Registered multilayer gravure printing of electronic thin film devices

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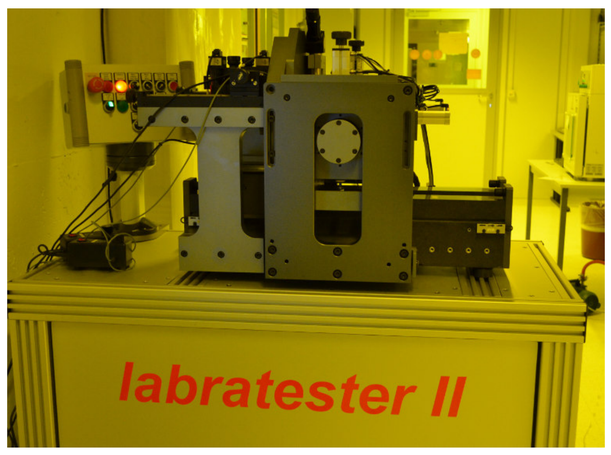
High quality printing equipment is a key enabler for printed electronics produced at low cost on large area, flexible substrates. In the framework of the CTI project *SWiss Precision Electronic GRAvure PrintEr* (SWIPEGRAPE), Centre Suisse d'Électronique et de Microtechnique (CSEM) supported the company Norbert Schläfli Maschinen Zofingen (NSMZ) to develop and validate a high precision laboratory gravure printing machine (*Labratester II)* for the fabrication of printed thin film devices e.g. single thin film transistors and inverters. Due to the high precision of the alignment system, *Labratester II* enables layer-by-layer printing with registration in the range of a few micrometres across 7 inch flexible or rigid substrates.
The results shows that the *Labratester II* is a versatile tool to close the gap between lab and production. In particular it demonstrates the capabilities for prototyping demonstrators, screening materials and refining processes before scale-up production of printed electronics. In addition the outcome shows that gravure printing is a suitable technology for printed electronics.

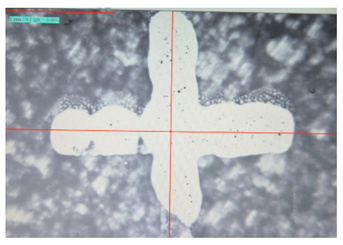
Labratester II

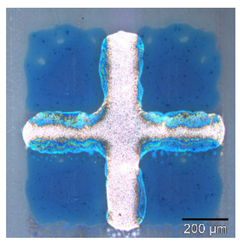
The Labratester II is a lab-scale, high resolution gravure printing system based on a Granite stone plate. This stone plate (face grinded in a precision of 300 nm) is directly used for the air-lubricated bearing carriage (vacuum chuck). This carriage is driven by a linear motor. The fully Chromium cylinders are direct laser engraved and driven by a torque motor.

- Printing area 7x7" (200 x 200mm)
- Registration in the range of a few micrometer
- Able to print on flexible and rigid (glass) substrate



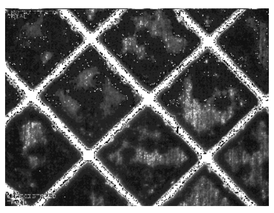
Labratester II



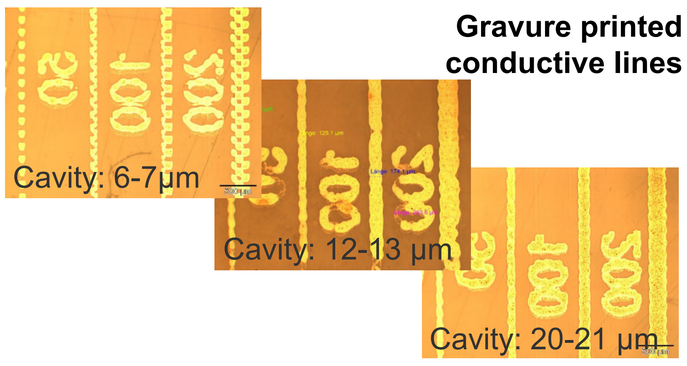


Alignment marks (screen view) and microscope image of over printed alignments mark (silver ink and UV-cross-linkable blue ink).

Cylinder engraving and prints



Microscope Image: Engraved cavities incl. patterning



Gravure printed conductive lines

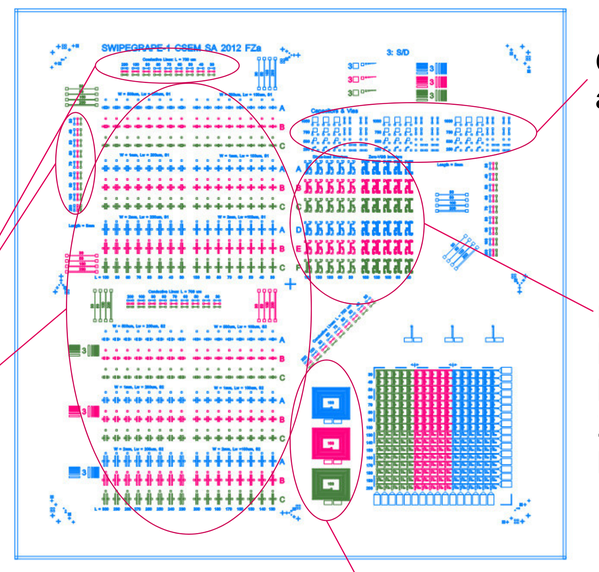
Design

The cylinder design includes variation of different devices in different dimensions and engraving cavities:

- Single Transistors
- Inverters
- Antennas
- Vias
- Capacitors
- Conductive lines

Conductive lines

Single Transistors
Variations in
- Channel length (L)
- Channel Width (W)
- Engravings Cavities



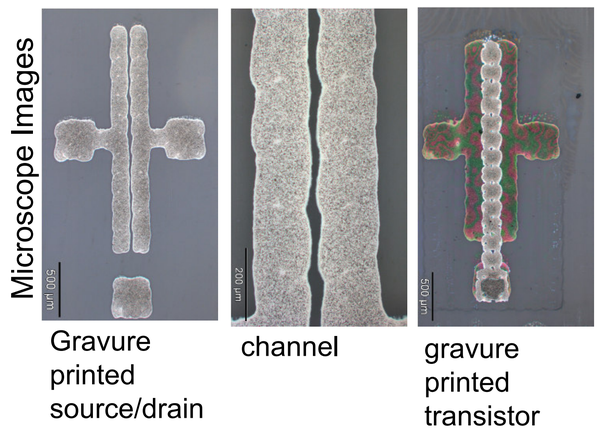
Capacitors and Vias

Inverters
Diode-load Inverters and Zero-V_{GS} Inverters

Antennas
different cavities

Printed layer and device

Printed device

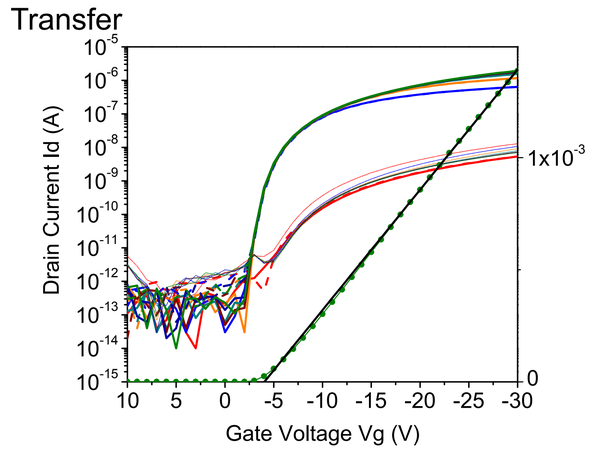


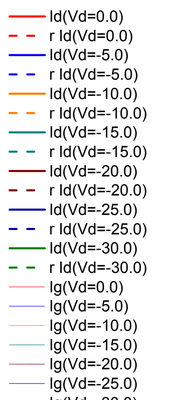
Gravure printed source/drain | channel | gravure printed transistor

Commercially available Materials:
Silver ink: InkTec PR-020
Semiconductor, Dielectric, Contact modification: Merck Lisicon
Substrate: Melinex ST506

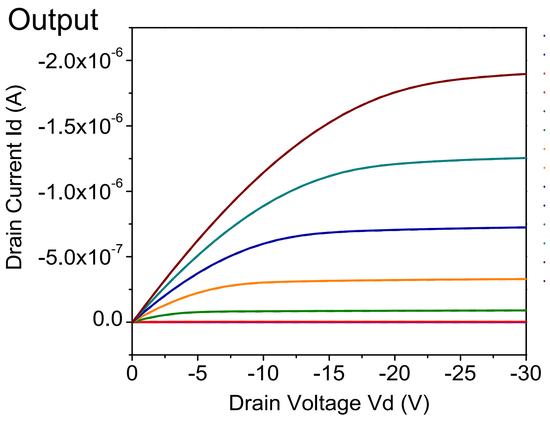
Results Single Transistor and Inverters

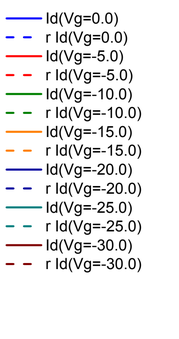
Transfer



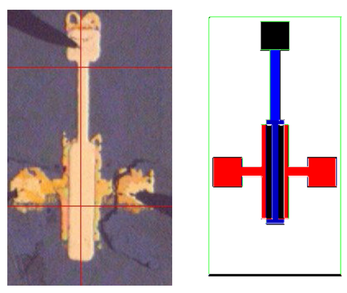


Output





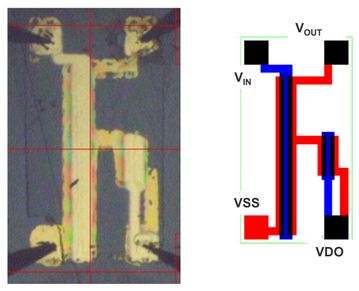
Transfer and Output curves of single OTFT



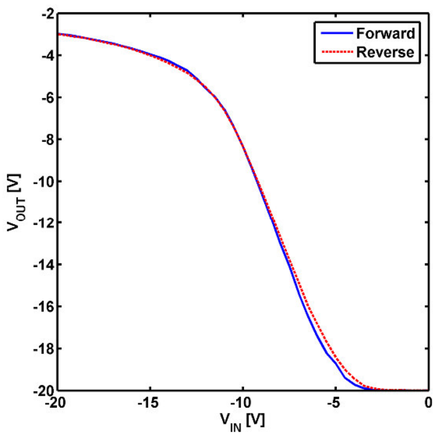
Mobility:	1.107 10^{-2} cm^2/Vs
Threshold:	-4.035 V
On/Off:	1.924 10^8
S:	0.6 V/dec
Ig/Id $\|_{Vgmax}$:	3.645 10^{-3}
$Id_{max}L/W$:	9.252 10^{-9}

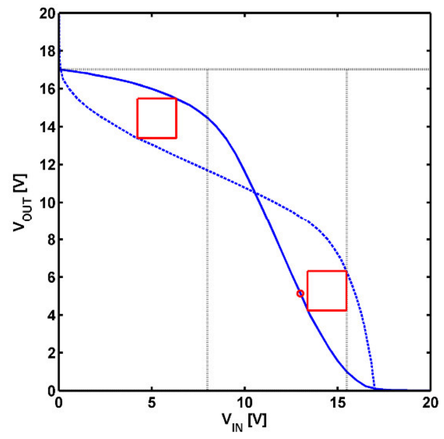
Notes:
The presented transistors and inverters are based on Gold source/drain electrodes (patterned by gravure-printed photoresist), gravure printed semiconductor and dielectric. Gate electrode was evaporated due to the mismatch of solvent of the printed conductors and dielectric layers. The used materials are commercially available. Nevertheless entire printed transistors was demonstrated with proprietary materials.

Transfer curves of an inverter with V_{DD} = 20V



V_{trip}:	10.5V
Gain:	2.26
NM_{MEC}:	2.09V





acknowledgements We gratefully acknowledge the financial support from the Commission for Technology and Innovation CTI; Project 13596.1 PFFLI-NM