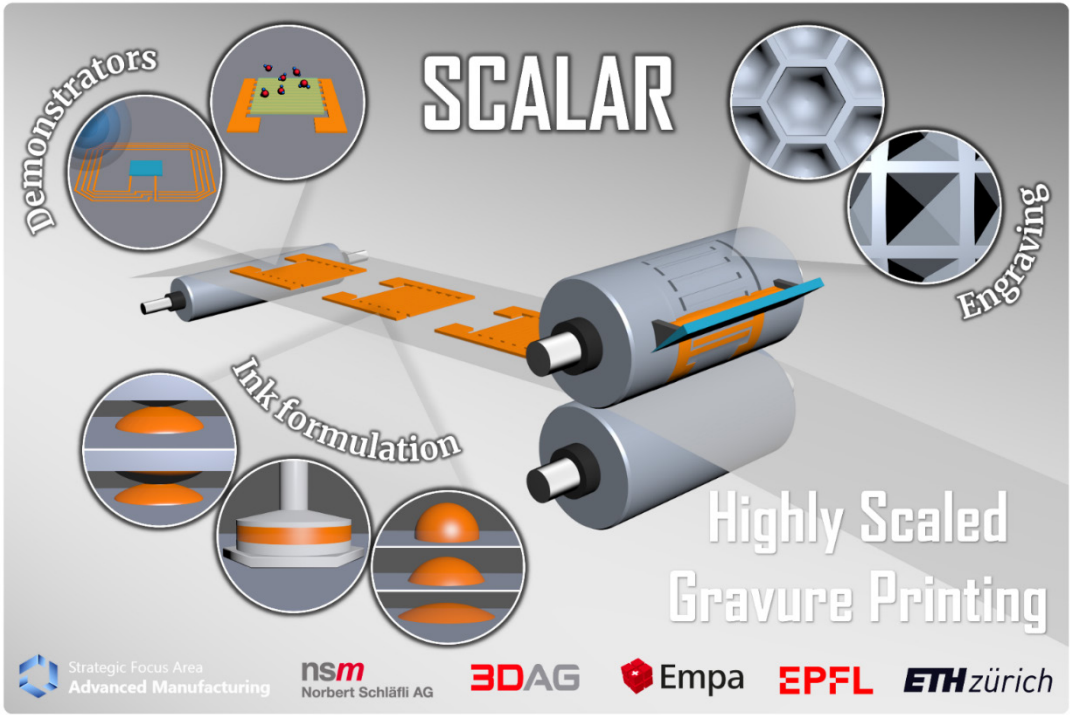
Highly Scaled Gravure Printing

SFA-AM Review Meeting

17 March 2022



SCALAR: Objectives and deliverables

The objective of this proposal is to **establish highly scaled gravure printing as manufacturing technology** for applications in PE and opto-electronics.
We define highly scale gravure printing as "printing 2 µm wide conductive line-features at a speed of 1 m/s on a DIN A5 area".

One deliverable will be a **high precision gravure printing unit at Empa (D3)** readily available for researchers of the ETH domain and industry collaborators. Recipes and standard operation procedures (SOPs) for ink synthesis and processing (D1) and gravure cylinder design and manufacturing (D2) will be available.

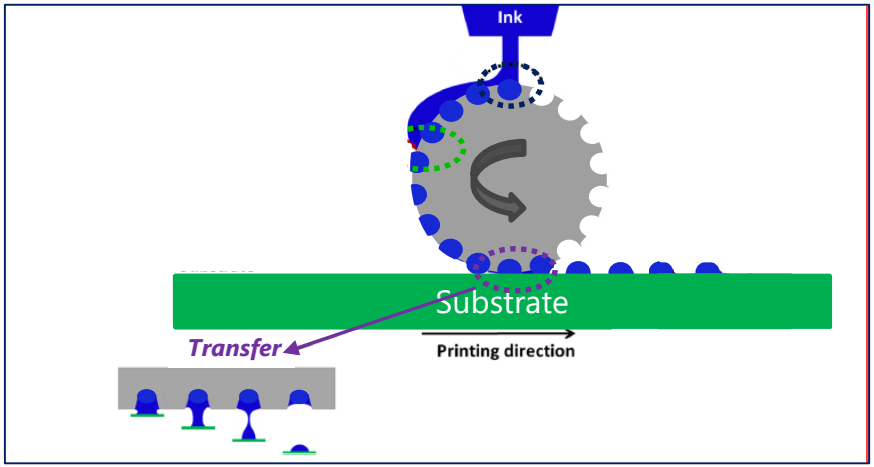
A further objective is **to show the direct applicability of gravure printing with demonstrator devices.**

Gravure printing

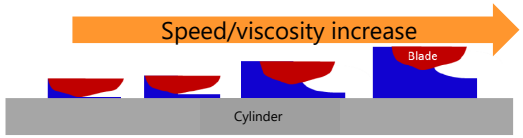
- Very successfully applied in graphics and arts industry

  Gravure AIMCAL Alliance: "The Process of Producing Fine, Detailed Images"

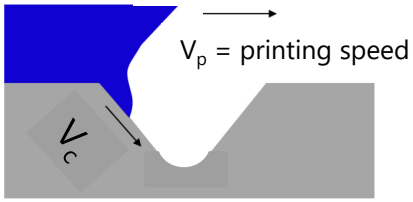
- Gravure is a contact printing technique where ink is transferred in the so-called ink splitting process from a cavity in a cylinder into a substrate
- The process allows for:
  - High speed;
  - High resolution
  - Relatively large amounts of material can be deposited



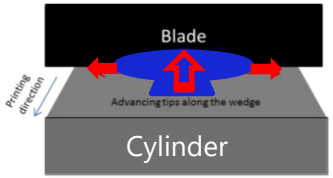
Process of gravure printing

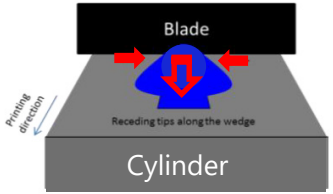


Lubrication film

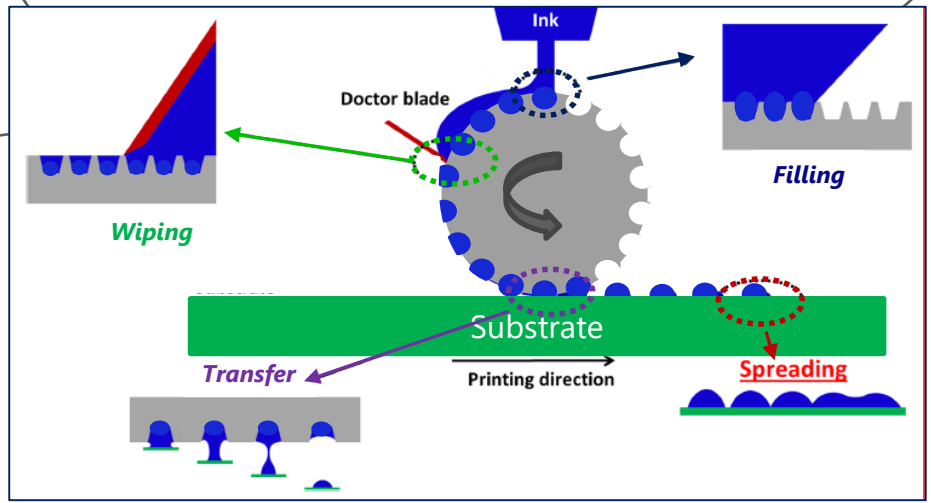


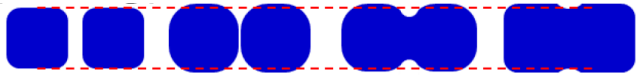
Air entrapement





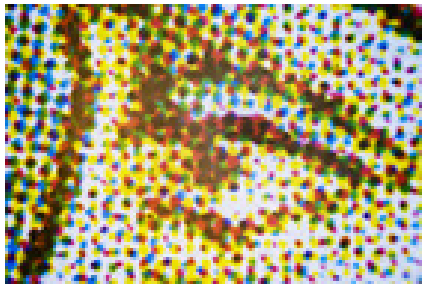
Drag out

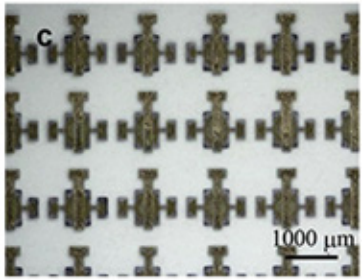




Thesis G. Grau 2017

Current challenges





http://www.androidauthority.com/

- Functional inks
- Defect free continuous films
- Overprint accuracy
- Higher resolution

- Potential of gravure printing is by far not fully exploited
- Prove of concept studies by Vivek Subramanian

<u>Some of the relevant parameters</u>

- Ink rheology and surface tension
- Shape and surface property of cavity
- Blade property and pressure
- Cylinder pressure

<u>There is a need for:</u>

- Theoretical understanding
- Ink synthesis, Up-scaling, Cost of inks
- Cylinder engraving
- Better control of printer parameters

Consortium - address all the challenges

Steering committee

Empa LFP
Project management

Stake holders

WP1
EPFL LAFT
Gravure printing inks
Gravure printing theory

WP2
Empa LAMP
3DAG
Laser cylinder shim foil engraving

WP3
Empa LFP
nsm Norbert Schläfli AG
Adaptions to nsm C600

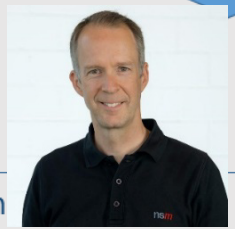
WP4
EPFL LESO
Mesh electrode

WP5
ETH PBL
Printed embedded components
Sensors

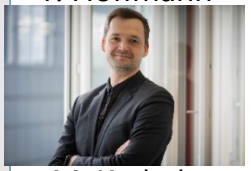

V. Subramanian


A. Schüler


J. Heier

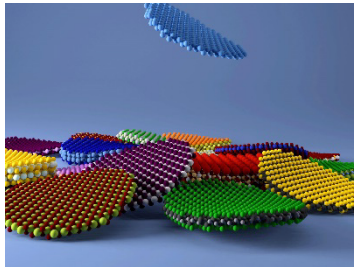

M. Schläfli

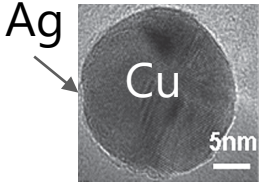

P. Hoffmann


M. Krehel


M. Magno

WP1 Theory & Ink - tasks





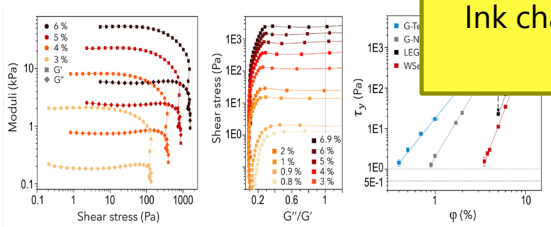
Nanoparticle & 2D materials inks

Print theory

Analysis of printed features

$$\frac{\partial h}{\partial t} = -\frac{\partial h}{\partial x} - \nabla \cdot (s \nabla \nabla^2 h)$$

Ink characterization



Viscosity, elastic and loss modulus

Synthesis up-scaling

High shear mixing

Flow reactor

WP2/3 Cylinder & Gravure printer

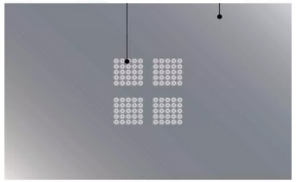
Laserablation of master

Empa LAMP: KrF Excimer laser at 248 nm, up to 600 mJ per pulse, repetition rates of up to 400 Hz

- High resolution (down to 2 micron)
- Greyscale shapes

From master to shim

3D AG: Nickel-forming



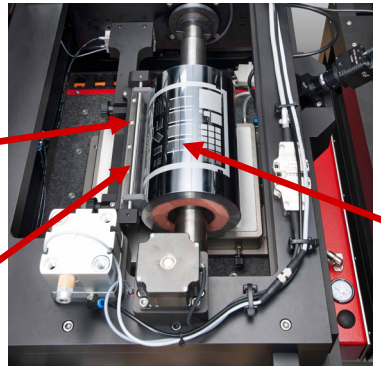
Lamination onto cylinder

Nsm Schläfli AG

Fine tuning of printer

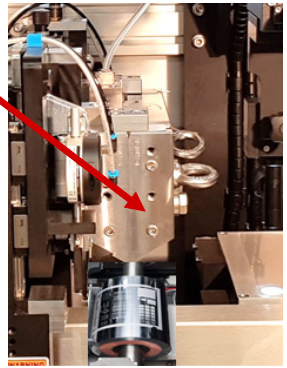
Vary of blade angle via mechanically interchangeable blade holder

Controlled doctor blade pressure (force measurement)

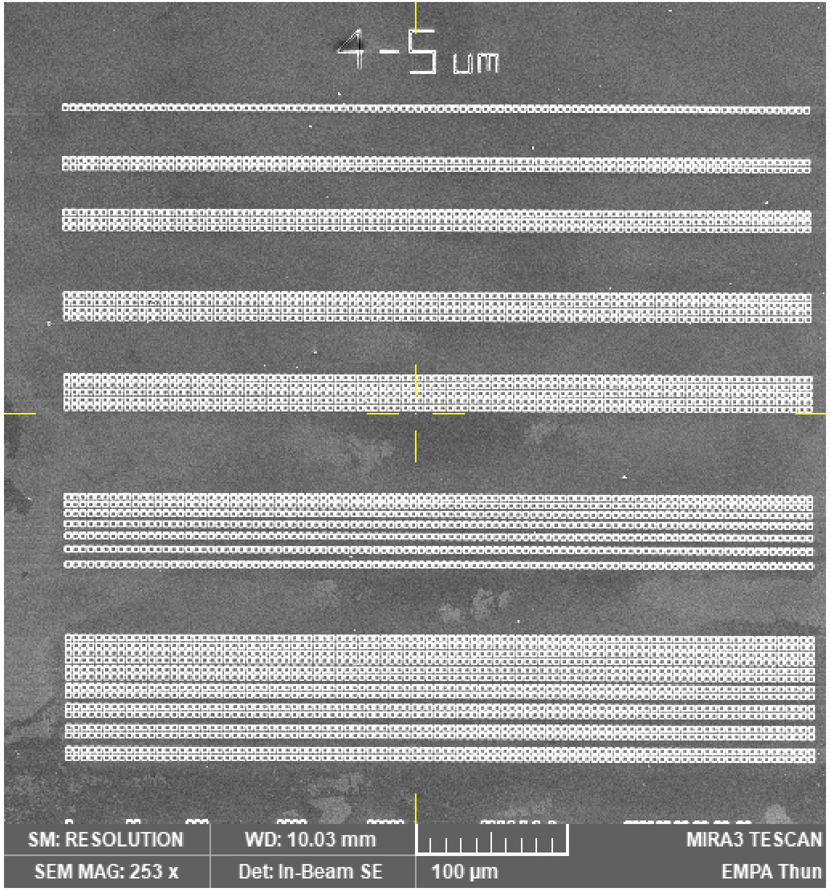


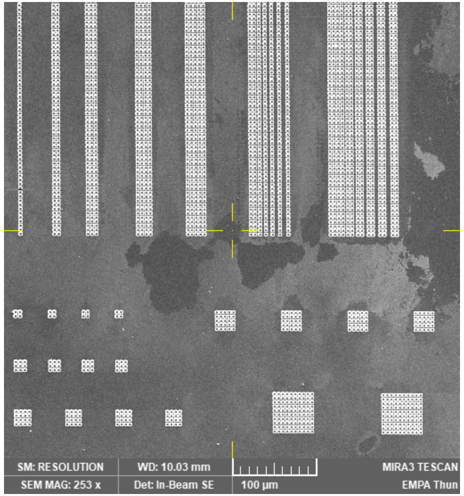
Pressure/force measurement rotogravure cylinder to substrate

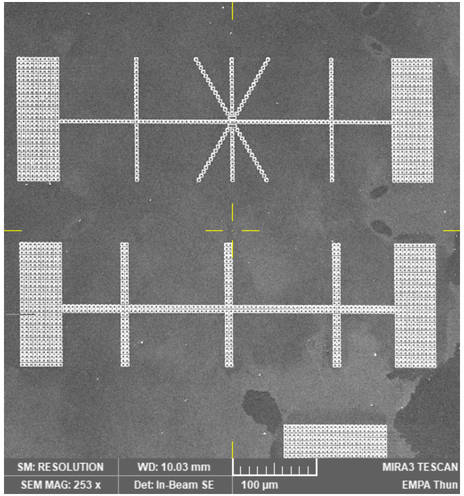
Software controlled inking via slot die head

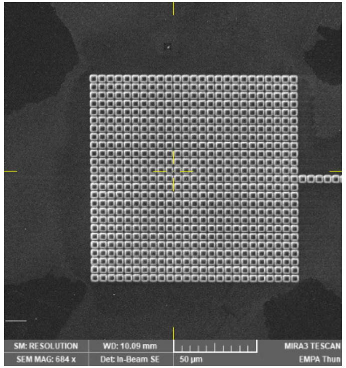


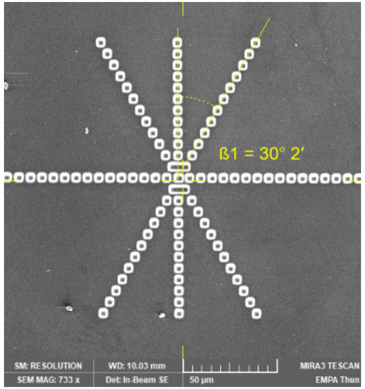
Test features





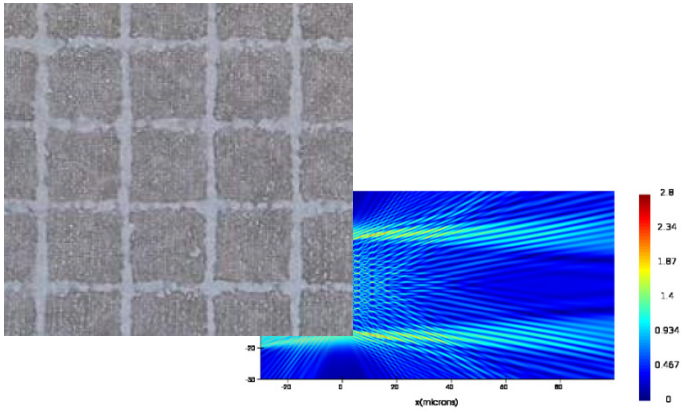






WP4 Applications – mesh electrodes

Many applications require transparent conductive substrates – away from TCOs
EPFL: Solar Energy and Building Physics Laboratory



Electrochromic windows on TCO basis:

- Slow switching time
- No switching in near-IR

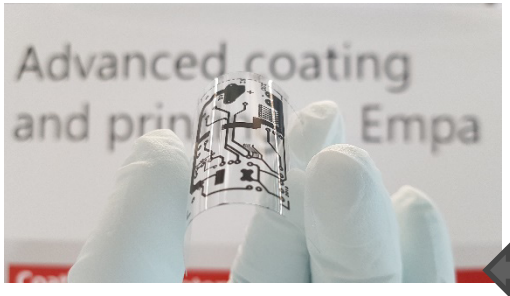
Solution:
Printed novel transparent hierarchical micro-/nanomesh electrodes:

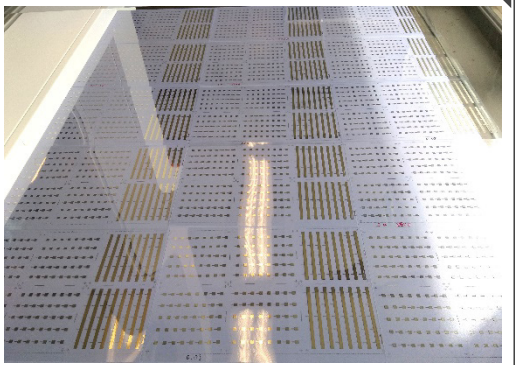
- We target a solar transmittance above 80%, and a sheet resistance below 10 ohms/sq
- System demonstrator with the dimensions in the order of 6 cm x 6 cm, switching time in the range from 1 min to 3 min

WP5 Applications – printed embedded components, sensors

- For numerous **electronic devices** traditional manufacturing can be replaced by **additive printing steps**

Printing

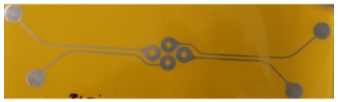


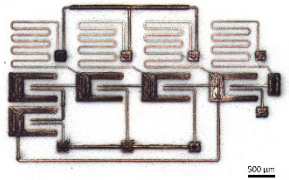


Characterization of

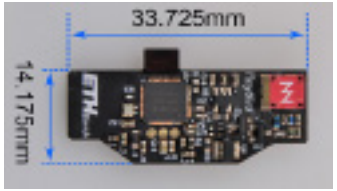
- Conductive features
- Passive components
- Interdigitated and spiral structures (capacitors and inductors, respectively)
- Antenna matching
- Simple circuits

PBL will set the design criteria for components and circuits to be implemented in devices





CENTER FOR PROJECT-BASED LEARNING



Sensor node for perpetual acoustic monitoring in bird research

Industry collaborations

Project plan

	Project Gantt-Chart	WP lead	Year 1				Year 2				Year 3				Year 4			
		Participants	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	**Inks - Theory - Printing**	**EPFL-LAFT**																
	T1.1: Conductive nanoparticle inks for conductors	LAFT					**D1.1**											
	T1.2: 2D Materials-inks: conductor, semi-conductor, dielectrics	LFP									**D1.2**							**D1**
	T1.3: Development of rheological models	LAFT / LFP																
	T1.4: Inks for supercapacitors	LAFT																
	T1.5: Integration of inks into final demonstrators	LAFT / LFP																
2	**Cylinder Engraving**	**EMPA-LAMP**																
	T2.1: Excimer laser structuring	LAMP																
	T2.2: Double replication flat Ni plate, transfer to WP1 / T1.5 60 x 60 mm^2 mesh electrode, transfer to WP4 T4.3	LAMP / 3D AG					**D2.1**											
	T2.3: Coatings - Mechanical testing	LAMP / 3D AG																
	T2.4: Structuring of PCB design 150 x 150 mm^2 on Ni sleeve	LAMP/nsm/3D AG																
	T2.5: Cylinder technology transfer to WP3 / T3.4	LAMP / nsm											**D2.5**					
	T2.6: Fabrication shims structures for new inks	LAMP/nsm/3D AG																
	T2.7: Iteration of T2.4 to T2.5	LAMP/nsm/3D AG																**D2.7**
3	**Adaptions to C600**	**EMPA-LFP**																
	T3.1: Blade pressure control	nsm / LAFT / LFP																
	T3.2: Cylinder pressure control	nsm / LAFT / LFP																
	T3.3: Ink feeding system	nsm / LAFT / LFP																
	T3.4: Transfer of shim foil to cylinder	nsm / LAFT / LFP														**M3.4**		
4	**Demonstrator - Mesh electrode**	**EFPL-LESO**																
	T4.1: Database of ink properties	LESO			**D4.1**													
	T4.2: Computer simulations	LESO				**D4.2**												
	T4.3: Laboratory-scaled electrochromic devices	LESO / LFP / LAFT						**D4.3**										
	T4.4: Optical characterisation	LESO							**D4.4**									
	T4.5: System demonstrator	LESO / LFP / LAFT									**M24**							
5	**Demonstrator - Embedded components**	**ETHZ-PBL**																
	T5.1: Requirements and Specifications	PBL / LFP / LAFT				**D5.1**												
	T5.2: Design and system integration of sensor node	PBL / LFP														**D5.2**		
	T5.3: Lab and experimental evaluations	PBL																