EPTAINKS

Lightening the load

Annalisa Colombo and Francesco Tassone explain how a new nanostructured light-diffusing ink can benefit screen printing

EPTAINKS offers a new ink for glass and plastic that promises an improved LED light diffusion and a smart (and fun) managing of the light.
The increasing demand for energy-saving solutions, also supported by EU legislation via dedicated directives and new energy efficiency targets (see the European Commission web-page about Energy Efficiency), is causing an acceleration in the research and development of new materials and technologies for a smart energy management.

Switching from the traditional incandescent light bulb or from the fluorescent lamp to the long-lasting efficient Light Emitting Diode (LED) source is one of the faster and simpler ways to cut the global CO_2 emission, the production of pollution and toxic waste, and the energy bill. Moreover, while the conventional white light sources have reached their physical limit of efficiency, the LED developments and performances are just at the start.

Besides the outstanding improvement that could be achieved by the research at the LED chip level in terms of efficiency, a smart management of the LED operating conditions could allow an increase in the luminous efficacy of the light source. In particular, given the point-like nature of the LED chip and the risk of eye-damage due to its high-brightness, the need to develop efficient light diffusers is quickly emerging.

Within this context, two new inks (SERINK LDI FOR PLASTIC and SERINK LDI FOR GLASS) implement optical diffusion over glass and plastic to allow the light coming from a LED strip to be managed in an efficient way.

Optical light diffusers
Two distinct types of optical diffusers are typically used – namely, surface-relief and volumetric. Surface-relief diffusers are made of micron-sized structures on the surface, while the volumetric ones are based on micron-sized beads that are uniformly dispersed inside the matrix, to scatter the light. In both cases, the use of micron-sized objects results into a loss of transparency in the optical device and a loss of efficiency in the light source.

Moreover, diffusion occurs in the Mie regime, which requires an over-control on the homogeneity of the micron-sized beads' distribution within the matrix. Conversely, the use of optical diffusers made of nano-sized beads allows diffusing the light according to the Rayleigh scattering [the dispersion of electromagnetic radiation by particles that have a radius less than approximately $^1/_{10}$ the wavelength of the radiation – a process named after Lord Rayleigh], that is simpler to manage and provides an optically transparent and efficient solution.

In an industrial process, it is difficult to achieve the dispersion of diffusers at a nano-scale level into a matrix. Moreover, the complexity of the subsequent production steps, including the optical characterisation and integration into the final lighting device, restrains the diffusion of these devices into the market.

Here we describe a new approach for brand new highly efficient optical diffusers, based on a nanostructured ink – developed both for glass and plastic substrates. The main advantage of this solution, developed for screen printing processes, is the versatility in terms of choice of the substrate (material and shape) and the design to be printed (writing, graphic artwork, and so on).

How it works

The aim of the developed ink is to implement the diffusion of light coming from a linear array of LEDs. In order to achieve this optical functionality, the ink has to be printed on an optically transparent substrate, such as Polymethylmethacrylate (PMMA), Polycarbonate (PC) or extra-clear glass.

Figure 1 shows the working geometry of the offered solution. In the scheme, the light coming from a LED array is injected in the edge of an optically transparent substrate, on which the diffusing ink is printed. The injected light is reflected over the parallel surfaces of the transparent plate, and thus guided along it, until it reaches the printed diffusing layer. Here, it partially diffuses out of the plate, making the printed artwork visible thanks to light emission.

Using an ink instead of a more conventional diffusing bulk panel allows a huge flexibility: it introduces the possibility to tune the amount of extracted light and to print arbitrary shapes such as characters or artwork. Moreover, when the light source is switched on, the printed artwork diffuses the light of the same color as the selected LED.

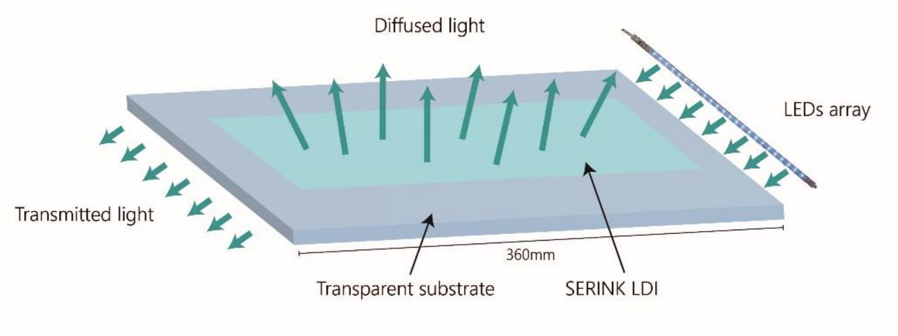


Figure 1: LED light is injected into a transparent substrate, on which the diffusing ink is printed

Screen printing application

In order to perform the optical characterisation of the developed ink, it was processed on an optical device by screen printing a 30cm long stripe. An ad-hoc optical set-up was realised in EPTAINKS R&D laboratories to properly measure the light diffusion. A light source consisting of a linear array of white LEDs with a 0.5 cm spacing was then aligned close to the polished edge of the device. The diffused light was collected and spectrally analysed with a fiber-optic coupled spectro-radiometer (Ocean Optics, USB 2000+ UV-VIS). The optical fiber was terminated with a cosine-corrected fiber head, placed almost in contact with the surface, at a known distance from the edge illuminated by the LED source.

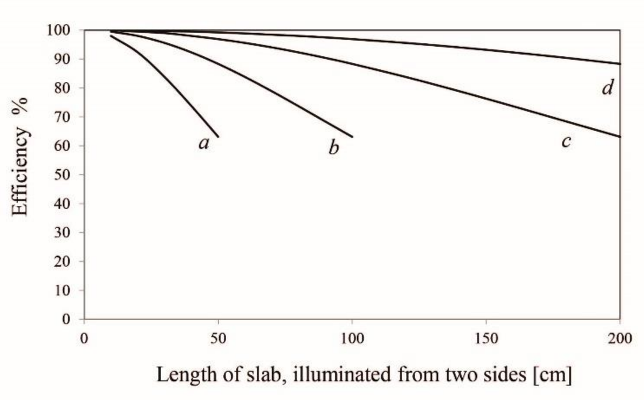
The optical parameters that describe the diffusion and allow achieving the desired effect are efficiency and uniformity. Efficiency describes the amount of light that comes out from the printed artwork compared to the light injected into the edge of the substrate. Uniformity describes the ratio between the minimum and the maximum intensity that are emitted by the artwork printed on the substrate.

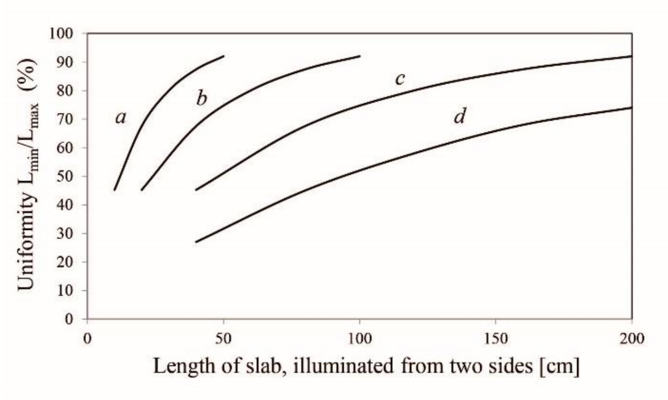
Figures 2 and 3 show the efficiency and the uniformity of the ink (SERINK LDI FOR GLASS) when screen printed through a 120th/cm frame on extra-clear glass. Measurements were taken by using an input source of 3600lm/m. The diffusing ink was appropriately diluted (1/2, 1/4, 1/8) with the specific blank ink to characterise the optical performances. Using this information, it is possible to appropriately dilute the product to obtain the desired performance, such as a specific light spreading on the whole printed artwork.

Indeed, a higher ink dilution (while keeping the other printing conditions unchanged), allows the light to travel through longer distances and provides for a more homogeneous luminous appearance. Alternatively, by changing the printing parameters (such as the frame threading), but keeping the ink dilution fixed, the light path within the substrate can be smartly managed.

From this point of view, it is important to remember that the human eye perceives the luminosity logarithmically and, therefore, is not able to recognise emission differences lower than 30%. **Figure 4** shows a prototype printed with the light diffusing ink introduced in this work.

At this time, this research activity is going on from the engineering point of view for the development of the optical device, in collaboration with SAINT GOBAIN.





Figures 2 and 3: Measurements taken when SERINK LDI FOR GLASS ink is screen printed through a 120th/cm frame on extra-clear glass

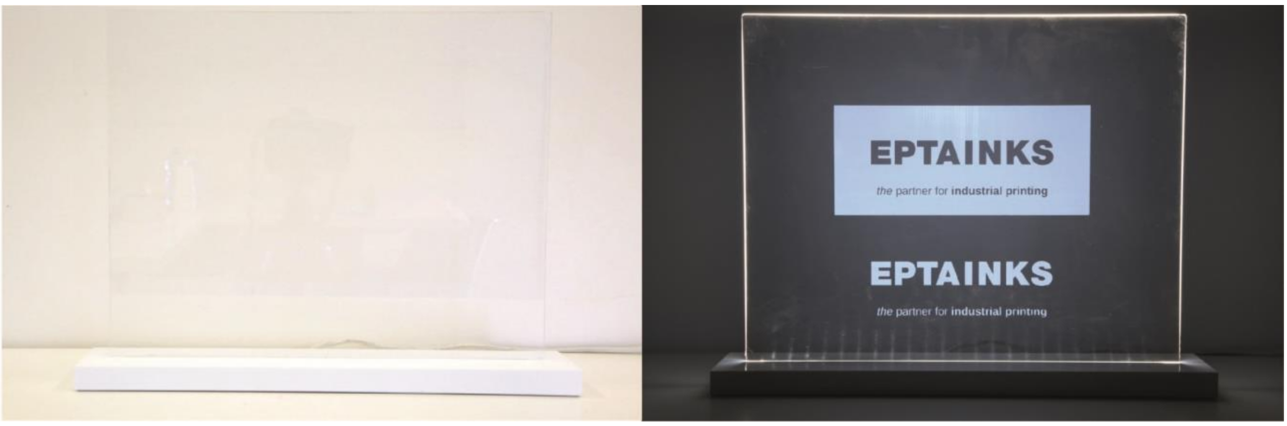


Figure 4: Prototype printed with the light diffusing ink

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Summary
A new light diffusing ink for optically transparent substrates has been developed. Starting from the legislative directives from EU about Energy Efficiency and taking advantage of the market demand, the offered solution represents a tangible improvement of the already outstanding performances of LED sources.

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