



LUT University: Activities of additive manufacturing

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Research Group of Laser Material Processing and Additive Manufacturing,

LUT Laser & 3DP

Definition

- According to ISO / ASTM52900 - 15
 - Additive manufacturing refers to all professional and industrial production
 - 3D Printing refers to all consumer applications.

→ Additive manufacturing is recommended to be used instead of 3D printing in professional contexts. Nevertheless, 3D printing means same in many public context.

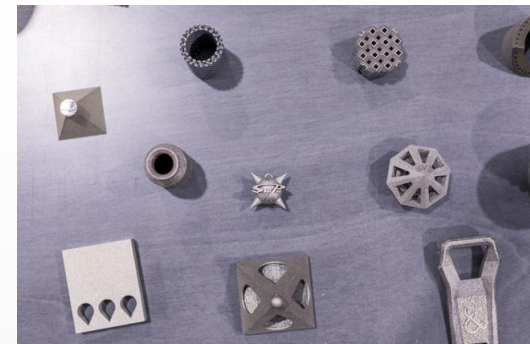
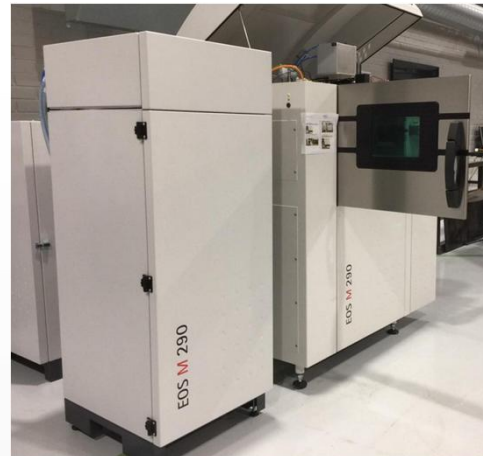


Background of LUT Laser research group

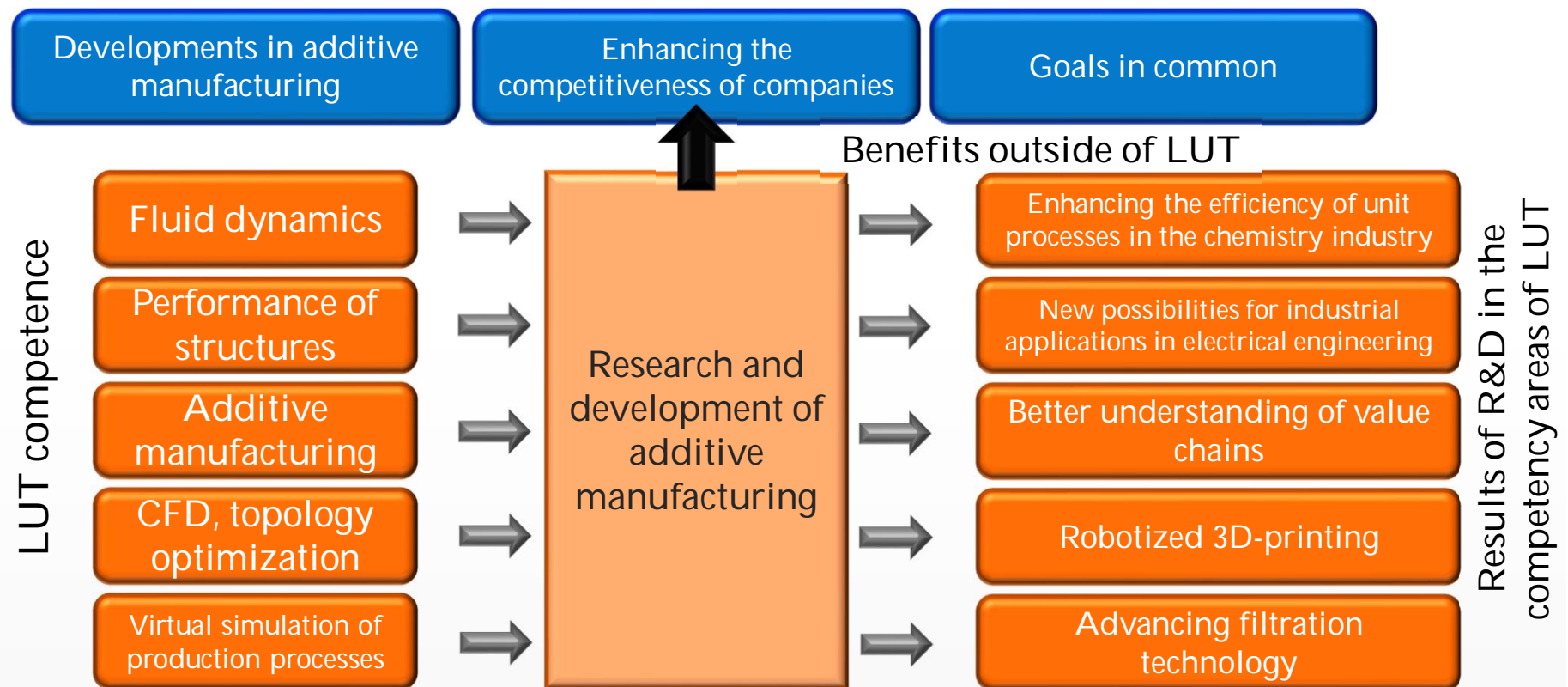
- Research in laser processing since 1985 and research in 3D printing since 2009
- The focus of the research in 1980s and 1990s was in laser welding, laser cladding, laser surface treatments, etc., in the 2000s, the focus was on laser welding and cutting and in the 2010s the focus was on laser welding and 3D printing.
- Head of the research group: Professor Heidi Piili
- Staff (11.5.2020): 12 persons, 10 working with additive manufacturing: 1 Professor, 1 Post-doc researcher, 2 Project researchers, 2 Postgraduate Students, 1 Laboratory Engineer, 1 Operator, 1 Master's Thesis worker, 3 Research Assistants.

Background

- Turnover ~ 1.1 M €/year
- Master's Theses ~ 8 /year
- Dissertations 1-2 /year
- Publications ~ 20 /year
- Citations > 450 /year



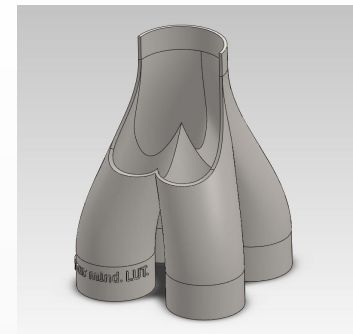
The focus of 3D printing in LUT University



Research of 3D printing

Since 2009

- Understanding the interaction between the laser beam and material
- Development of process efficiency and control, e.g. through on-line monitoring
- Utilization of the benefits of 3D printing in product design
 - Mechanical properties
 - Freedom of design
 - Design of internal structures
 - Durability, circular economy, costs



Research of 3D printing

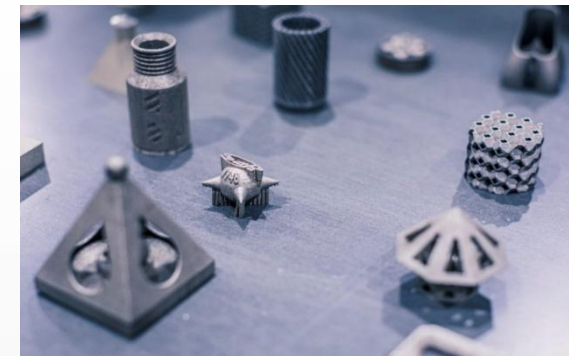
Since 2009

- Digital tools from idea to printing (Dassault Systemes: 3D Experience, ANSYS, nTopology)
- Printability of products
- Bottlenecks of 3D printing (support structures, industrial implementation)
- New applications brought by 3D printing (electrodes, fuel cells)



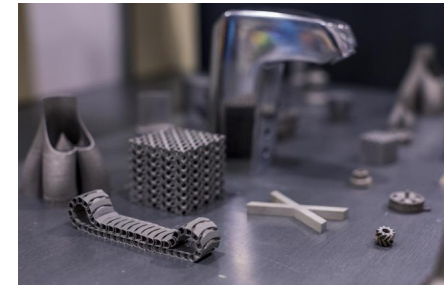
Machines

- Metal AM systems:
 - Metal powder bed fusion machine (EOS M series), 5/2011
 - EOS M 290, 9/2019
 - Directed energy deposition machine (powder) since 1995 and directed energy deposition machine (wire) since 2001



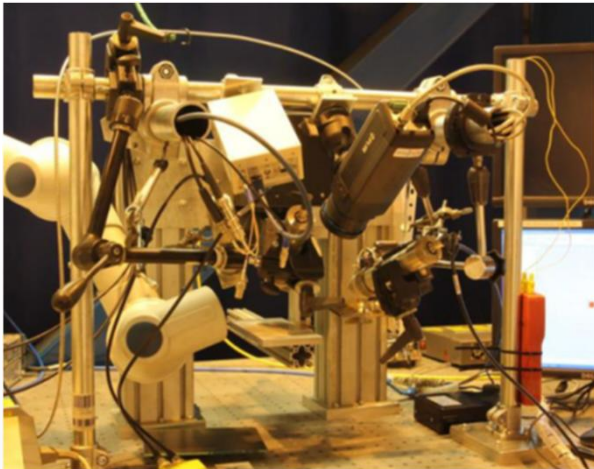
Machines

- Plastic AM systems:
 - Prenta Duo
 - Prenta Duo XL
 - Ultimaker S5 Pro Bundle
 - Creo C5
 - Plastic powder bed fusion machine coming in 5/2020



Equipment

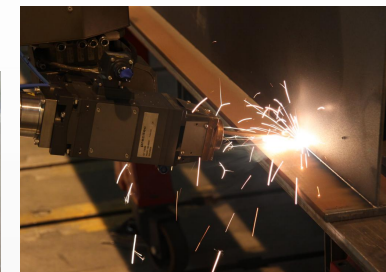
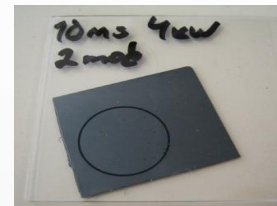
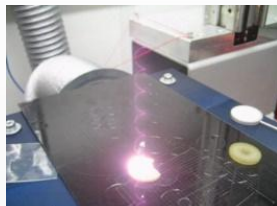
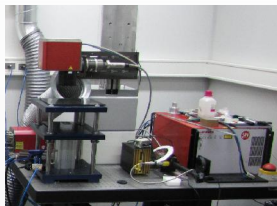
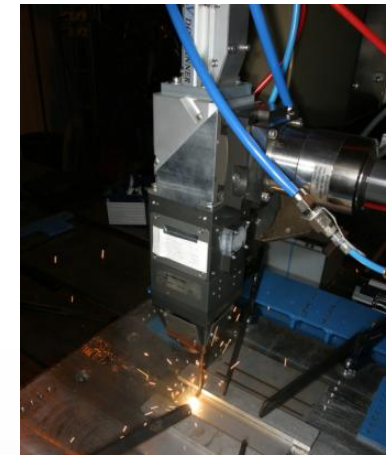
- Monitoring tools
 - High-speed camera
 - Pyrometers
 - Thermal camera
 - Photodiodes



Source of images: LUT Laser&AM

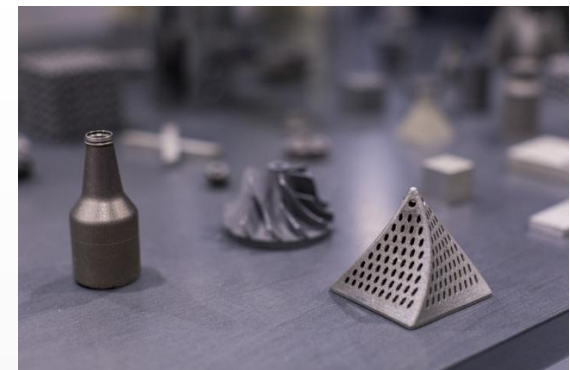
Research projects

- During 2009-2020 LUT Laser & 3DP research group has carried out
 - 9 large research projects
 - > 65 peer-reviewed publications
 - > 45 Theses (Bachelor's and Master's)



Research projects

- Currently in progress:
 - 6 research projects
 - 1 Master's Thesis
 - 8 dissertations
 - 12 Bachelor's Theses
 - Several industrial application and R&D projects



Current projects

Project	Funding	Period
Recovery of Gold from waste utilizing AM, "ReGold-AM"	Academy of Finland	2019 - 2023
"PRE3DACC - 3D-ACCELERATOR", "3D ACCELERATOR-AMASI"	EIT Raw Materials	2019 - 2020
Chief Expert in Engineering, "CEE"	European Social Fund	2019 - 2021
Metal 3D Innovations, "Me3DI"	ERDF	2018 - 2020
Manufacturing 4.0, "MFG4.0"	Academy of Finland, STN	2018 - 2023

Finished projects

Project	Funding	Period
Micro- and mill structured reactors for catalytic oxidation reactions, "Micatox"	Academy of Finland	2014 – 2017
Hub of Application Laboratories for Equipment Assessment in Laser Based Manufacturing, "APPOLO"	EU 7th framework	2013 – 2017
Art residence for creation of feeling based value by advanced manufacturing, "Lares"	Tekes	2014 - 2015
Development of Manufacturing technologies	Fimecc Oy / Tekes	2012 - 2015
Fast co-tuning for individual needs "Fast Coins"	Tekes	2013 - 2014
Use of laser in innovative business model generation	Tekes	2010 - 2012
Laser in manufacturing of functional surfaces and structures, "FuncMama"	Tekes	2009 - 2012
Laser based manufacturing of miniature chemical reactors, "FabTech"	Tekes	2009 - 2011

Finished projects

Project	Funding	Period
Additive manufacturing in nuclear power plants, "SAFIR"	SAFIR2022	2019
New Art of Reason, "NewArea"	Business Finland	2016 - 2019
PRE3DACC - 3D-ACCELERATOR	EIT Raw Materials	2019

Projects in preparation

Project	Funding	Period
"FidimaTools"	Business Finland	2021-2023
Advanced Mechanics and Materials for Detectors and Accelerators "AMMDA"	Academy of Finland	2020-2023
"Supermarsu"	Academy of Finland	2020-2021
Surface modification of additively manufactured catalytic module units for separation and purification technology "Surfamald"	Academy of Finland	2021-2023
Waste-2-resource-2-product	Business Finland	2021-2023

AM electrodes

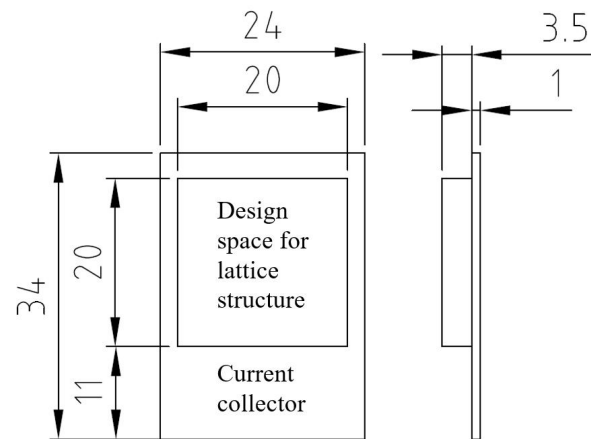



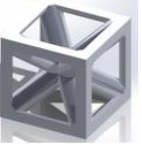
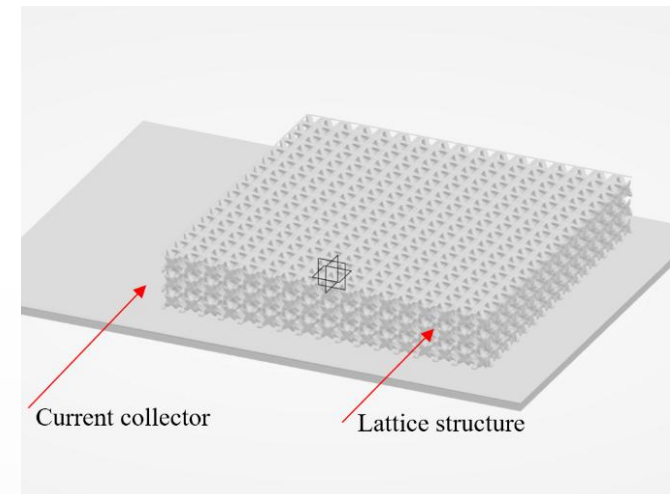
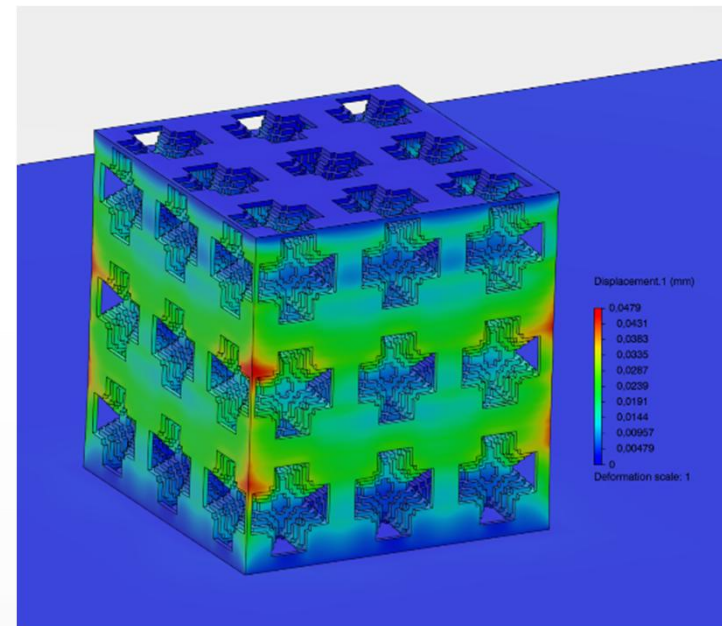
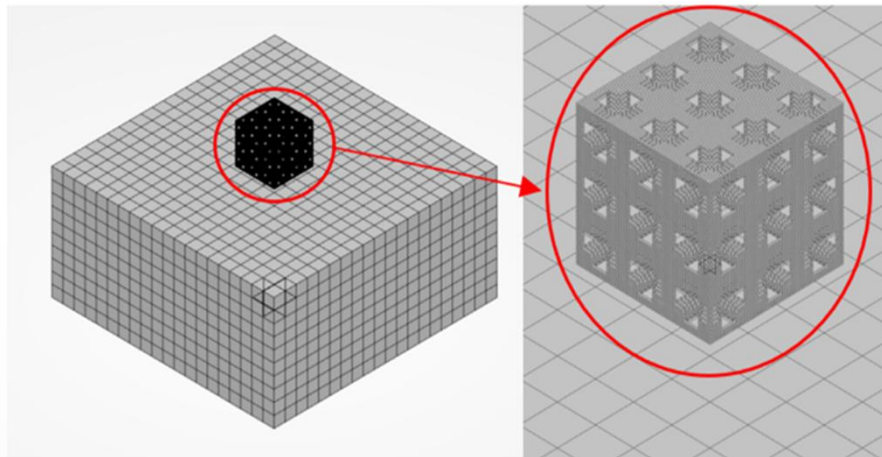


Table 1. Lattice cell comparison.

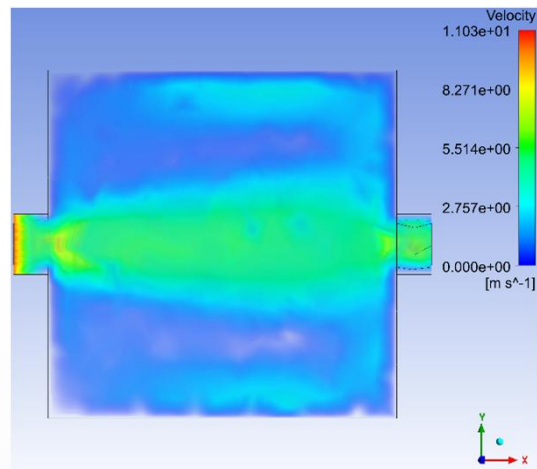
Lattice cell geometry				
	1	2	3	4
Surface Area [mm ²]	5.99	5.76	9.4	10.39



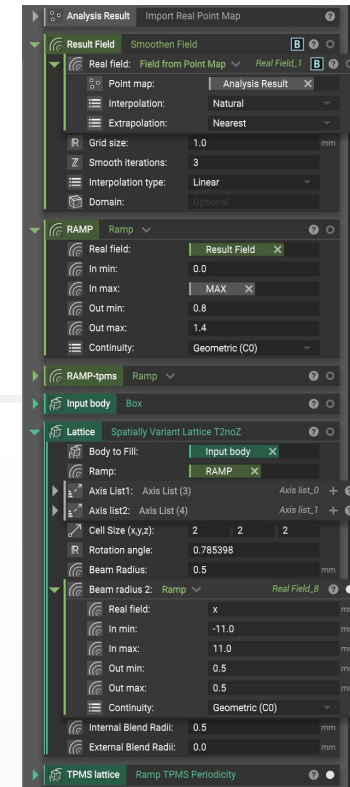
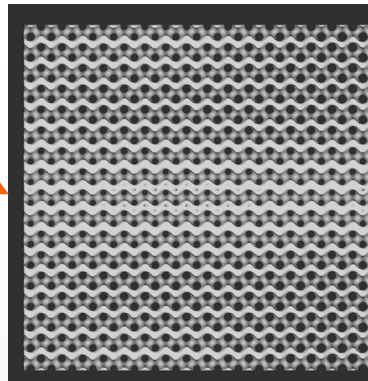
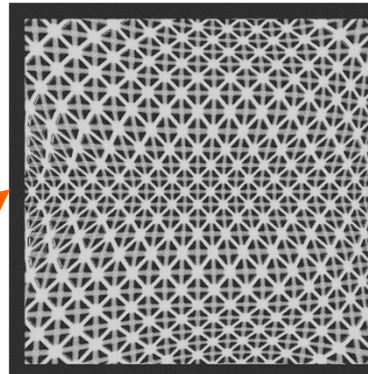
AM electrodes



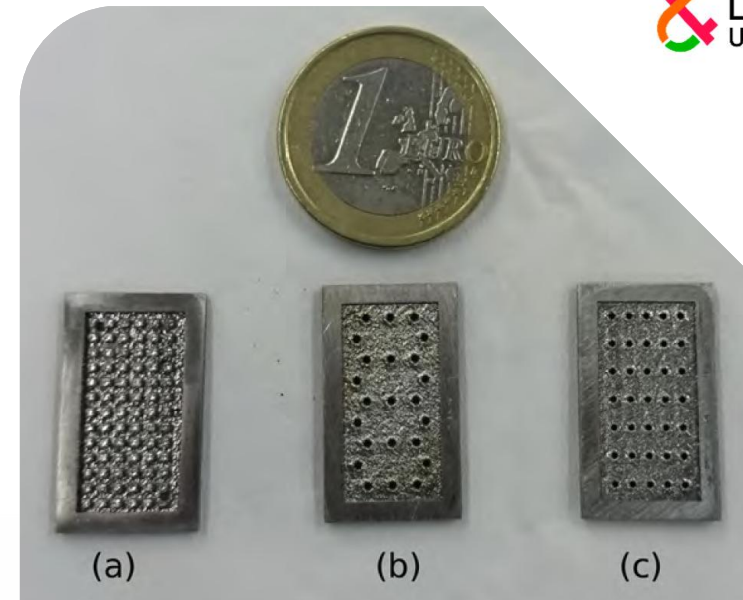
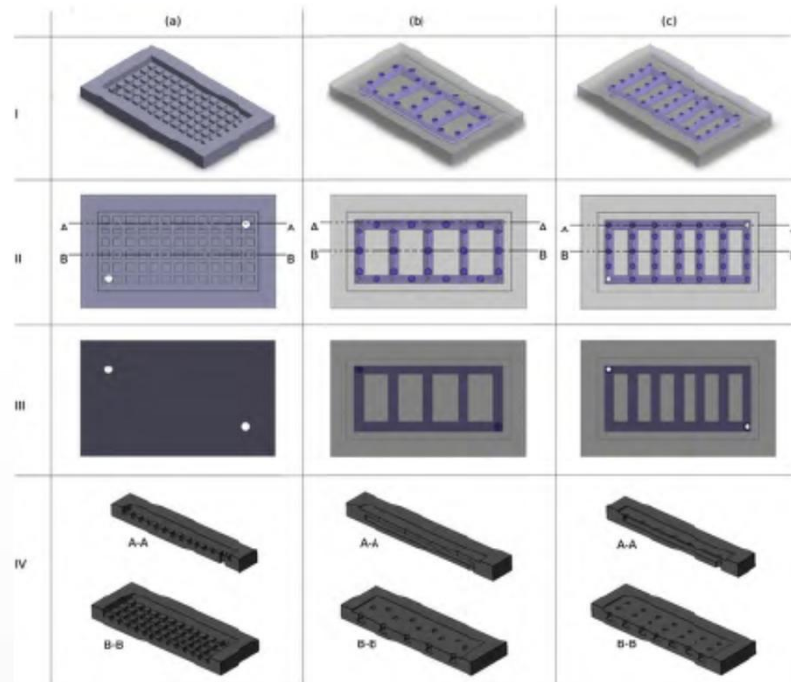
AM electrodes



nTopology



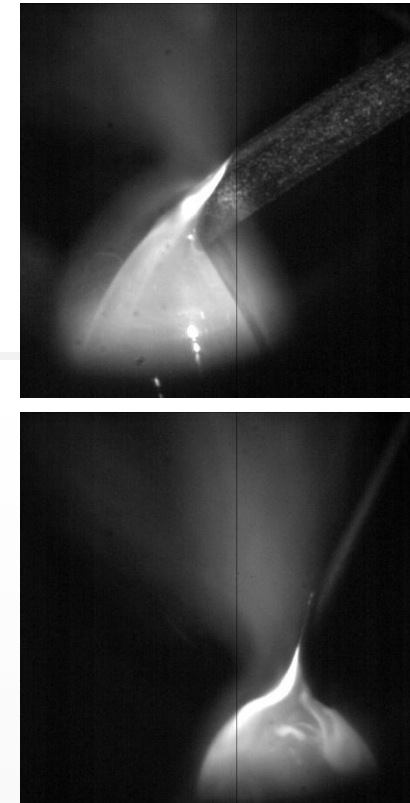
AM fuel cells



Flowfield plates	i_{\max} [mA cm ⁻²]	P_{\max} [mW cm ⁻²]	OCV [V]	R_{cell} [Ω cm ²]
Type E1	1515	363	0.906	0.446
Type E2	1488	344	0.902	0.504
Type G	1200	238	0.977	0.590

Current topics of the research

- Mechanical properties of 3D printed parts
- Fatigue properties of 3D-printed parts
- The effect of 3D printing on design
- Monitoring of the process
- Laser based wire-DED (aka WLAM)
 - Enables to produce larger structures
 - Enables to achieve higher printing speed
- Circular economy and additive manufacturing



Education of 3D printing

Master's studies

- The education of additive manufacturing started in 2013.
- The aim is to produce knowledge in 3D printing.

Course	ECTS	Students (average)
BK30A0901 Additive Manufacturing – 3D printing	5	125
BK30A0803 Digital Advanced Manufacturing with Lasers	5	25
BK30A1201 Laser Materials Processing	5	25
BK30A1301 Laser Based Manufacturing for Design	5	20
BK30A1000SS Additive Manufacturing - 3D Printing, LUT Summer School Course	3	35
Total:	23	230

3DP
Machines
PBF, LMD
Design
3DP

Education of 3D printing

Doctoral studies

- Postgraduate education started in 2017 with one course.
- LUT University offers a PhD courses in additive manufacturing worth of 30 credits.

Course	Credits	Students (average)
BK30AJ110 Postgraduate Course in Laser Based Additive Manufacturing and 3D Printing	10	10
BK20AJ105 Postgraduate Course in Advanced Welding Processes	10	10
BK30AJ105 Postgraduate Course in Advanced Digital Photonic Manufacturing	10	10

Industrial training

- A course set tailored to the needs of the industry.
- General course for the industry with 14 learners was organized in 2014.
- The Me3DI project organized an open course in spring of 2019: 125 learners from 55 companies, average grade 4.2 (max 5).
- The CEE project will produce a training course set that will be piloted in 2020.
- R&D projects for companies about the effect of additive manufacturing on product design, profitability, and material properties.

Social impact

- Heidi Piili is a founder and ambassador of the Finnish unit of Women in 3D Printing
- Many of the researchers at LUT Laser & 3DP are members of the Finnish Rapid Prototyping Association, FIRPA and Suomen Hitsausteknillinen Yhdistys, SHY (which actively promotes additive manufacturing).
- We are actively involved in international collaboration and discussion on 3D printing.
- Training of the experts in Finland.

Thank you for your interest

LUT University

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and
Additive Manufacturing

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