Hub of Application Laboratories for Equipment Assessment in Laser Based Manufacturing

Supported by the European Commission

COOPERATION

APPOLO project within FP7 framework

5 June, 2015
APPOLO Workshop
Lappeenranta, Finland

www.appolo-fp7.eu
FP7 project No 609355

Dr. Gediminas RAČIUKAITIS
Head of Department of Laser Technologies,
Center for Physical Science and Technology
Savanoriu Ave. 231, LT-02300 Vilnius, Lithuania
graciukaitis@ar.fi.lt

CENTER FOR PHYSICAL SCIENCES AND TECHNOLOGY

General official information

- Collaborative project of 7th Framework Programme (large integrated project)
- Call: FP7-2013-NMP-ICT-FOF “Factories of the Future”
- Objective: FoF-ICT-2013.7.2 Equipment assessment for sensor and laser based applications

- **APPOLO**
- **Hub of Application Laboratories for Equipment Assessment in Laser Based Manufacturing**

- **EC Grant Agreement N° 609355**
- **Start: 01 September, 2013;** **End: 31 August, 2017**
- **48 months**
- **Our efforts:** **1112 PMs**
- **Total estimated budget:** **14’007’330 €**
- **EC contribution:** **10’999’954 €**

- **We are 22 partners from 8 countries (LT, CH, DE, ES, FI, IS, IT, NL, BE):**
  - **Public research & universities** **6**
  - **Industrial research** **1**
  - **SMEs** **11**
  - **Large** **3**
- New 16 partners are on selection process after **the Open Competitive Call**

APPOLO concept

- **focuses on** emerging innovative laser technologies and processes, which need to be customised, tested and validated :
  - **Customized** – service of application labs for trials;
  - **Tested** – experiments at variable conditions;
  - **Validated** – reliability and process quality assessment in the close-to-manufacturing environment.

- **exploits** the unique combination of distributed knowledge in
  - academic application labs,
  - equipment producers,
  - system integrators and
  - end-users

to enable the development of innovative processes, products and machineries for industrial laser material processing applications.

- **seeks** to establish and coordinate the **Hub of laser application laboratories** to provide the high-quality integrated services.

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Goal of the FP7 project APPOLO

- **establish and coordinate connections between**
  - **the end-users, which have demand on laser technologies for (micro)fabrication;**
  - **knowledge accumulated in the application laboratories of research institutes and universities;**
  - **the laser equipment manufacturers (preferable SMEs: for integration, lasers, beam control and guiding, software, etc.),**

&

- **facilitate**
  - **faster validation of the process feasibility**
  - **adaptation or customization of the technology & equipment for manufacturing conditions, including:**
    - reliability of components;
    - their interaction;
    - assessment of the dedicated production processes;
    - process speed, quality and repeatability;
    - economics issues.

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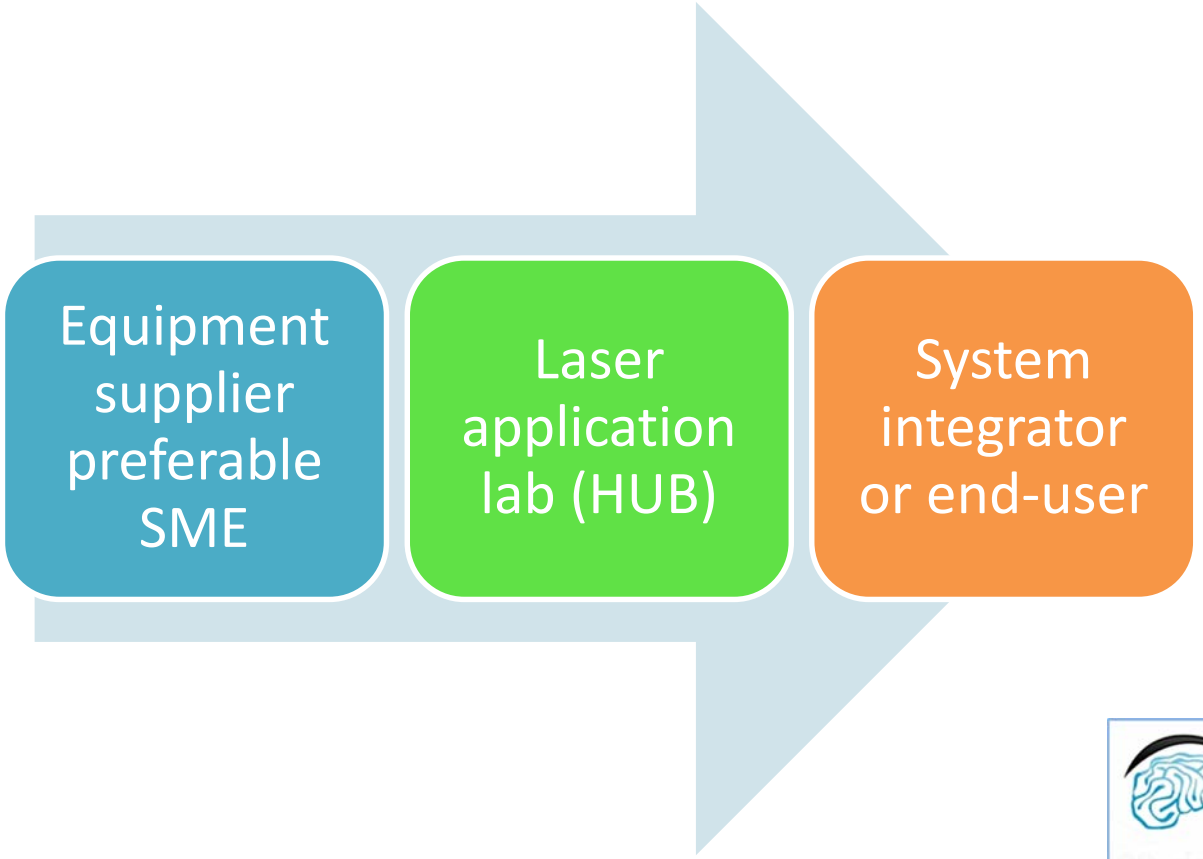
Goal of a ICT call and APPOLO

Reducing barrier to enter into market with new product (equipment for laser-based manufacturing)



THINK INDUSTRY

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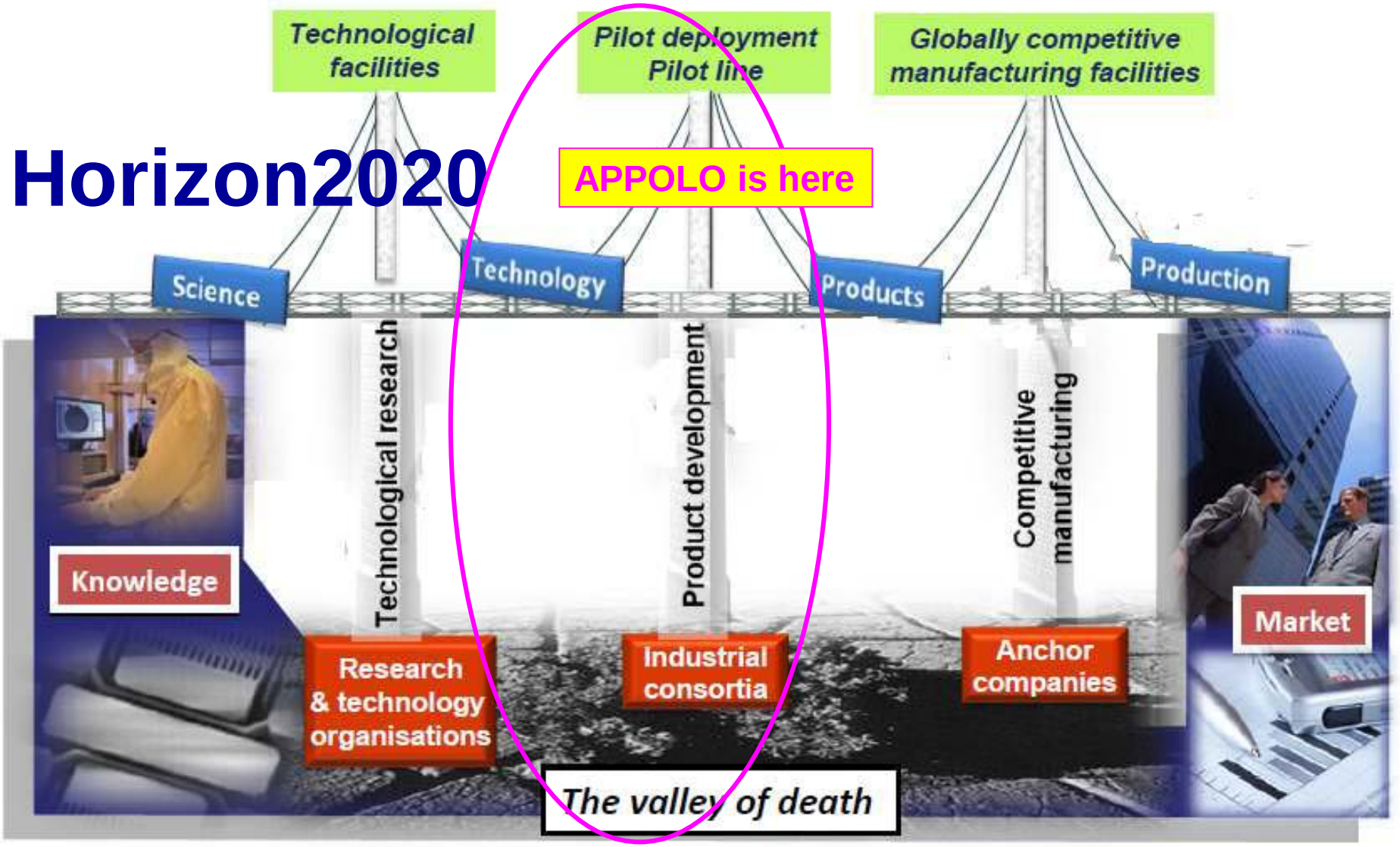
Horizon2020



EC High Level Group on Key Enabling Technologies Status Report 28/06/2011:

the Three Pillars Bridge to Pass across ”Valley of Death”

Technology readiness levels

Technology readiness levels (TRL)

"blue sky" research

- **TRL1** - basic principles observed
- **TRL2** - technology concept formulated
- **TRL3** - experimental proof of concept

Applied research

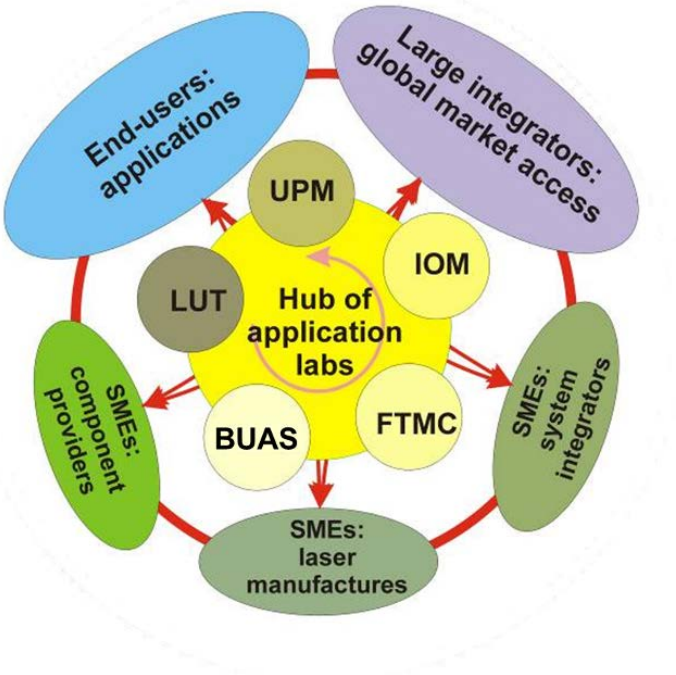
- **TRL4** - technology validated in lab
- **TRL5** - technology validated in relevant environment (industrially relevant environment in case of key enabling technologies)
- **TRL6** - technology demonstrated in relevant environment (industrially relevant environment in case of key enabling technologies)

Technology development

- **TRL7** - system prototype demonstration in operational environment
- **TRL8** - system complete and qualified
- **TRL9** - actual system proven in operational environment (competitive manufacturing in case of key enabling technologies or in space)

Position of APPOLO and a part of PPP FoF

APPOLO: idea and implementation



Hub of laser application laboratories

Core of the consortium - **laser application laboratories:**

- around Europe;
- connected to a virtual hub,

in order to

- accumulate knowledge and infrastructure
- promote the easy-to-access environment
- develop and validate of laser-based technologies

in

the **8+7** equipment assessment value chains:

Industrial Advisory Board

Input form other assessment chains

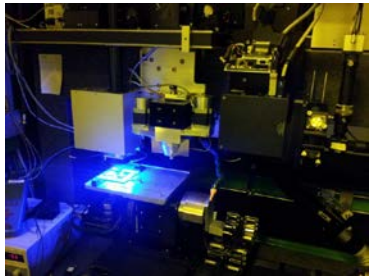
Assessment procedures → Equipment assessment → Integration for process validation → The equipment in processing → Validation with or at end-user

Report on equipment

Report on equipment In process

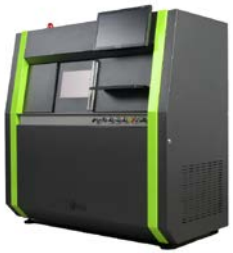
Final report

APPOLO: the consortium along the value chain



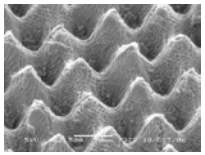
END-USERS:

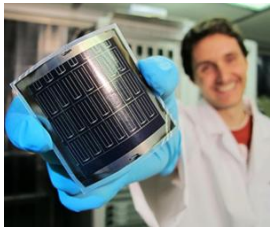
- Centro Ricerche Fiat SCPA
- Daetwyler Graphics AG
- Abengoa Solar New Technologies SA
- Mondragon Assembly Sociedad Cooperativa (SME)
- Sachsische Walzengravur GmbH
- Bioage SRL (SME)
- Flisom AG (SME)
- ...



APPLICATION LABORATORIES:

- Center for Physical Sciences and Technology
- Leibniz-Institut für Oberflächenmodifizierung e.V.
- Bern University of Applied Sciences
- Lappeenranta University of Technology
- Universidad Politécnica de Madrid





SUPPLIERS:

- Ekspla UAB (SME)
- Time Bandwidth Products AG (SME)
- OneFive GmbH (SME)
- Next Scan Technology BV (SME)
- Amsys Ltd. (SME)
- ELAS UAB (SME)
- Lightmotif BV (SME)
- ...

Picosecond

MATERIALS:

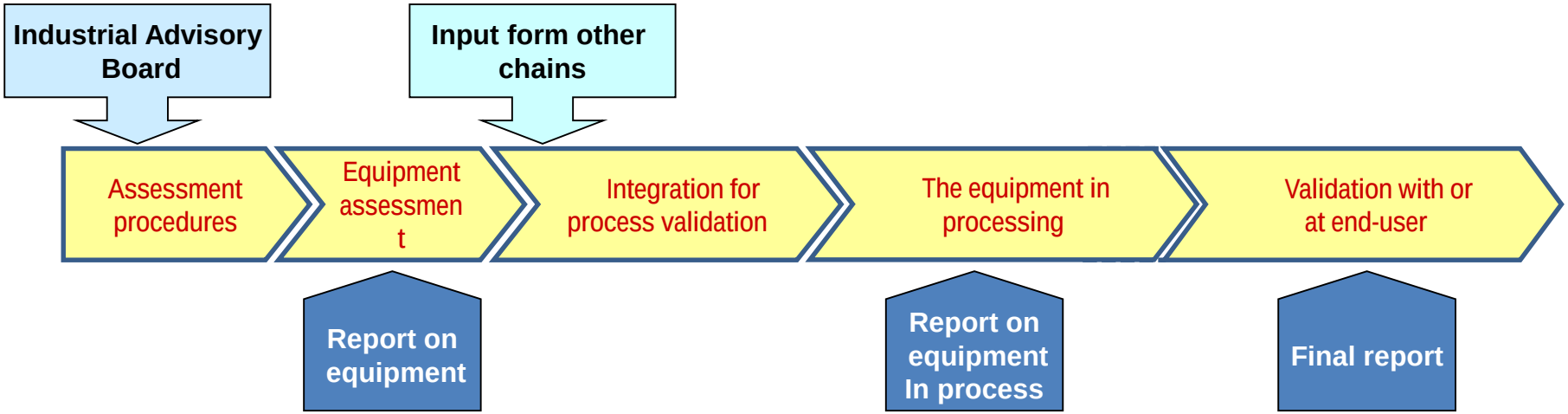
- Eidgenössische Materialprüfungs- und Forschungsanstalt

IPR MANAGEMENT & EXPLOITATION

- engage AG (SME)

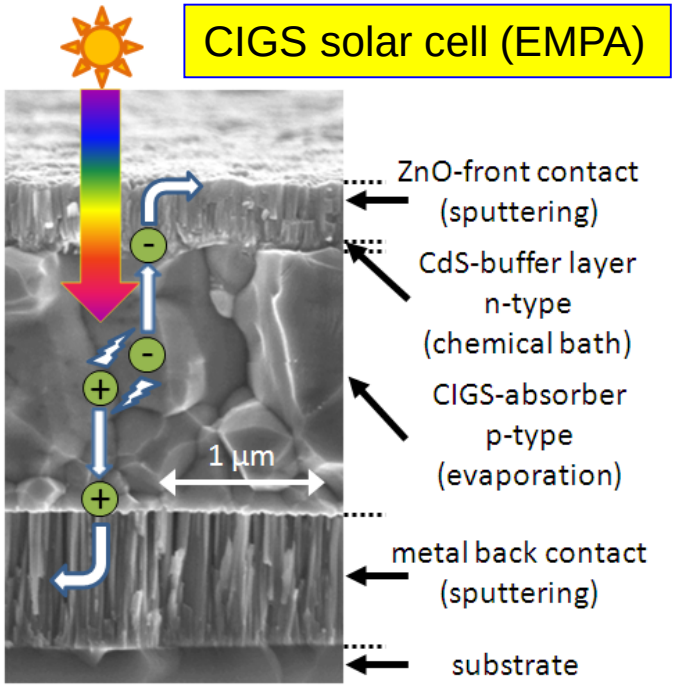
APPOLO: Clusters of activities

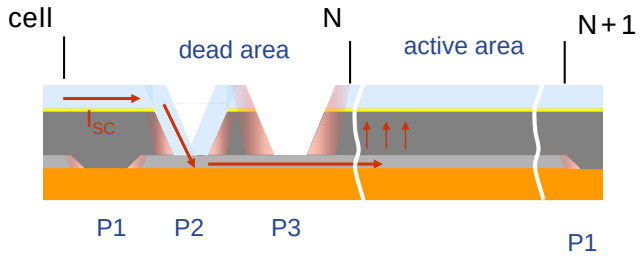
- **Thin film CIGS solar cell scribing with picosecond lasers:**
  - Novel lasers, scribing concepts, intelligent laser beam control & integration into machines
- **Laser surface texturing:**
  - New laser, high speed & precision laser texturing & dedicated nanostructures for surface functionalisation;
  - Integration in to machines for automotive and printing/decorative applications
- **Laser patterning for flexible 3D electronics:**
  - New patterning concepts, 3D patterning; Integration with other techniques (ink-jet, LIFT)
- Parallel activities on **sensing and monitoring techniques** for processing and validation.



CIGS cluster: reliable laser scribing processes

- Assessment of **equipment** and its interaction
  - 1.34 µm ps-laser
  - ps-fiber laser with pulse on demand feature
  - fast polygon scanner
  - on-line scribing process monitoring tool
- Integration & assessment in the process
- Final validation at end-user facility
- Approaches for thin-film CIGS solar cells on different substrates (glass, polymer, metal)
- **Key issues:**
  - selectivity in layer processing;
  - narrow “dead” interconnection zone;
  - minimised residual side effects;
  - high process speed.





Standard monolithic integrated interconnect scheme: P1, P2 and P3 scribing processes performed between deposition steps

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Assessment procedures

Phase I Optical testing

Phase II Laser in process

Phase III Laser in process in industrial production environment

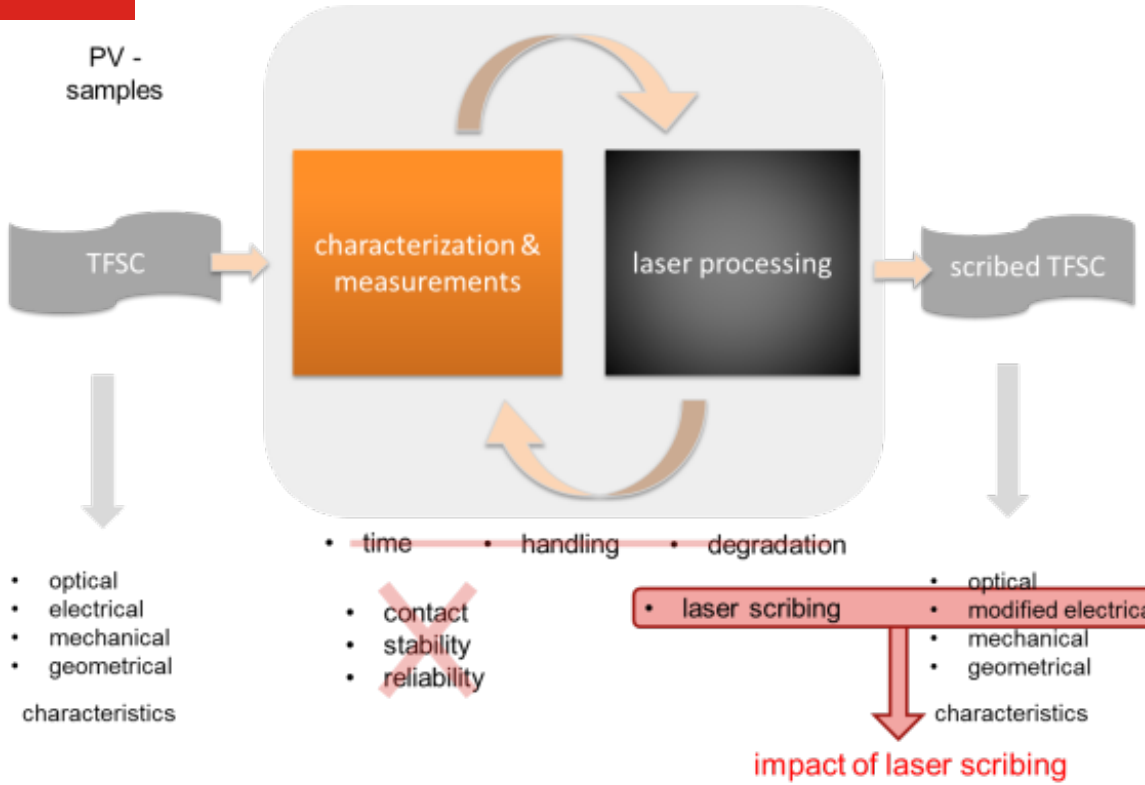
Schematic representation of the 3-stage assessment process in CIGS solar cell scribing

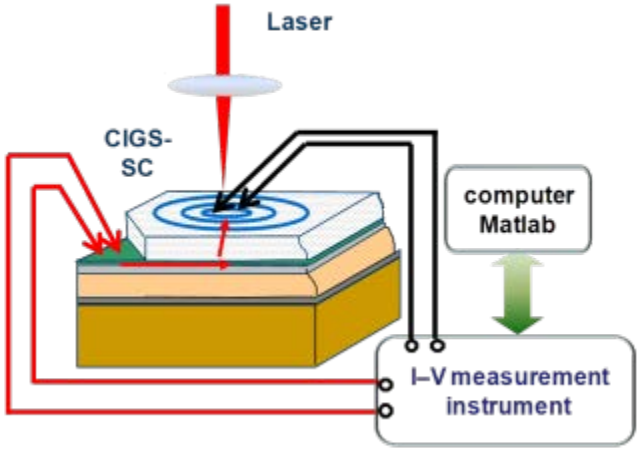
Bern University of Applied Sciences

Flisom Flexible Solar Modules

EMPA Materials Science & Technology

Evaluation procedures and methods





Approach of **in-process measurement** of the laser impact on the electrical properties of functional devices,

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Verification of new equipment

Pulse energy, focus spot and rep. rate must be adjusted together for most efficient material removal

Polygon scanner 100 m/s

Atlantic ps laser
13 ps, > 60 W, 1 MHz

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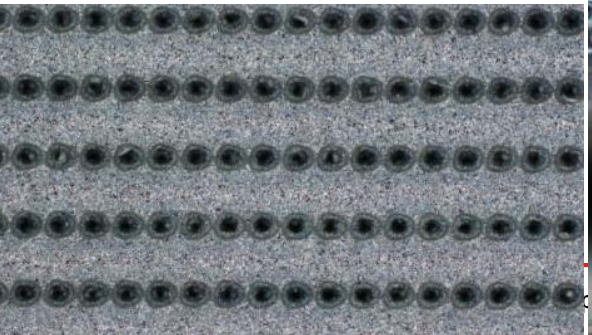
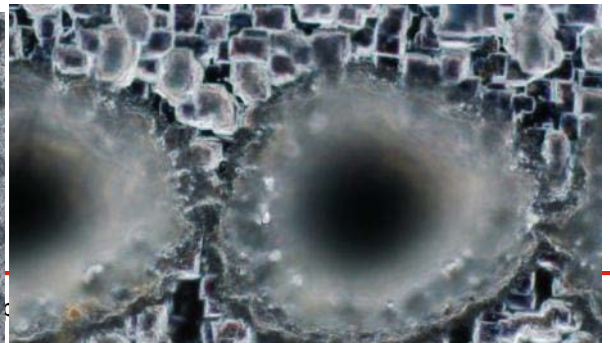
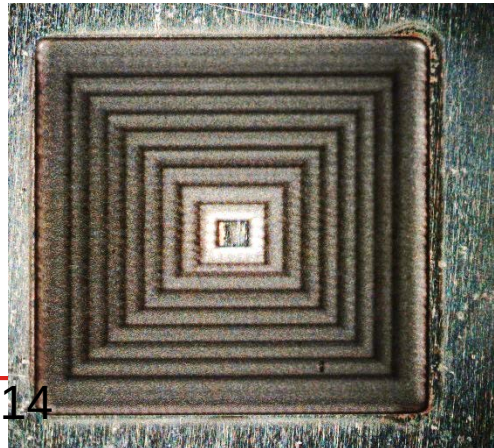
3D

Repeatability: 2000 times @ 50 m/s



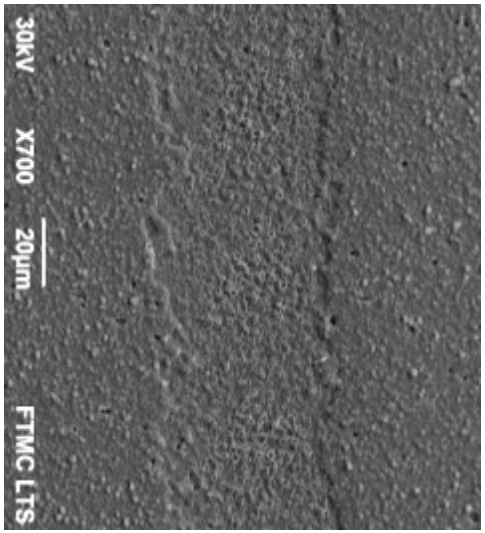


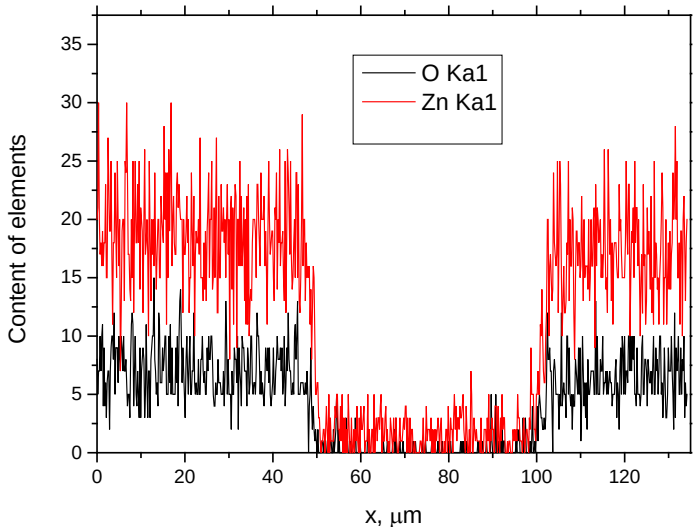


Thin film solar cell scribing

P3 type scribe is used for isolation of the adjacent cells:

- ❑ Removal only the top-contact or the full structure up to the molybdenum back-contact.
- ❑ TCO removal requires less laser power and small laser pulse overlap.





EDS analysis

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30 W, 987 kHz, 49.35 m/s, single pass

ps-laser and polygon scanner

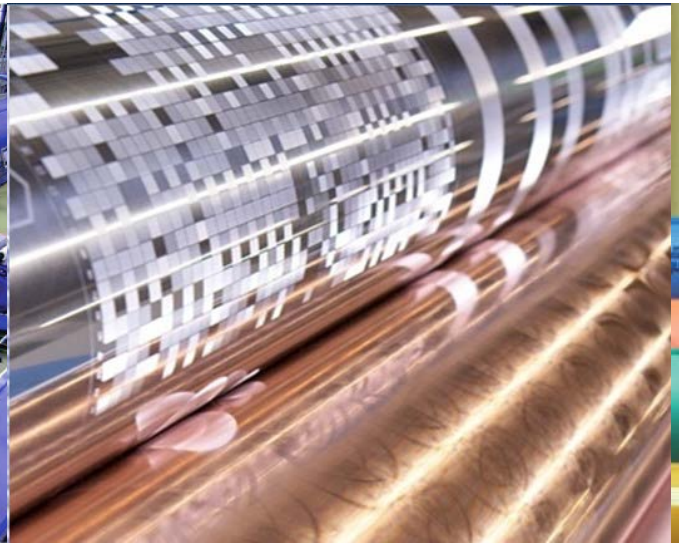
EKSPLA

next scan technology

Texture cluster: fast structuring for printing/decoration

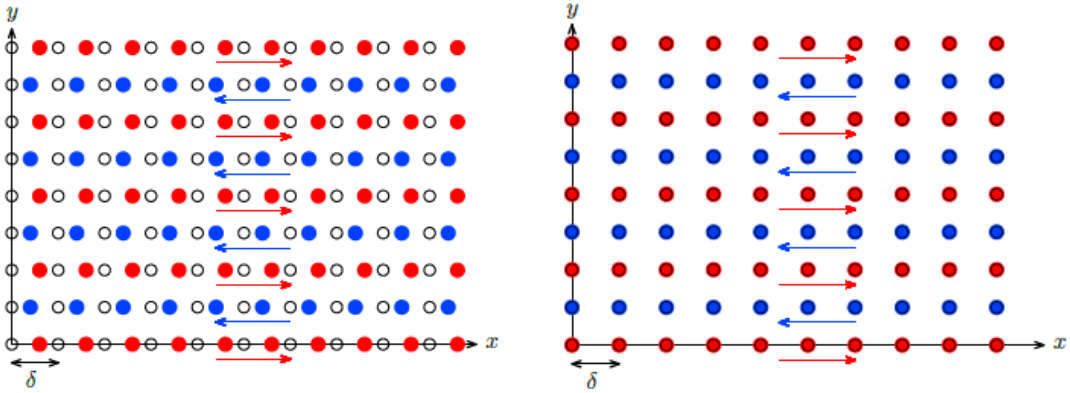
High resolution 3D micro-structuring with ultra-short pulse lasers for embossing

- evaluation and validation of the **lasers and fast scanning** polygon devices;
- integration of the fast scanning devices on an **existing gravure setup**;
- evaluation of process strategies and process parameters **for industrial production**;
- validation of equipment in development of **special structures**.

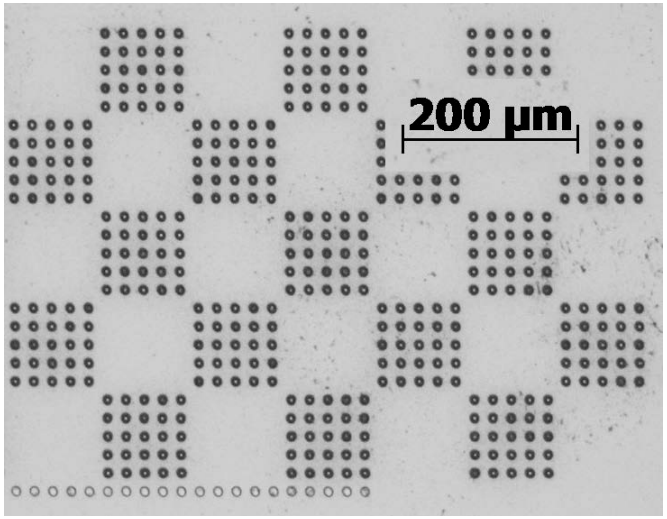


Precise control of galvoscanner at high speed

Synchronized bidirectional scanning



Unaligned and aligned spot positions



The used galvoscanner offers two different tuning modes:

1. Higher precision and work up to a scan velocity of **3 m/s**.
2. Scan speeds up to **15 m/s** but reduced precision at high speeds.

In both scanning modes, there is a trade-off between precision and speed.

The processing time is divided by two from unidirectional to bidirectional mode.

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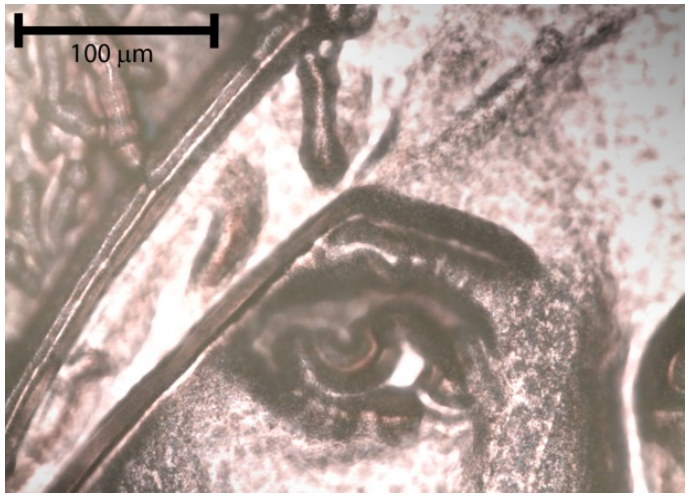
Precise machining of 3D structures

- Slicing the **grayscale image** into a given number of levelled black and white images.
- The **black and white images** are then processed one by one.

Grayscale and black and white image



Detail of machined structure

Result with **100 slices** at 532 nm, 1 MHz, 1.2 W and 3 µm pitch.
Image size on target is approximately **1.5x1.5 mm²**.
Processing time of one layer is 1.2 s and the overall process time is **2 minutes**.

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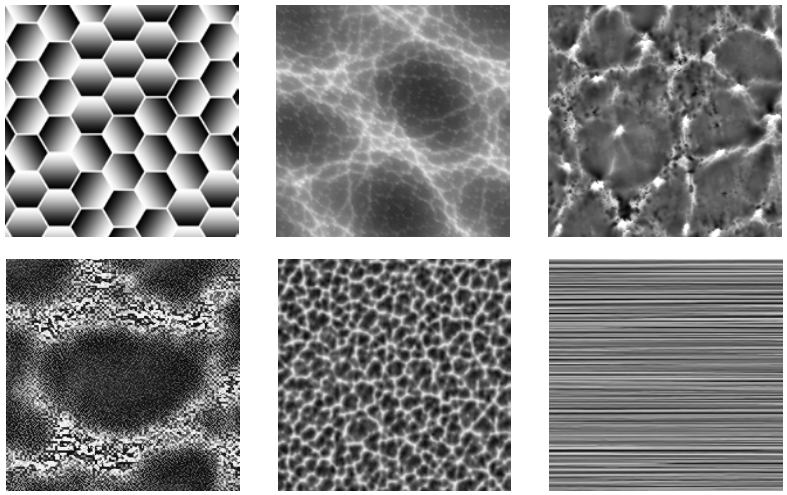
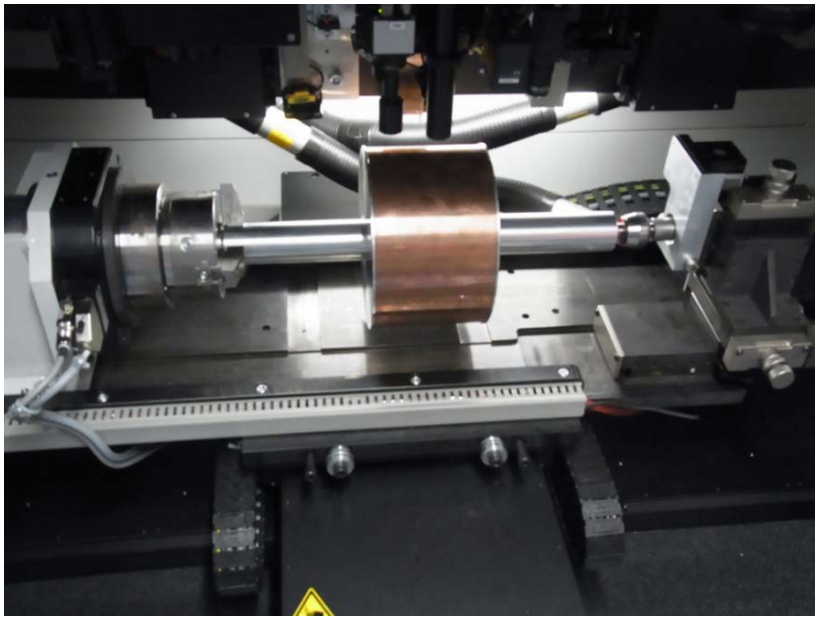
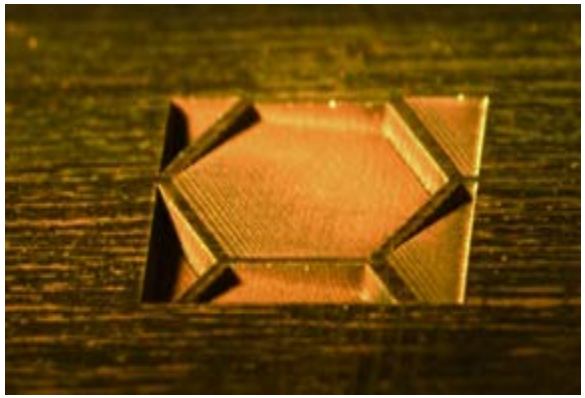
Laser texturing of printing rolls for embossing

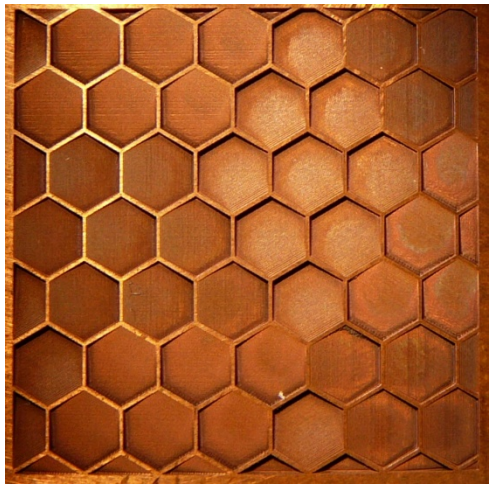


Examples of grey scale images of application related topographies





Honeycomb structure in copper laser written by ps-laser



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Texture cluster: surface functionalisation

- Surface engineering – to create **soft-touch and anti-glare effects** by functional textures on molds for automotive industry
- Assessment and optimization for **3D mold texturing** method
- Validation of combined technology by production of real **automotive** part with added soft-touch texture

Leather imitation on moulded surfaces car's interior parts.

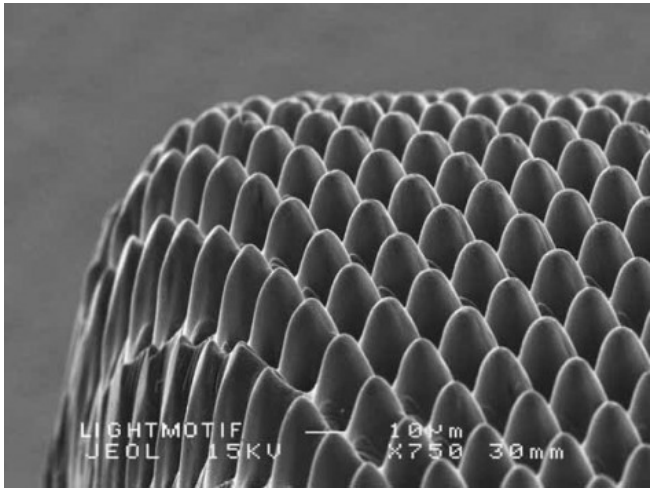
Applications of surface texturing include:

• **Friction reduction** in lubricated contacts: on pistons or bearing surfaces

• Change of the **haptic properties** of surfaces: to reduce skin friction and to create silky soft surfaces

• Changing **wetting properties** of surfaces: super water repelling surfaces

• Change of **cell growth** on surfaces: the attachment of bone to implants



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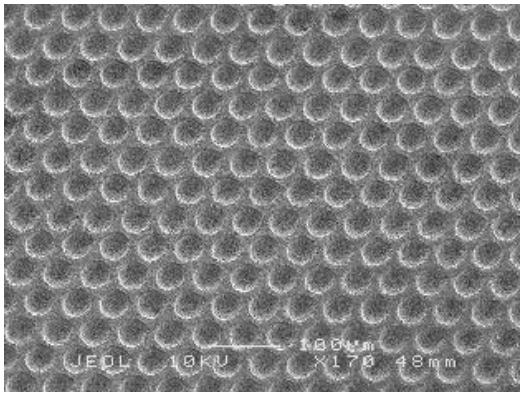
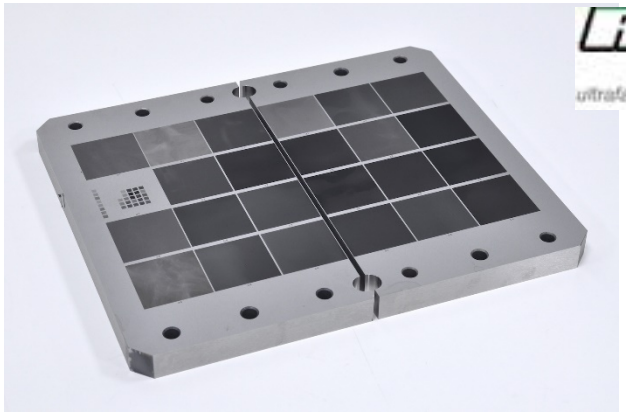
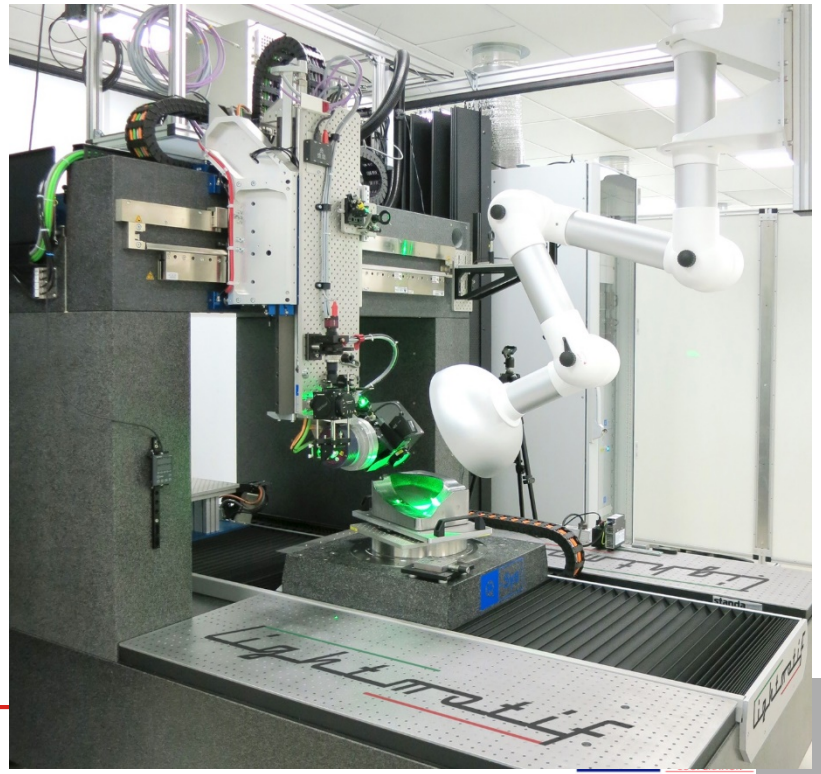
Laser texturing of moulds



SEM measurements of one test texture



Two laser textured mould inserts

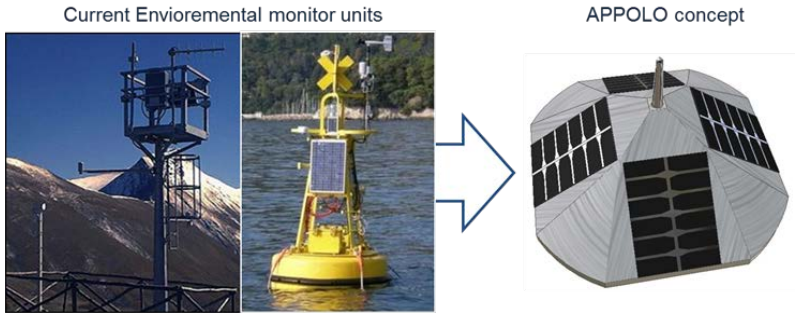


LDW cluster: 3D interconnections on plastics

- Validate reliable schemes for **direct writing of 3D wiring** by laser radiation.
  - overcome basic problems of current state of the art;
  - process standard plastics instead of using highly specialized costly material;
  - saving resources by adding material for laser functionalisation.

Integrated switches in central console for interior commands.

- Demonstration of new capabilities in surface functionalisation by lasers for 3D wiring and **flexible electronics**;
- Assessment of new laser beams for writing 3D / flexible electronics;
- Validation of the electric interconnections made by lasers in **real conditions**.



Example of APPOLO concept as applied in current environmental monitor unit.

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Molded interconnect devices (MID)

FIZINIŲ IR TECHNOLOGIJOS MOKSLŲ CENTRAS

There are no limits to **MID!**

Telecom

Automotive

Computing

MID

Consumer goods

Medical

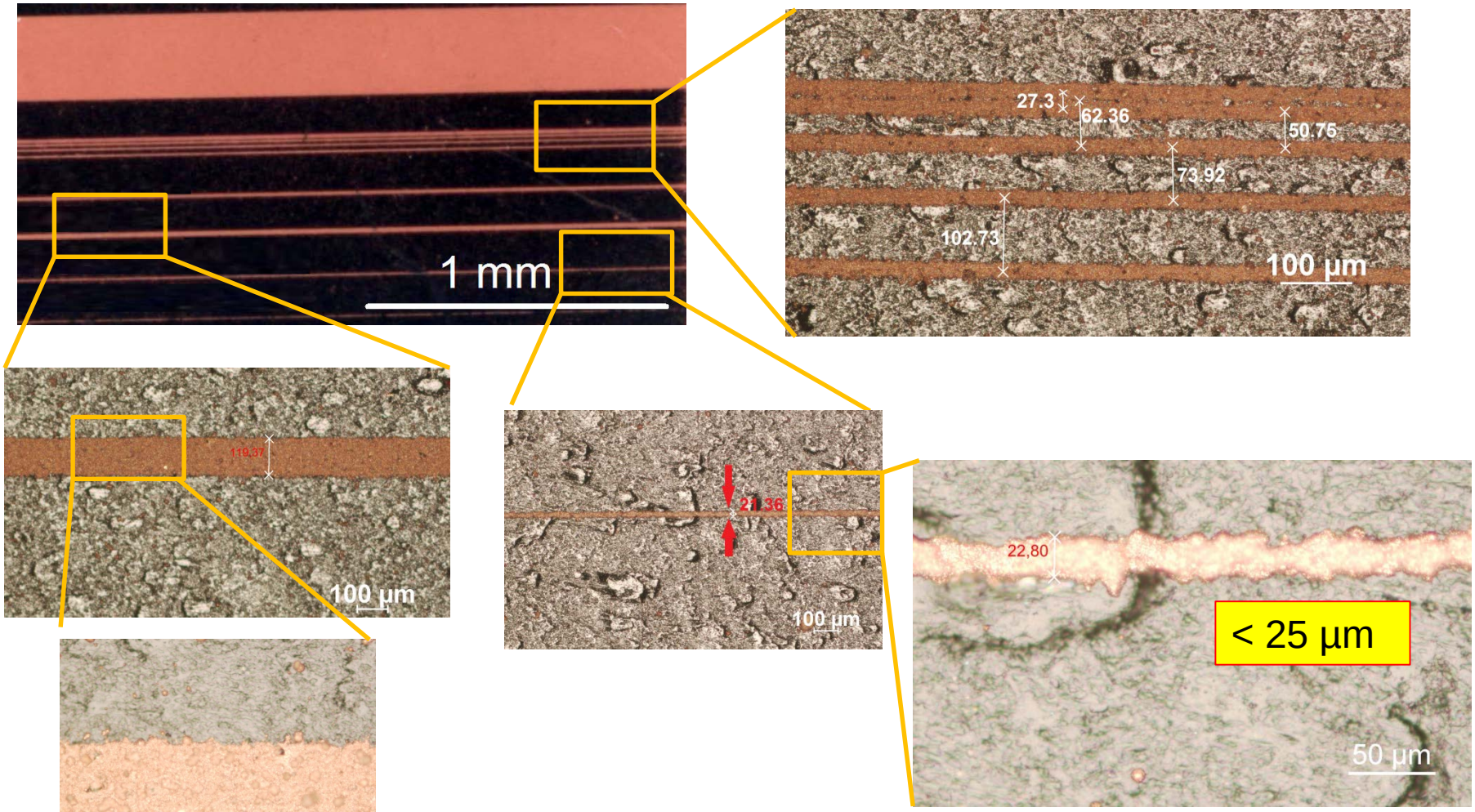
Lighting

supported by

Selectivity of plating

FIZINIŲ IR TECHNOLOGIJOS MOKSLŲ CENTRAS

Laser-modified surface of polymer + electroless plating



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Application for electronics

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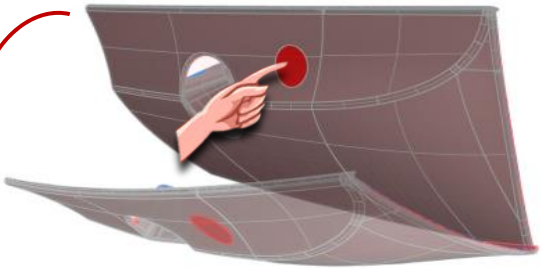
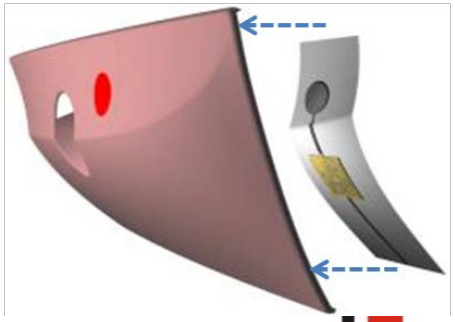
Dashboard Electronic Design

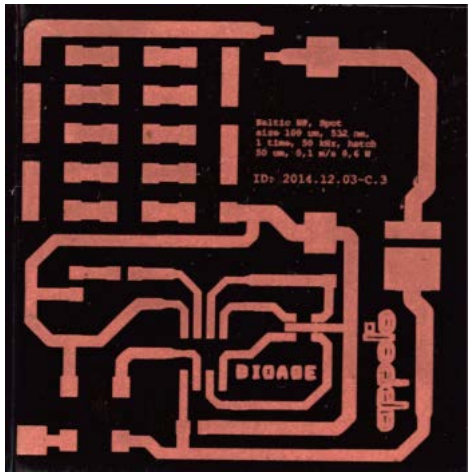
CRF CENTRO RICERCHE FIAT





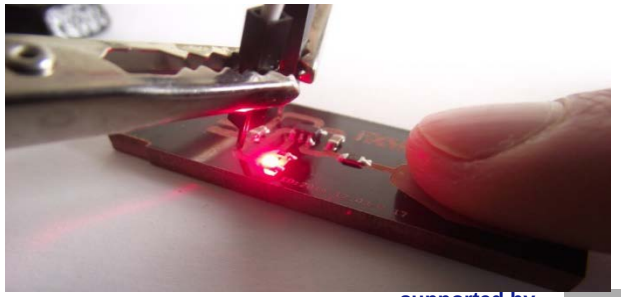
appolo

Hub of Application Laboratories for Equipment Assessment in Laser Based Manufacturing



Conductive tracks for Temperature sensor

BIOAGE



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New materials and approaches

SABIC Innovative Plastics:
NX07354 (PC/ABS)
DX11354 (PC)

CRF CENTRO RICERCHE FIAT

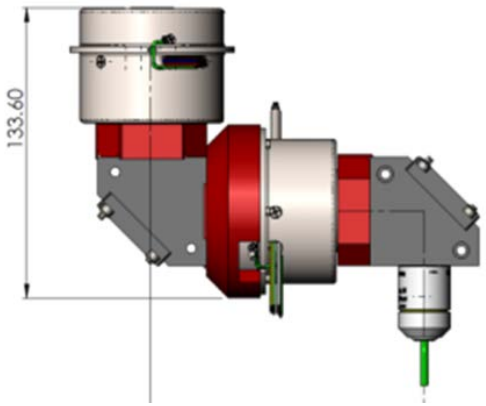
CRF Carbon-based materials

Material:	NX07354	DX11354	PP X1	PPX2	PPX3
Sheet resistance of plated surface [Ω/□]	0.036	0.029	0.0177	0.0871	0.025
Laser scanning [m/s] speed	**0.1**	**0.1**	**1**	**1**	**1**
Number of scans	20	1	1	1	1

On a way to real 3D

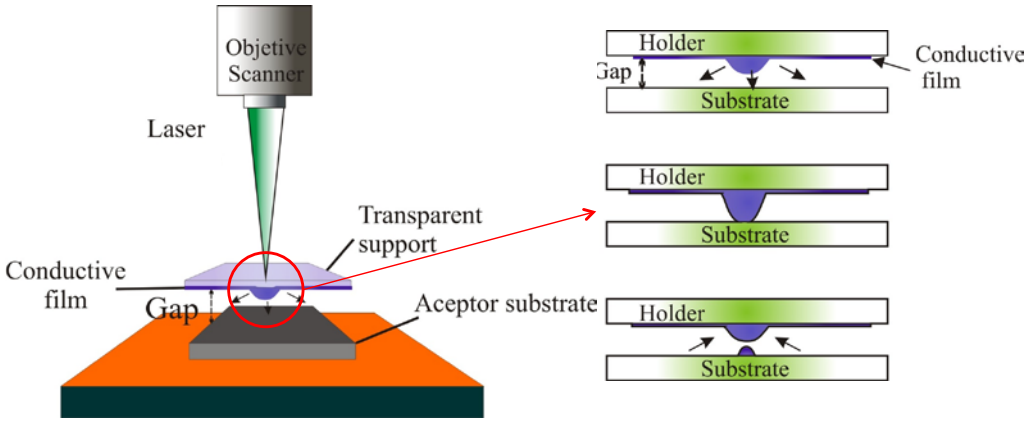
Elas

AMSYS, LTD.

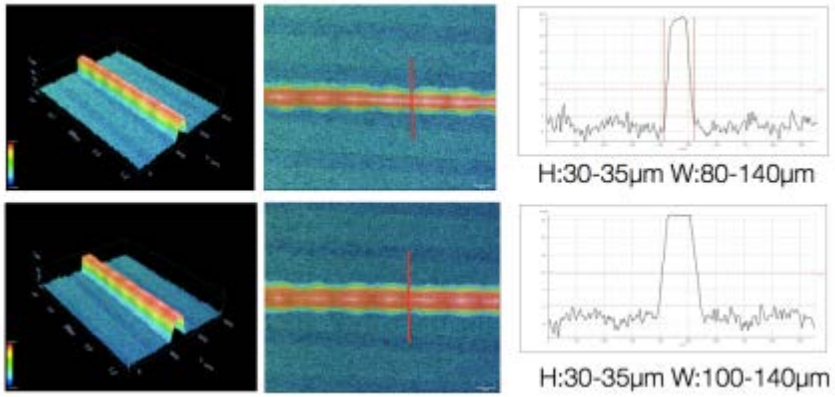


LDW cluster: LIFT for PV applications

- Laser direct writing of flex electronics and **photovoltaics** in planar geometry will be assessed and validated:
  - adding material techniques (especially **LIFT**)
  - post-deposit **firing/curing techniques** using laser technology.



Principle of LIFT process for metallisation of thin-film solar cells



LIFT silver paste line obtained at UPM at industrial velocities (2 m/s)

Standard way is to use ns-lasers, however, ps-lasers provide benefits in the line width

On-line monitoring tools

- Development and validation of **on-line monitoring tools** and beam control systems which are necessary:
  - **process control** during the assessment experiments;
  - on-line tools to be assessed and integrated into laser processing systems.

- **On-line tools for integration** into laser processing systems:
  - **surface profile monitoring tool** with polygon scanner;
  - **auto-focusing unit** for laser processing in 3D electronics.

APPOLO Workshop
- Online Monitoring in Laser Processing
- 5Th of June, 2015
- LUT Laser, Future Factory, Tuotantokatu 2, Lappeenranta, Finland

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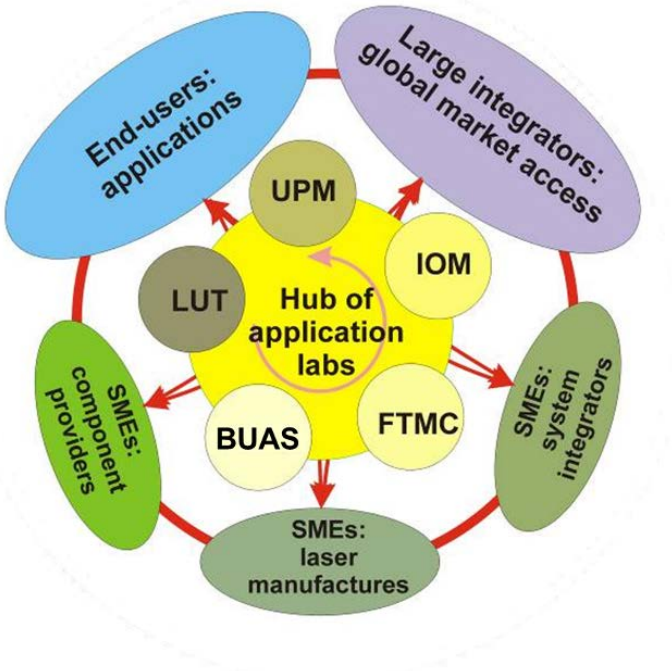
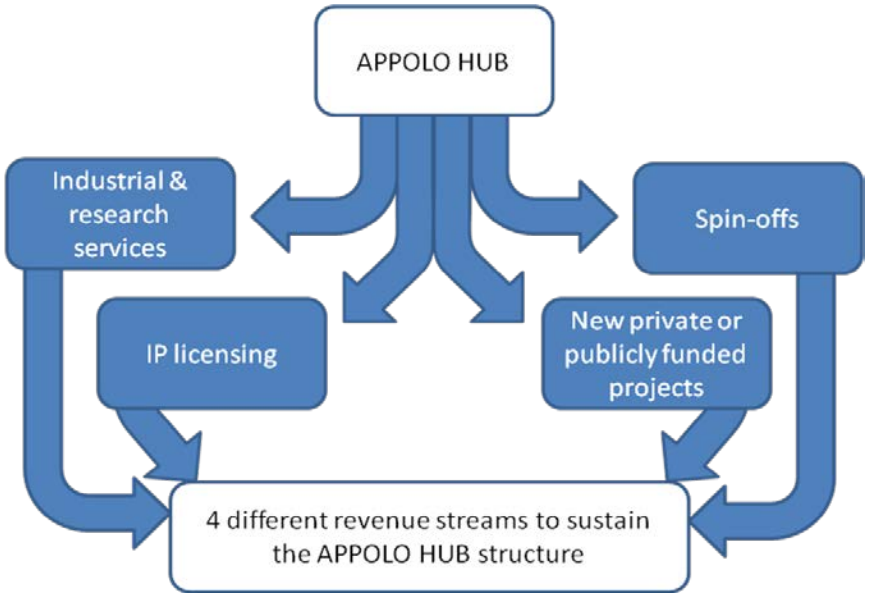
HUB of application laboratories



- **Industrial Advisory Board (IAB)**
  - industrial partners in the consortium
  - end-user companies interested in the project results but standing outside the consortium
  - industrial associations like EPIC
- IAB: technical requirements and procedures for assessment in specific application fields

- **Objectives of the HUB:**
  - prepare procedures for assessment service;
  - manage and analyze of assessment projects;
  - compare with alternative technologies.
- HUB activities are intended to prepare
  - operational procedures for efficient assessment execution;
  - high-quality assessment service;
    - assessment procedures (IAB)
    - standards for assessment
    - certification of equipment
  - attract potential HUB customers:
    - **equipment suppliers** looking for applications/validation;
    - **end-users** looking for solutions (equipment which can provide technology);
    - **system integrators** –specific requests they do not have possibility to test at home.
  - pave a way for sustainable operation of HUB as laser technology service provider.

Approaches for HUB sustainability



1. **Services**: HUB participants perform services either for industrial or public/research customers (e.g. patterning, validation, …)
2. **IP licensing**: Jointly developed IP can be licensed centrally, avoiding costly and timely individual negotiations
3. **New projects**: The HUB can act as a single entity to acquire new projects and can thus bring unparalleled depth, knowledge and excellence to bear.
4. **Spin-Offs:** New companies, developed either in tandem with corporate partners or as spin-offs based on HUB IP can generate significant returns when the HUB exits its position (i.e. sale of shares, IPO).

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Consortium: research versus industry

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http://appolo-fp7.eu/

6 research entities & 16 companies, more 16 companies will join