Printed Electronic
on Flexible and Glass Substrates

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Abstract
Organic electronic is a platform technology that enables multiple applications that are based on organic electronics but vary widely in their specifications. Organic electronics is based on the combination of new materials and cost-effective, large area production processes that open up new fields of application.

Thin, light-weight, flexible and environmentally friendly are main features describing organic electronic. It also enables a wide range of electrical components that can be produced and directly integrated in low cost, high effective reel-to-reel processes. Intelligent packaging, low cost RFID, flexible solar cells, disposable diagnostic devices or games, and printed batteries are few of examples of promising fields of application for organic electronic[1].

The paper presents technology of manufacturing electronics elements on flexible and glass substrates. Fabricated structures were characterized form the point of shape, surface and geometry. Variety of substrates were investigated, within some, low cost, non specialized substrate, design for other purposes than organic electronic. Results of substrates influence on printing process was describe in article.

InkJet printed electronic.
Organic electronic can be fabricated using well known printing techniques. The most desirable are roll-to-roll techniques. They require expensive tools, high cost test runs. That is why these technology is rater useless for research and development laboratory tests. Small companies and research institutes are more interested in InkJet technology. InkJet printing is more proper for small scale production and prototyping. Inkjet printers does not require any tools or process changes for fabricating new set of elements. They can print from graphic bitmap files straight to the substrates. Making prototype fabrication cost very low. This advantage makes InkJet printing the leader of organic electronics fabrication technologies. That is why investigation of the inkjet printing process is crucial for the fabrication of printing electronic issue.

In Tele- and Radio Research Instytute investigations and test have been made on self build InkJet printer. Printer is based on MicroDrop piezo-electric printing head, with nozzle diameter of 50 µm, and drops volume from 35 to 55 pico liters. The pH of ink is to be in range 1 to 12, and the viscosity in range 1-15 cP[2]. This allows to test high variety of commercial inks and new inks produced by other research institutes and companies. The printer schematic is shown in figure 1.

The printer is design for investigation of organic inks features, printing parameters, ink/print head and ink/substrate compatibility, printing electronic elements as well. However it is possible to use inorganic inks based on metal powders, such as nanosilver based inks. Printer with it control unit is shown in fig. 2.
Two CCD cameras are used to control printing process. Camera one is used to control jetted drop shape, size and trajectory. Second camera controls drop deposition on substrate and pattern quality. Drop size and shape can be changed by adjusting amplitude, delay and frequency of electric control impulse. Control parameters must be adjust and optimized for each ink because of their very different viscosity, in ranges 10-250V and 2-100 µs.

In this letter are presents result of test on PEDOT:PSS based organic ink for inkjet printing and Nano Silver based inks. Printer parameters were adjusted to get single drop on demand, which is important for high quality inkjet printing. PEDEOT:PSS ink parameters were set to 60V and 4 µs, ink and substrate temperature was set to 25°C, and single drop could be jetted. Single drop jetted on demand is shown in fig. 3.

Nano silver single drop is much harder to get. Ink viscosity and density is much higher than PEDOTs. Printing parameters were set to 122 V and 11 µs of impuls length.

Profile measured on Laser profilemeter, shows that PEDOT dots has so cold “coffee ring” or “donut” effect. Silver ink doesn’t have this effect. Ink, deposited on substrate, spreads forming an wave, solvent evaporates so fast that the wave isn’t able to go back and form regular shape. Methods of reducing
coffee ring effect were not an issue in this investigations, however higher temperature of the substrate, cause faster solvent evaporation making wave spreading harder reducing coffee ring. Obtained dots diameter was for PEDOT:PSS 350 µm, and 253 nm of maximum height. And for silver 150 µm and 1,5 µm of height.

Next substrates used in investigation were Felix Schoeller p_e smart papers. These are specially designed papers for printed organic electronic[3]. It has polymer layer laminated on its surface (Fig. 6). This polymer layer reduce absorption and by using different polymers surface energy can be controlled.

Printed dots on paper substrate are shown in figure 7.

Dot profile is sferoidal. There is no coffe ring effect, and surface is smooth. Diameter is 62 µm and height is 15 µm.

Silver dot height is 0,7 µm and diameter is 250 µm. As you can see in Fig. 8 dot is also sferoidal and smooth.

Printing conductive lines on glass and flexible substrate was the main issue of investigation. Every electronic element is build of lines made of materials with different features. Fabricating lines on glass surface needs overcoming an coffee ring effect. One of the most popular method was tested – printing dots in spacing less than the dot diameter. The results of PEDOT:PSS conductive line is shown in figure 9.

Dots printed close to each other form leader line, they should be printed close enough to form a smooth surface[4]. Width of e line is an dot diameter – about 350µm, and its height is up to 300 nm.

Line printed on paper (Fig. 10) has more smooth surface, the line is continuous. However printing on paper is more difficult. Electric charge on surface can change the trajectory of a jetted drop. Removing surface charge form paper is difficult and charge can easily be generated from air.
In figure 11 a nanosilver conductive track is shown. It is 150 µm width, and 3 µm high. Sharp edges are not affected by the “coffee rings”. In case of a silver ink, each drop overlays on previous one. More detailed picture is in figure 12.

Because of this effect, surface is quite rough. But while sintering the surface is getting smoother. Nano particles of ink “melts” together forming smooth track.

Printing on standard photo paper was unsuccessful, absorption, surface roughness, foil cover thickness is random in random places. Making standard photo paper useless for printing electronic.

References

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