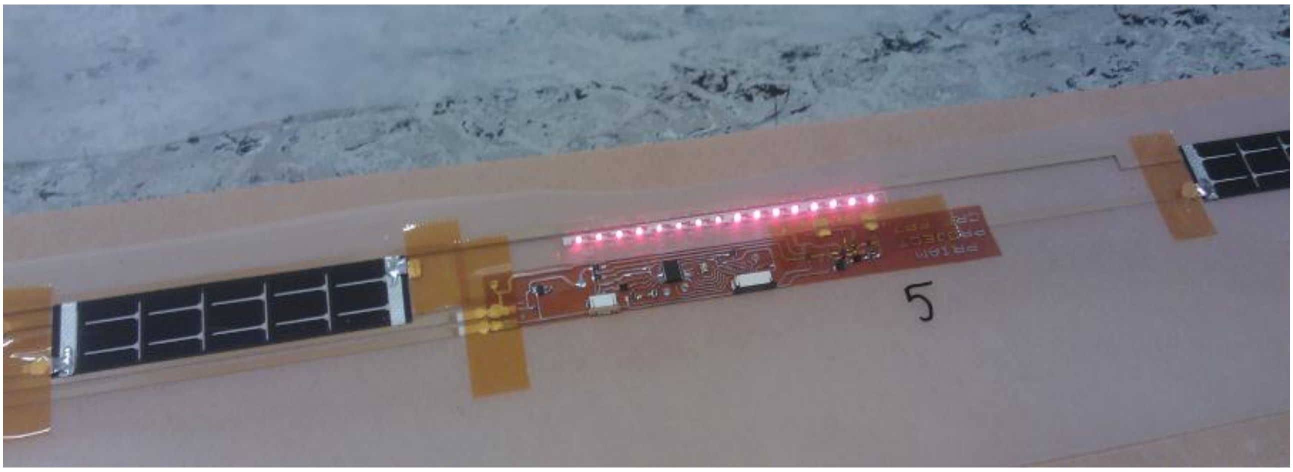


Figure 41 - Partial view of the HMSL backplane with BBs assembled

The described processes permitted to assembly the prototypes for the validation tests. Five Info panel letters and five Automotive High Mounted Stop Lamps were assembled.

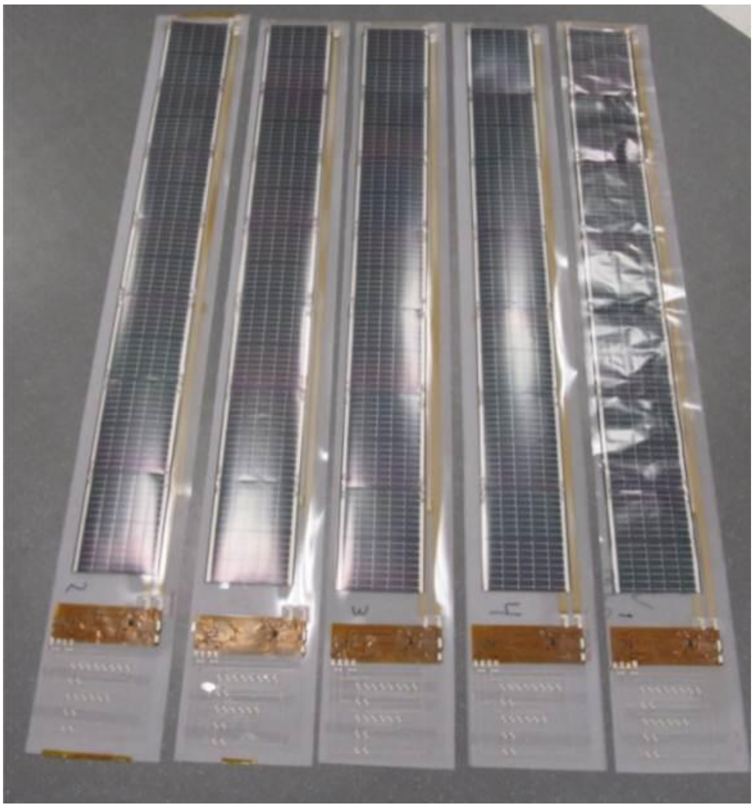


Figure 42 - Info panels preliminary demonstrators

3.4 Validation tests

PRIAM consortium identify all tests required by European regulations in terms of public information application and automotive application.

The list of tests which have been performed is the following:

- **Humidity and Storage (HS) 85°C/85%:** verify functional performance of component after exposing to high temperature and high humidity (85°C and 85% RH) for a specified time to simulate accelerated test condition for temperature and humidity experienced during the vehicle's service life.

- **Thermal Cycle (-40°C/+85°C):** Verify functional performance of component after exposing to thermal cycling from -40°C to 85°C for specified thermal cycles to simulate accelerated test condition for temperature changes experienced during the vehicle's service life. The test allows to discover the defects in the manufacturing process of the component and the variation of its functional parameters.

- **ESD Test:** verify the resistance to electrostatic discharge between contact pads and air.

- **Vibration Test:** verify the resistance of the electronic components and interconnections to the vibrations.

- **UV Test:** verify the resistance of the plastic parts to the UV light.

- **Working Temperature - info panel (Cold Cycle -40°C and Dry Heat Cycle +55°C):** verify functional performances of entire product at temperature of -40°C and +85°C. The test allows to discover the thermal behaviour of the device at extreme cold temperature and at temperature of 55°C and notice defects on displayed information and the variation of its functional parameters.

- **Autonomy test:** Verify the autonomy of the device

- **Degree of Protection:** Verify the protection level of device against water and dust.

- **Salt test – info panel:** Verify the resistance of the device to salt ambient

- **Corrosion agents - Automotive demonstrator:** Verify the resistance of the device to corrosive agents as H_2S

- **Optical Test - Info Panel:** Measurement of optical performances of the demonstrator

Following tables summarize the result obtained by testing the info panel demonstrator and a comparison between these results and the target objective.

Legend:

✓ Ok for regulation and project objective

✓ Ok for regulation but not for project objective

✗ No test performed but confident in good results

✗ Test performed with bad result both for project objective and regulation

INFO PANEL

		Performed Tests and objectives	Deviations and Considerations	Result
1	Temperature	Working Temperature: -40°C/+55°C (Class T2 and T3 of the regulation EN12966-1)	NO	✓
2	Protection Degree	NONE	Test has not yet performed because it is mainly related to packaging aspects. A type of packaging has been designed and SOLARI is confidential to reach IP55 degree of protection with the designed packaging	✗
3	Optical tests and characterizations	**Luminance:** +30% compare to the actual devices at the same drive current (measured according to regulation EN12966-1)	**Luminance level**: is in according with EN12966-1 and compared with existing products the value of luminance for both colours is >30% as expected	✓
		Chromatic coordinates: Class C2 of the regulation EN12966-1	**Chromatic Coordinates:** class C2 of EN12966-1 has been reached	✓
		Visible angle: Class B6: +15°/-15° horizontal; 0°/-10° vertical (measured according to regulation EN12966-1); Class B4: +10/-10° horizontal; 0°/-10° vertical (measured according to regulation EN12966-1)	**Visible angle**: Class B6 of EN12966-1 has been reached	✓

		Contrast: +30% compare to the actual devices at 40.000lux of illumination (measured according to regulation EN12966-1)	**Contrast Ratio:** R2 Level of EN12966-1 has been reached modifying the demonstrator with the implementation of a black mask. In this case no improvement has been reached compare to existing device. An improvement could be reached modifying the material of the mask or painted the substrate with not reflective paint in order to decrease the level of reflection.	✓
		Uniformity: Ratio onto 12% of the pixels 1,5 (measured according to regulation EN12966-1)	**Uniformity Ratio** is in accordance with the regulation	✓
4	Lifetime from LED data	Lifetime from LED data	The data will be carried out for the data sheet commercially available estimated 15000h lifetime. Thanks to optimization of heat disposal in consideration of particular design of the contact pads	✓
5	UV resistance	UV test 100h of UV exposure	The test has been performed on bare demonstrator without packaging and no damage has been noticed	✓
6	Thermal Cycle	Verify functional performance of single components after exposing to thermal cycling from -40°C to 85°C	The tests has been performed and luminous flux derating has been evaluated. -20% of derating in luminous flux is well accepted for the application considering the number of cycles (1000)	✓
7	Salt test	NONE	Test has not yet performed because it is mainly related to packaging aspects. Type of packaging has been designed and SOLARI is confident to pass the test with the designed packaging	×
8	Vibration	Vibration Test according to EN12966	NO	✓
9	ESD	Electrostatic discharge resistance	The test has been performed on demonstrator without any damage	✓
10	Storage Temperature	HS test to verify the performance of the demonstrator after exposure to 85°C and 85% humidity for ~1500h	The test has been performed and derating of luminous flux has been evaluated. -20% of derating in luminous flux is well accepted for the application.	✓
11	Autonomy	Fully charge-fully discharge test Continues running test	15h autonomy from fully charge to fully discharge has been reached.	✓

HIGH MOUNTED STOP LAMP

		Performed Tests and objectives	Deviations and considerations	Result
1	Temperature	Temperature -40°+55° C High Temperature Operating Endurance (HTOE) Thermal Cycles: Verify functional performance of single components after exposing to thermal cycling from -40°C to 85°C	The test has been performed at 85°C as upper limit without batteries building block The derating of luminous flux has been evaluated. -20% of derating in luminous flux is well accepted for the application considering the number of cycles (1000) Issue is represented by batteries operating temperature which is maximum 60°C	✓
2	Vibration tests	X, Y, Z vibration for approx. 48 h	NO	✓
3	Humidity	Humidity 85/85 (85°÷85%RH)	NO	✓

		Verify functional performance of component after exposing to high temperature and high humidity (85°C and 85% RH)		
4	Electrostatic discharges	ESD test Test to verify the resistance of the electronic components to electrostatic discharges	NO	✓
5	Degree of Protection	Water IP65 (to be defined due to the used packaging) TEST NOT PERFORMED	Test has not yet performed because it is mainly related to packaging aspects. Type of packaging has been designed and CRP-CRF are confident to pass the test with the designed packaging	×
6	Corrosion	Verify the effects caused by the influence of corrosive environmental (H_2S) that can damage the electrical contacts and connections. TEST NOT PERFORMED	Test has not yet performed because it is mainly related to packaging aspects. Type of packaging has been designed and CRP-CRF are confident to pass the test with the designed packaging	×
7	UV resistance	UV test Test to verify the resistance of the plastic parts to the UV light.	The test has been performed on bare demonstrator without packaging and no damage has been noticed	✓
8	Autonomy	15h expected Fully charge-fully discharge test. Test based on average absorbed power to simulate the stop lamp activation during the use of the vehicle.	The size and quantity of the thin film batteries, due to their efficiency, permitted to reach 10h of autonomy. The solution is to increase the batteries size.	×

4. Potential impact

4.1. General project impact

Generally the main goal of PRIAM is associated to printed electronics technologies. Although there is tremendous potential for related products (portable equipments (infotainment and entertainment), toys, computers, aircraft, e-cards, e-papers, stretchable displays etc...), high volume sales of printed electronics will mostly occur in the retail and supply chain management industries. It will take at least until 2010 for the full scale commercialization of printed organic batteries, photovoltaic panels, flexible and active displays, as well as some logic components. The commercial success of other innovative products such as e-papers and e-books are harder to predict because they would largely depend on the availability of e-content providers and customer adoption. In this scenario expected PRIAM products could improve the penetration of printed electronic devices in the selected market.

Printed electronics is now a key value-adding element for many sectors of industry, and the predicted nanotechnology future will also be largely delivered by micro and nanotechnologies. Nevertheless, although the EU is the worldwide technology leader, it is facing significant threats from the low-wage countries (China and Asian countries), due to the high costs and long development costs. That is why it is more important than ever to rapidly adapt to the new printed electronics market by developing high-quality and low-cost products with a reduced time to market, to counter international competition. The processes and materials convergence towards reliable flexible products will improve competitiveness within Europe strengthening its economy stability and creating new job opportunities.

PRIAM contributed to following associated community objectives.

Quality of life and safety (elderly people): improvement in road visibility allows improving vision and driving comfort, thus reducing the occurrence of accidents and increasing safety. Fall-outs of the proposed technology to signalling and information displays will also lead to more efficient information delivery and usability of information systems.

Environmental: the proposed process led to a substantial reduction in volume of developed products (especially for lighting modules) from actual several centimetres to a few millimetres (more than 10 times). The compactness of the system as well as the thickness of the devices resulted in reduced plastic/materials consumption and therefore lower environmental impact. Lighter and stand-alone devices have an impact on fuel consumption with a reduction in the range 10-15% with related reduced CO_2 and exhaust gases production. Furthermore, energy saving inherent to the efficiency of LEDs, also contributed to the preservation of natural resources. Furthermore this will have a huge impact on energy saving as incandescent bulbs are replaced by more efficient new inorganic sources.

Impact on education: wider benefits are also resulted from the project in terms of its contribution towards science and engineering education. PRIAM project has been shown as best practice example given during various presentations (Workshop Young Entrepreneuers, participation in http://myfuture-ausbildungsmesse.de) to motivate young people to become involved in new technologies.

Furthermore PRIAM members have identified industrial needs from different sectors which are all related to the same core challenge: developing convergence of processing technologies for emerging micro manufacturing and multifunctional objectives production to be implemented at industrial level. With this purpose PRIAM contributed to strengthen the main European technical platforms related to organic electronics, manufacturing, and electronic smart systems participating in the Strategy meetings of the following platforms: **OE-A, OLAE, MINAM, EPOSS, NANOFUTURES**. The wider societal implications are discussed in D7.6 deliverable.

4.2. project Exploitation

4.1.1 Exploitation and business plan for Road signs and info-panels

Present situation

SOLARI is the largest Italian producer of road signs, info-panels on highways and airports currently expanding its product lines addressing novel road lights based on high level of integration of microoptics and LEDs.

Objectives

The investment made for the new product lines addressing novel road lights based on high level of integration of microoptics and LEDs are expected to induce a great rise in the market share.

Product description

New families of easy to install road-signs, signboards and info panels characterized by being light emitting, energy autonomous and RF connected to either or both the infrastructure or to passing vehicles. Packaging made to sustain many year of exposition under harsh environmental conditions.

Market analysis

The increasing age of EU drivers asks for a new family of products addressing the low visibility of road sign at night. The installation of either fluorescent lamps or LEDs lamps requires for an expensive connection to the grid. Non integrated solutions based on the use of solar panel, batteries and lamps requires for difficult installations. The strength of the proposed products is that they can be adapted to the existing road panel signs.

Market Strategy

Describe above proceeding by a step by step approach starting from owner costumers.

Financial projection

That market is potentially very large and just a small portion will ask for the definition of considerable expansion plans. The technology and the solutions addressed within PRIAM could reasonably lead to an optimist view of expansion of the product lines. The Italian market alone would lead to a turnover of several hundred millions€/year. Provided that the proposed solutions will be easily installed and robust to several years of expositions to harsh environmental conditions, it is the opinion of SOLARI's market and commercial experts that the price issue will be properly addressed balancing the manufacturing capability and the market requests.

4.1.2 Exploitation and business plan for taillights

The developments of the first prototype of a taillight will follow those for road signs. The technological approach will manage the steps toward a gradual acceptance within the automotive context up to the first preliminary plan for a large scale implementation of the technology within the taillight division of Automotive Lighting.

Present situation

Filament lamps are gradually replaced in the first installations with LEDs sources.

Objectives

The new signalling and taillight product families are addressing both the conventional market and the new one of the Electrical Vehicles for which energy saving and the reduction of overall system complexity are crucial aspects.

Product description

The new taillight does not require cabling and does not need to be connected to the main battery system, it allows a simple installation, it is typically much thinner (<5mm) and much lighter (< 50%) than the conventional ones. It can be easily replaced with new ones offering personalisation and new opportunities to stylists. It simplified the overall structure of the vehicle body. The RF element assures the communication with the central computer and the pedal. Product life is not expected to be lower than that of the conventional technology.

Market analysis

Automotive OEMs ask for: lower costs systems, energy savings, CO_2 reduction. The three major EU Tier1 (Automotive Lighting, Valeo and Hella) are facing the competition from emerging and lower cost countries specifically for the systems adopting the lowest technology that is for the taillights much more than for headlamps.

Market Strategy

The sale within the automotive is made directly by the sales unit of the Tier 1 supplier. The availability of first demonstrators before the end of the project allows the pragmatic vision of short-term production. New technology offers several points of strengths in terms of lower weight, lower consumes, no cabling, simplified body.

Financial projection

Product cost will be initially determined by the purchase of the BBs. With respects to the offered strengths of the product the price can be allocated giving a good reasonable profit.

4.1.3 Individual partners' exploitations intentions

Centro Ricerche Plast-Optica S.p.A.

The main goal is the application of the project's results within the industrial partners by applying processes, tools and materials developed within the project in their industries. The most relevant objectives of the exploitation activities is technology transfer to end-users. In this sense, CRP will play the role of link between project and automotive lighting industry. The automotive lighting components and the developed technologies will be proposed by CRP to Automotive Lighting Italia (main shareholder of CRP) for the final production/assembly. Automotive Lighting Italia is, together with Valeo and Hella, one of the European main producers of lighting devices for automotive field. There are currently no automotive lighting devices (rear and front lamp) integrating components based on flexible technology. In this sense, PRIAM has allowed a very important contribution in the advancement to respect the state of the art. The project has open up possibility to automotive industries to exploit a set of interesting technologies for the production of innovation LED-lighting based devices.

Centro Ricerche FIAT S.C.p.A.

CRF exploited PRIAM results promoting them to FIAT System Integrators, Tier1 and Tier 2 covering all the OEM supply chain. Obviously CRP, involved in the consortium, as and for

Automotive Lighting, will be the favourite supplier. Within new company structure, that involves several car brands including Alfa-Romeo, Lancia, FIAT, Chrysler, Maserati and Jeep, FIAT has been defined a General Innovation Master Plan including innovate at medium-to-long term. CRF is the responsible for GINP at European an WW level.

Solari di Udine S.p.A.

The main goal is the application of the project's results within the industrial partners by applying methodologies and tools developed within the project in their industries. The city information device prototype will be addressed towards main markets addressed by SOLARI and where the application will find their first industrialization. Actually Solari market, for city information systems are located in Italy, France, Nederland, Norway and others European countries. The technology and solutions could reasonably lead to an optimistic view of expansion of this SOLARI product line with an increase of turnover of +20%.

Technical Research Centre of Finland

VTT could understand the practical specifications of user interface applications in areas of automotive, advertisement and home sectors. In addition, screening of other potential markets, applications and customers for VTT related to user interface integration based on developed technology. Then develop thorough capability to integrate various functionalities in flexible substrates in sheet-to-sheet and roll-to-roll compatible process. Utilise R2R compatible hybrid pilot prototype manufacturing line for printed hybrid systems, ramped-up during 2012 within OULU PRINTOCENT innovation centre. Hybrid Pilot line has been used to identify and tackle the major obstacles on commercialization and achieve knowledge on critical economical elements, such as manufacturing yield, cost-of-ownership, needed investments and return of investment (ROI). Hybrid Pilot line will be used broadly to demonstrate the technological capabilities and market potential together with various industrial partners outside consortium.

MicroTEC

MicroTEC developed new solutions to products, based on results (new products and new RMPD-Rotation capabilities), and be able to offer those solutions being available at fab scale. They will also provide training and licenses to other partners developing other solutions to products and their potential for other applications to the market. microTEC usually work together with OEM suppliers, which already have channels to the market. Based on the RMPD®-Rotation solutions microTEC will firstly use the knowledge gained to support product partners like CRF, CRP accessing their own markets. Currently RMPD®/3D-CSP technologies are successfully applied for various other products (LED packaging, light panels, etc.), etc. suitable for integrated or OLAE based technologies as well. Marketing activities has also helped generation of new jobs for SMEs in Europe and give "best practice" examples for SMEs addressing different markets, as well as gender issues.

AMEPOX

AMEPOX aims are to gain expertise and know-how on low sintering temperature and functional metal-based inks for inkjet printing (including serigraphy), applied to several substrates substrates. Mid-term exploitation of the project results has allowed us to offer an improved range of product to our customers, to develop collaborations with automotive and electronics leader companies and to operate on new market (e.g. automotive).

CEA

CEA aims to further develop competencies and know-how on the integration of devices onto non-conventional substrates and in new manufacturing processes. For CEA, acquiring new competencies will in turn lead to new technological and business partnerships that will improve scientific and technological networking between R&D partners, and improve the transfer of knowledge to industrial.

4.3 Project Dissemination

During the three years of the project the Consortium attended to the main European Conferences on Plastic Electronics, Optics, Photonics, Batteries…
A list of the main Conferences has been reported in the Table 6.

Conference / exhibition	Location/Period	Partner involved	Type of Participation
Photonics21	Brussels (Be) 15.1.2010 17.2.2011	microTEC, CRF	Platform meeting with several workshops
MEDTEC Stuttgart	Stuttgart (Ger) 23-25.3.2010	microTEC	Presentation of PRIAM project
LOPE-C	Frankfurt (Ger) 31/5.1/6.2010 30.06.2011	CRF	Presentation of PRIAM project
OLAE concertation meeting	Brussels (Be) 14-15.06.2010 10-13.07.2011	CRF	Presentation of PRIAM project
Nanofutures 2010	Gijon (Sp) 14-17.06.2010	microTEC, CRF	Presentation of PRIAM project
IS-FOE	Thessaloniki (Gr) 06-09.07.2010 10-13.07.2011	CRF, CEA, VTT	Invited talk - Presentation of PRIAM project
Industrial Technologies 2010	Brussels (Be) 07-09.09.2010	microTEC	EC organized networking event, matchmaking session, where PRIAM will be presented Chairing Session + one2one meetings
Plastic Electronics Conference	Dresden (Ger) 18-21.10.2010	VTT	Presentation “Embedding Flexible OLEDs into Polymer Products by Injection Overmoulding Process”
ICT Exhibition	Brussels (Be) 27-29.9.2010	microTEC	Presentations (poster/talks/one2one)
Roadex Railex	Abu Dhabi (UAE) 28-30.11.2010	Solari	exhibitor + Flyer
Be Flexible” 9th	Munich (Ger) 2.12.2010	Amepox	Presentation + poster about Ink Jet printing technology
SIFERR	Lille (Fr) 04-05.11.2011	SOLARI	Exhibitor
Battery 2011	Cannes (Fr) 28-29.09.2011	CEA	Presentation of the Thin Film Battery activities (poster)
EMPC 2011	Brighton (UK) 12-15.09.2011	AXMC	Presentation about: “Influence of different type protective layer on silver metallic nanoparticles for Ink-Jet printing technique

GULF TRAFFIC	Dubai (U.A.E) 12-14.12.2011	SOLARI	Exhibitor
IEEE Nano 2012	Birmingham (UK) 20-23.08.2012	Amepox	Presentation: "Interconnection process by ink-jet printing method"
Decorative Automotive Plastics conference	Koln (Ger) 9-10.10.2012	CRF	Invited talk: "Plastic sheets with printed functionalities"

Table 6 – Extract of principal conferences attended during PRIAM project

A press release, regarding PRIAM project, has been published on "*+Plastic Electronic*" magazine in August 2010. The coordinator, according with the consortium, has released an interview (interviewer Dan Rogers) in respect with the main objectives, the applications, the beneficiaries and the potential impact on specific market sectors for the final outcomes developed within the project.

The article is available at webpage http://www.plusplasticelectronics.com/lighting/smart-signs-and-lighting-created-for-automotive-market-16823.aspx.

Figure 43 - Article about PRIAM on +Plastic Electronics web page

The two "Press Releases" can be found in the News Section, as shown in Figure 44 and Figure 45.

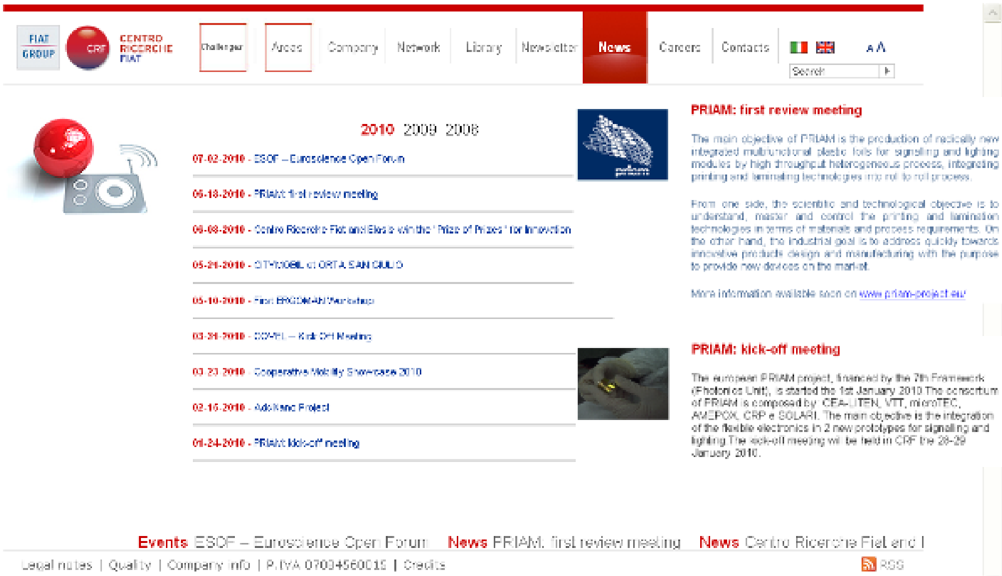


Figure 44 - PRIAM Press Releases on the CRF web-site at the beginning of the project

31st, January 2013

PRIAM project

Printable functionalities for truly autonomous, intelligent lighting and signalling systems

The PRIAM project is a STREP project funded by the ICT program of the European Commission's 7th Framework. PRIAM started on January 1st, 2010, and finished on 31st December 2012.

The main objective of the project is the development of a radically new multifunctional plastic foils to be used in road signals and automotive lighting modules.

PRIAM consortium has achieved three demonstrators for automotive and signalling purposes as respectively High Mounted Stop Lamp, Rear Combination Lamp and parking status sign. Automotive and owners characterization processes have been passed out to validate selected demonstrators. Exploitation to transportation sectors and to other industrial fields has been successfully started.

Please see attached a flysheet concerning actual newsletter.

You are then invited to download, from the web site, the last flyer regarding final project outcomes.

Picture of parking status sign

Picture and application of taillights

Download the PRIAM flyer on http://www.priam-project.eu/Fe/
Download the Public Reports on http://www.priam-project.eu/Fe/Site/t01/Results/2
Download the News on http://www.priam-project.eu/Fe/Site/t01/News/1
For any questions please contact: nello.lipira@crf.it

PRIAM project
Funding Scheme: ICT-2009.3.3
Start date of Project: 01.01.2010, duration: 36 months

To send us your feedback, please contact nello.lipira@crf.it

Figure 45 - Press Release # 3 (January 2013)

The PRIAM web-site (www.priam-project.eu) has been periodically upgraded in the private and in the public area containing technical exchanges and public deliverables.

In the home page the flyers of the project can be downloaded.

Figure 46 - Updated version of Flyer (January 2013)

As reported in the web-site, the contacts of the consortium are:

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