Inks for sustainable paper electronics

Sustainability has become a necessity in the electronics industry. Saralon GmbH (Chemnitz, Germany) introduces its latest inks with this purpose in mind

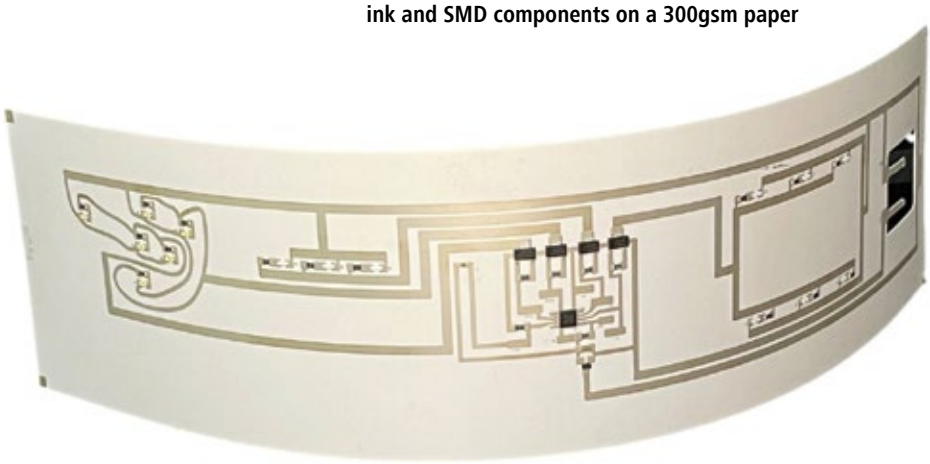
The global electronics industry crossed the one trillion dollars mark in 2019. With this jubilant achievement the mounting trouble of electronic waste is further amplified. In 2019 only, 54 million metric tonnes of electronic waste were generated, implying on average 7kg of electronic waste per person. Less than 20% of the electronic waste are collected and recycled properly. That means, more than 80% are simply dumped somewhere in our surroundings. Certainly, there is a need to improve electronic waste collection and recycling processes. But at the same time, efforts are needed to produce electronics with more sustainable and easily disposable materials. Typically, electronics are produced on printed circuit boards (PCB) which are made of non-biodegradable polymeric materials. A biodegradable alternative of PCB can be paper, which has been used for centuries for writing and printing purposes. If electronics are deposited/placed on paper, a large portion of electronic waste will become biodegradable.

Challenges with paper electronics

Colour printing on paper is a well-established industry. Various printing machines are available to print colour inks on paper with superfast speed. These printing machines can be turned into electronic-producing machines if colour inks are replaced by electronic inks. Currently, the technology to print electronics on paper is in its nascent stage. Before its commercial success, three main challenging goals – suitable paper, electronic inks and simple production process – need to be achieved. The paper which is suitable for colour inks cannot be easily used for electronic inks. The main issue related to commercially available paper is its humidity-dependent dimensional stability. When paper is heated it shrinks by losing water. It can or cannot return back to its original dimension after regaining the lost water. This shrinkage and expansion of paper substantially influence the performance of electronic devices printed on it. This also creates trouble in printing multiple layers one after another, as accurate registration cannot be maintained. The second issue with paper is its surface roughness. Compared to plastic substrates, paper has higher surface roughness. This creates problems in depositing a smooth layer of an electronic ink. The third issue with paper is its low water barrier properties. Typically, electronic device performance deteriorates in the presence of water. If electronics are deposited/printed on paper, the paper must provide a good barrier against water. That means, for electronic applications paper must have good dimensional stability, low surface roughness and good water barrier property.

Many paper manufacturers are working in this direction and a few papers are already commercially available with these characteristics. Apart from improving paper, there is a huge need for electronic inks which are suitable for paper. Most of the commercially available inks for printed electronics are designed for plastic substrate, especially PET. PET has very low surface roughness, good dimensional stability and relatively good water barrier property. For paper electronics, inks are needed that can dry or cure faster (<60 seconds) and at lower temperature (<100°C). This way only the dimensional stability of the paper can be maintained for multiple layer printing with accurate registration. Saralon GmbH has developed a series of electronic inks for paper electronics production. Together with electronic inks, Saralon is simplifying electronic printing processes to realise the challenging goals as mentioned above. Some of its latest inks for paper electronics and their applications are briefly explained below.

Fig. 1: Printed conducting silver ink, conducting adhesive ink and SMD components on a 300gsm paper



Light emitting paper

Light has always been fascinating for humans. Currently, LED based technology is leading the lighting industry. Apart from lighting applications, tiny SMD LEDs are being used in various items e.g. packaging, advertisement wallpapers, PoS, books, leaflets and many more. SMD LEDs have become so cheap that they can easily be used in various low-cost products. Most of the time LEDs are used on PCB

or on flexible plastic in which etched copper conductors are used. Saralon has developed a suitable water based conducting silver ink for paper which dries fast and hence maintains the dimensional stability of the paper. The ink can also be used on rough paper surfaces.
In order to fix LEDs and other SMD components on the printed conducting silver, Saralon has developed a low temperature curing conducting adhesive. The conductive adhesive can be cured even at 100°C while maintaining the dimensional stability of the paper. A paper-based LED board is shown in Figure 1. Many times, creasing is required to fold paper without damaging the paper. Commercially available conducting silver inks get damaged by creasing. In order to solve the issue, Saralon has developed a water-based stretchable silver ink that can be printed at the crease area to prevent any damage by creasing. That means by using the ink, paper can easily be folded at crease without damaging the conducting silver layers.

NFC tags on paper

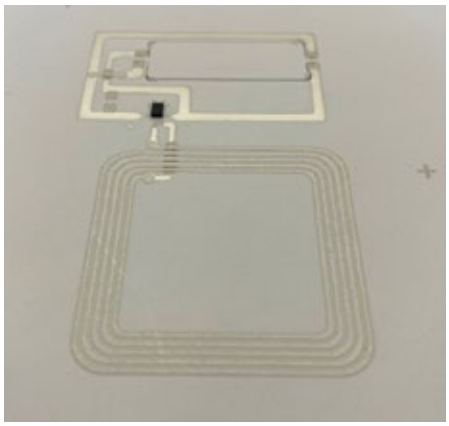


Fig. 2: Printed NFC antenna and NFC chip on a 300gsm paper

Commercially available NFC tags are mainly placed on plastic substrates. Generally, NFC tags are disposed with household waste. Therefore, there is a need to produce NFC tags more sustainably and more biodegradably. Saralon has developed a high conducting silver ink to print NFC antennas on paper. The ink can be cured easily at ~100°C and possesses a low resistance of <15mΩ/sq/25µm. The ink is of a very high solid content (86%), which means that printing a thick layer is easy in one print run, which is needed for printing low resistance NFC antennas. Saralon has also developed a conducting adhesive to easily pick-and-place QFN or wafer NFC chips. Typically, QFN chips need less than 200µm line width of conducting adhesives separated by a gap of less than 200µm. It is very challenging to print conducting adhesives on paper with good registration accuracy. Saralon's innovative conducting adhesive to fix QFN chips on paper can solve these issues. Figure 2 shows an NFC tag produced on paper, which is produced just by printing four inks.

Printed battery on paper

The battery is an important component of electronic devices. Commercially available batteries are either in metal casing or in plastic pouch. Printed batteries available in the market are also in plastic pouches. In order to convert printed batteries into more sustainable batteries, plastic pouches must be replaced by a biodegradable material e.g. paper. Saralon has developed inks and printing processes for Zinc-Manganese dioxide batteries which can easily be printed on paper. This battery development was a part of the EU Horizon 2020 funded project IMPETUS (grant agreement No. 761167). The IMPETUS project aims to realise a "Pilot line for paper based electrochemical test strips dedicated to quantitative biosensing in liquids" at tagtron GmbH located in Vöcklabruck, Austria. The battery can be screen-printed by using only seven inks on a suitable barrier paper. The battery shown in the picture was produced on a barrier paper provided by Felix Schoeller Holding GmbH & Co. KG. The advantage of Saralon's battery inks is that all layers of the battery are printed. Complicated steps of paper placement as separator or the injection of electrolytes are not required during the battery production.

Fig. 3: Printed Zn-MnO_2 battery on paper, developed in the EU Horizon 2020 funded project IMPETUS

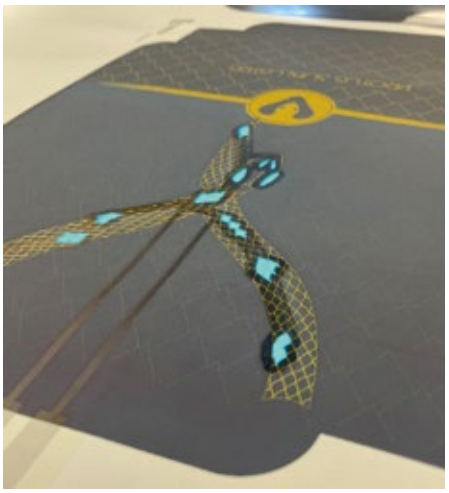


Fig. 4: A printed electroluminescent display on 100gsm paper, with offset printed graphics on top of it

Printed electroluminescent display on paper

Commercially available electroluminescent (EL) inks are mainly for PET substrates. That means inks are drying at a higher temperature and with a slow drying rate hence cannot be easily used for paper substrates. Figure 4 shows Saralon's development in the field of EL displays printed on paper. Saralon has developed four EL inks which can be dried even at 70°C. Most screen printers include thermal dryers which can reach up to 70°C only. Here, Saralon's four different EL inks are printed on a 100gsm paper by a sheetfed screen printing machine in ambient conditions. After that, graphics are printed by an offset printing machine. Connecting the paper with a suitable power source can light up the printed areas. This illuminating paper can be used for multiple applications e.g. boxes, labels, bags, posters, PoS. The amazing properties of this light emitting technology make sure that the paper can be rolled up and also be bent. Apart from thermal drying EL inks, Saralon has also developed UV curable EL inks. These inks are conducting silver ink, UV curable dielectric ink and UV curable EL phosphors. The UV curable inks have the advantage that they are suitable for fast printing machines.

Image sources: Saralon GmbH