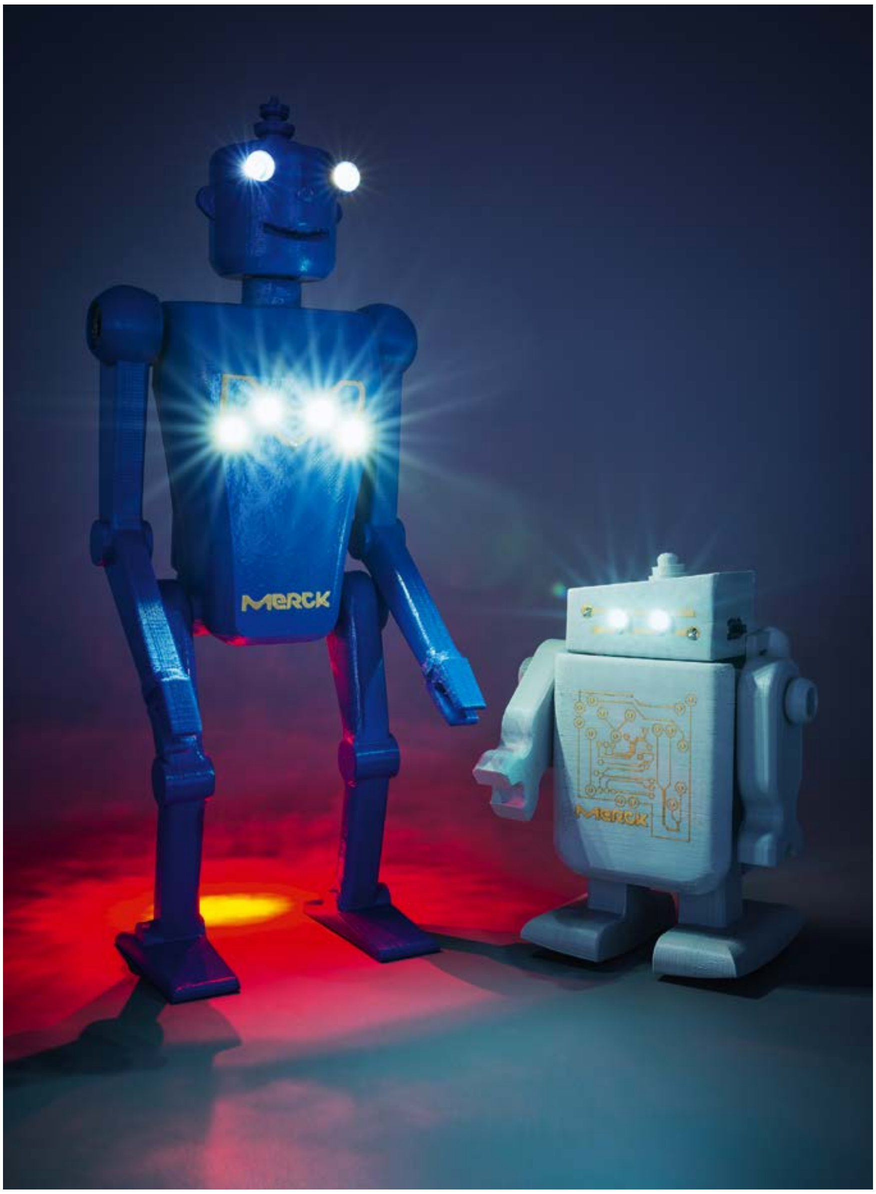
Entering the Third Dimension with Light-Colored LDS Additives

Selective Metallization of Plastic Components with Laser Direct Structuring

Three-dimensional molded interconnect devices combine electronic and mechanical functions. Plastics additives are necessary for activating surfaces using lasers, and they enable selective metallization. Relevant parameters of various additive/polymer combinations have been identified in a current study.



The robots highlight the combination of the additive FDM process and LDS technology and will be exhibited at Laser World of Photonics 2017 (© Merck and http://www.thingiverse.com/thing:170932)

Steady progress is being made in the miniaturization of electronic and mechatronic components with increasingly higher performance. These advances call for special manufacturing procedures such as laser direct structuring (LDS, developed by LPKF Laser & Electronics AG in Garbsen, Germany). In LDS, a polymer interconnect device with integrated additives is injection molded, activated three-dimensionally with a laser, metallized, and subsequently equipped with components. This process is contingent on sufficient laser activation of the plastic and on the capacity of the metallization process. In addition to the additives that are already commercially available for laser activation, Merck KGaA, Darmstadt, Germany, has collaborated with LPKF to develop a new light-colored additive for a wide variety of polymers, such as polycarbonate-acrylonitrile butadiene styrene blends (PC+ABS), polybutylene terephthalate (PBT), liquid crystal polymers (LCP), polyamide (PA), and glass-fiber-reinforced polyamide (**Fig. 1**, **Table 1**). The light-colored additive can be used in the lighting sector, for instance, or colored for other applications. Currently most of the commercially available LDS additives are tailored for dark application.

The manufacture of an LDS component is a complex process that depends on individual process steps. The process chain comprises the manufacture of additives and compounds, injection molding, laser structuring, metallization, and equipping of the LDS component, which is then used, for example, in the auto- »

Fig. 1. Merck and LPKF have developed an additive for laser direct structuring of light-colored plastic components. Shown here is a light-colored powder-coated component that is selectively metallized using the LDS process (© Merck)

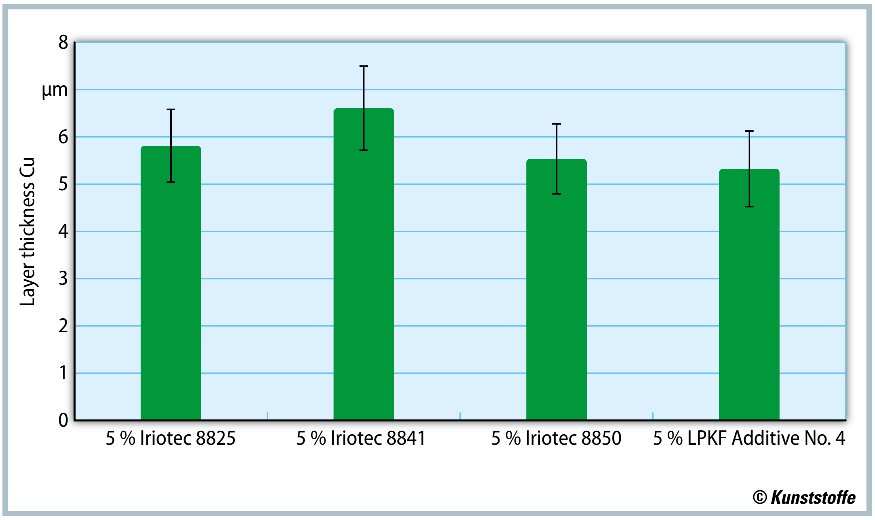


Fig. 2. Comparison of the copper layer thickness of various additives in PC+ABS. Copper deposition is between 4 % and 24 % greater with the Iriotec additive than with the reference (source: Merck)

motive sector, in telecommunications, or in medical devices.

Specific Metallization Behavior

The complex composition of the metallization bath depends on the respective bath manufacturer, and there are also different recommendations with regard to bath temperature and dwell time during metallization. This presents a challenge for the metallization process of various polymer/additive combinations because these baths have been developed and optimized for different applications.

Knowledge of the component/bath composition is thus essential in order to design a cost- and time-efficient process. A two-stage process is used in industry for difficult-to-metallize components. In this case, the component is first metallized in a more aggressive and instable strike bath (generally a lower deposition rate) for copper seeding and then metallized in a more stable built bath (with a higher deposition rate) for building up the copper layer. Alternatively, a single-stage process can also be run and is examined more closely below.

The respective polymer with integrated additives was structured at lab conditions with a test pattern (84 fields) as an example using a 10 W laser under suitable laser conditions at a frequency of 80 kHz, a writing speed of 3000 mm/s, and 99 % power. It was noted that the behavior of the copper deposition would differ for other laser parameters. Metallization was performed using a MacDermid Copper 100 bath (manufacturer: MacDermid Inc., Waterbury, CT/USA). Both the layer thickness and the deposition rate were determined by differential weighing. An overview of the experiments of the Cu metallization test series is provided in **Table 2**.

Improved Copper Deposition in PC+ABS

PC+ABS plays a predominate role for structured LDS polymers used as antennas. Therefore, the metallization behavior of LDS additives in the Merck Iriotec 8000 series was examined compared to a reference with a 5 wt. % PC+ABS content. Metallization was carried out for 40 min at a temperature of 55 °C. The deposited copper layer thicknesses as seen in **Figure 2** exhibit an increase in copper deposition of between 4 % and 24 % compared to the reference sample. The increased Cu deposition of Iriotec 8841 can be attributed to the composition and the resulting metallization seeds. The additive consists of a copper-containing compound, whereby Iriotec 8825 and 8850 consist of a tin-/antimony-containing compound. When Iriotec 8841 is used as a polymer additive, a stabilizer must also be used

	Iriotec 8825	Iriotec 8841	Iriotec 8850
Chemical composition	Based on mica/ tin antimony oxide	Based on copper phosphate	Based on titan/ tin antimony oxide
Color	Light-colored pigment	Light-green-colored pigment	Light-colored pigment
Temperature stability	High stability in all plastic applications	Additional stabilization is recommended	High stability in all plastic applications
Particle size	< 10 µm	< 10 µm	< 1 µm

Table 1. Overview of product properties of the Iriotec LDS additives (source: Merck).

	Temperature-dependent metallization*	Time-dependent metallization#	Polymer dependent metallization at 55 °C
5 % Iriotec 8825	PC+ABS	PC+ABS	-
5 % Iriotec 8841	PC+ABS	PC+ABS	-
5 % Iriotec 8850	PC+ABS	PC+ABS	PC+ABS, PBT, LCP
5 % LPKF Additive No. 4+	PC+ABS	PC+ABS	-

+ LPKF Laser & Electronics; * bath temperatures: 52, 55, 57, 60°C; # bath dwell times: 10, 20, 30, 40 min

Table 2. Overview of metallization processes carried out (source: Merck)

since otherwise the polymer might degrade due to the copper. In order to obtain further insight into the deposition kinetics, time- and temperature-dependent tests were conducted.

Variation of Bath Temperature and Metallization Duration

The test series was conducted at 52, 55, 57, and 60 °C to estimate the energy required for copper deposition during metallization and to draw conclusions about the deposition behavior of the various additives (**Fig. 3**). At 52 °C the bath activity is too low, whereas at 60 °C over-metallization was observed due to the instability of the bath. The bath activity and the resulting copper deposition rate increase as the temperature rises. The differing deposition behavior can possibly be attributed to the different chemical composition of the metallization seeds.

While Iriotec 8841 follows a nearly linear dependency as the bath temperature increases, the test results for the other additives showed that the jump in the deposition rate is more significant when the temperature rises from 52 °C to 55 °C and from 57 °C to 60 °C than it is between 55 °C and 57 °C. This results from the optimum bath temperature during metallization for which the bath was developed and fine-tuned. In summary it can thus be said that the bath temperature during metallization significantly influences the metallization quality and consequently must be constantly checked.

The layer thickness was recorded at 10-min intervals up to a maximum dwell time of 40 min. A look at the time-dependent development of the Cu layer thickness (**Fig. 4**) shows a nearly perfectly linear behavior. In this case as well, the behavior of the various additives can be attributed to their different chemical composition.

The copper is deposited on the seeds of the activated additive. An increase in the deposition rate was observed due to the initial Cu seeding of the surface for 10 min. This can be attributed to an autocatalytic process, caused by the already deposited copper. A drop in bath activity as time passes can be attributed to the consumption of reducing agents (formaldehyde), sodium hydroxide, and copper in the metallization bath. For a process that is to run continuously, the recommendation is to check the values for formaldehyde, sodium hydroxide, and copper regularly or in-situ and to take measures in the event of deviations.

In order to study the metallization behavior of plastics with integrated additives for different application fields, such as in the mobile telephony, medical, and automotive sectors, Iriotec 8850 was incorporated into the plastics mentioned at the beginning, PC+ABS, PBT, LCP. A clear difference is recognizable in the metallization behavior (**Fig. 5**), which may possibly be attributable to the different chemical composition of the polymers and the resulting influence on the copper reaction. Consequently, the suitable polymer can be selected and the additive can be adjusted to match it, depending on the application field.

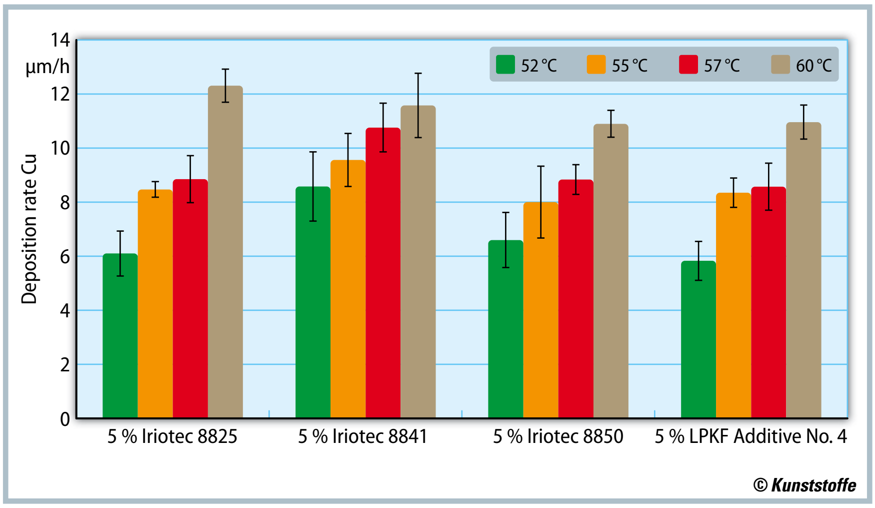


Fig. 3. Temperature-dependent copper deposition rates of various LDS additives in PC+ABS (source: Merck)

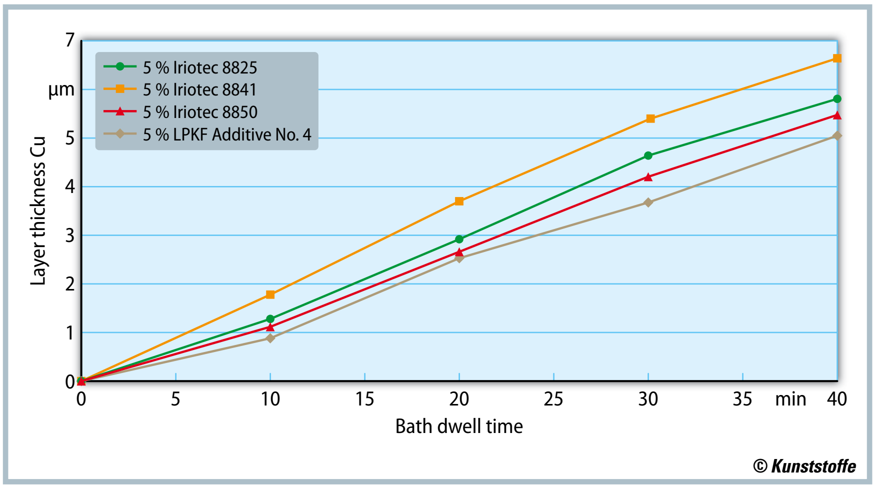


Fig. 4. Time-dependent determination of the copper layer thickness of various additives in PC+ABS (source: Merck)

Conclusion and Outlook

The use of laser additives from Merck enables light-colored plastics to be selectively metalized using the LDS process. The following major parameters were identified:

- The metallization behavior depends on the polymer, additive, and bath composition used.
- An increase in the bath temperature increases the deposition rate; instability of the bath and over-metallization must be avoided.
- Adapting the metallization parameters to the respective additive saves time and costs.
- The manufacturing process for LDS components is highly complex. For optimum results, the respective »

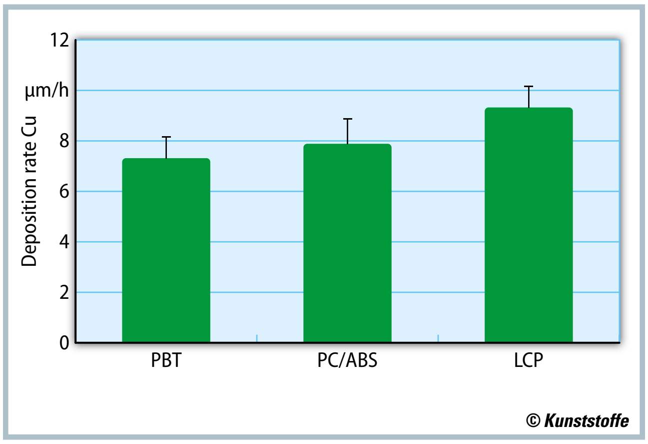


Fig. 5. Copper deposition behavior of Iriotec 8850 in various plastics (source: Merck)

experts must collaborate in the various process steps and adhere to design guidelines.

In addition to the previously established application fields, the LDS process can also be combined with new processing techniques such as the fused deposition modelling (FDM) 3D printing process. For this purpose, the Iriotec 8000 pigments are used as additives in colored 3D print filaments. The object is printed and then functionalized using the LDS process. The demonstrator shown as an example in the cover photo is a robot equipped with LEDs, manufactured by Merck KGaA and to be exhibited at the Laser World of Photonics trade fair (Munich, Germany, June 26-29, 2017; booth A3/415).

This advanced approach illustrates the new possibilities for combining 3D printing and LDS technology and thus opens up an even faster path from an idea to a functional finished product. ■

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AntiSkid

Additive with Superior Anti-Slip Properties

With AntiSkid, **Ampacet Corporation**, headquartered in Tarrytown, NY/USA, offers innovative new additive technology for flexible packaging applications that require a non-slip surface, whether for optimum functionality or for visual and tactile appeal.

AntiSkid, available in a variety of particle sizes, contains proprietary organic anti-skid ingredients. AntiSkid is available in particle sizes similar to medium (100 grit) and coarse (40 grit) sandpaper. Particle concentrations can be adjusted higher or lower, depending on anti-slip application needs. AntiSkid can be used in 2 mil or greater multi-layer films, and is suitable for blown and cast film and sheet extrusion processes under normal conditions.

In addition to its anti-slip advantages, AntiSkid performs well during the extrusion process and can easily be combined with other functional and special effects additives to achieve a wide range of desired visual effects. It offers unique textural and tactile appeal and translucency in flexible packaging, and a variety of dramatic looks are achievable – from antique plate glass to moisture droplets, according to the manufacturer.

Suggested applications include adhesive labels, anti-slip tapes, double-sided tapes, heavy-duty sacks, extruded parts, flooring and decking, roofing membranes and tire wrap embossed film alternative. AntiSkid is FDA approved, and can be extruded into the film structure for applications such as stand-up food pouches that can be reverse printed for enhanced visual and tactile appeal for added shelf impact. It also eliminates the need to overprint a non-slip treatment.

Stand-up pouch treated with AntiSkid technology (© Ampacet)

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