3D PRINTED STRUCTURAL ELECTRONICS: THE NEW MANUFACTURING PARADIGM
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Our mission:

TNO connects people and knowledge to create innovations that boost the competitive strength of industry and the well-being of society in a sustainable way.
TNO FACTS

- Dutch Research Institute.
  - 7 locations
  - 2800 Fte.

- Location Eindhoven.

3D Printed Electronics conference, Jan 19th 2016, Eindhoven

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TNO FACTS

INDUSTRY
- Flexible & Free-form Products
- Space & Scientific Instrumentation
- Sustainable Chemical Industry
- Semiconductor Equipment
- Networked Information

HEALTHY LIVING
- Predictive Health Technologies
- Food & Nutrition
- Prevention, Work & Health

URBANISATION
- Mobility & Logistics
- Environment & Sustainability
- Buildings & Infrastructures
- Smart Cities

DEFENCE, SAFETY & SECURITY
- Missions & Operations
- Force Protection
- Information Superiority
- Human Effectiveness
- Cyber Security & Resilience
- National Security & Crisis Management
Digital Manufacturing of Intelligent products

WHAT IS INDUSTRY CRAVING FOR? (NEED)

Manufacturing solutions for freeform, reliable, cost effective and resource efficient production of intelligent (IoT) products.
WHAT IS 3D PRINTING OR ADDITIVE MANUFACTURING?

“Technologies that build 3D objects by adding layer-upon-layer of material, whether the material is plastic, metal, concrete or one day…..human tissue”*

However, technology is still in infancy stage:

- Insufficient productivity reproducibility & product quality
- Need for large format printing
- Limited material portfolio
ADDITIVE MANUFACTURING TECHNOLOGIES

AM Technologies

Laser based

- Laser sintering (LS)
- Laser Melting (LM)
- Laser Material deposition (LMD)
- Stereo lithography (SLA)

Nozzle based

- Fused deposition modelling
APPLICATIONS OF AM TECHNOLOGIES

- Textiles
- Dental
- Aerospace
- Automotive
- Electronics
- Jewellery
- Implants
- Speciality food
- Toys/collectables
- Surgical devices & aids
- Prosthesis and orthotics
- Armaments
- Furniture
- Industries
- Sports

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ADDITIVE MANUFACTURING RESEARCH @ TNO

- Developing industrialisable systems for **multi-material additive and hybrid manufacturing** for mass customization and manufacturability with customers in the value chain

**Medical**
- Dental - multi-material, full colour, bridges and crowns
- Prosthetics – multi-property for multi-functionality, intelligent insoles

**3D Structural electronics**
- Smart exoskeletons, Hybrid microfluidic devices (LOC)
- Automotive and lighting applications
- Structural monitoring & building elements

**Pharma / food**
- Printed food products (multi-material, personalized, multi-texture)
- Printed pills - multi-material for controlled release, smart pills

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“Structural electronics involves electronic and/or electrical components and circuits that act as load-bearing, protective structures, replacing dumb structures such as vehicle bodies or conformably placed upon them.”*

“The fabrication freedom offered by 3D printing techniques, such as stereolithography and fused deposition modeling have recently been explored in the context of 3D electronics integration referred to as 3D structural electronics or 3D printed electronics”**

** Eric MacDonald et al, “3D pritning for the rapid prototyping of structural electronics”, IEEE Access, Volume 2, 234- 242,March 2014,
STRUCTURAL ELECTRONICS: MARKET POTENTIAL

Fig. 1.8 Structural electronics market 2015 and 2025 $billion globally, excluding BIPV

Source: IDTechEx
STRUCTURAL ELECTRONICS: TECHNOLOGIES

In-mold electronics

Source: Plastic electronic

Source: TakoTek
STRUCTURAL ELECTRONICS: TECHNOLOGIES

Molded interconnect devices

Source: LPKF
STRUCTURAL ELECTRONICS: TECHNOLOGIES

Conformal printing

Source: university of Illinois

Source: Optomec
STRUCTURAL ELECTRONICS: TECHNOLOGIES

- 3D Printed Structural Electronics (3DPSE)

Source: KECK centre, The University of Texas at El Paso
3DPSE: COMMERCIALISATION

GE & Autodesk made a strategic investment in Optomec. December 11, 2015

Nano dimension: **DragonFly 2020**

3DPSE Tool Released by NovaCentrix and nScrypt, November 3, 2015

Voxel 8
Neotech AMT GmbH, developing systems for 3D Printed Electronics (3D PE).

Smart Sensory Prosthetic Links Wearers to the IoT with 3D Printing
3D PRINTED STRUCTURAL ELECTRONICS: APPLICATION AREAS

“Combining knowledge from flexible electronics, materials development, systems engineering and additive manufacturing”

“Transforming dump objects into smart devices”
3D PRINTED FUNCTIONAL PARTS

Mechanical

Shoe soles (graded properties)

Cooling (complex design)

Innovation for life

Sensors (customisation)
3D PRINTED STRUCTURAL ELECTRONICS

Advantages:

• Detailed customisation at a unit level possible
  • Potential to incorporate micro-systems
  • PCB less design
  • Conformability
• Multi-material/multifunctional compatibility
  • Bio-compatible
  • Strong and lightweight
  • Functionally graded material properties
• High resolution integration possibility
• Thermal management integration (microfluidic cooling)
• High level of complexity: makes reverse engineering difficult
• Potential for high reliability: ruggedness
3DPSE : CHALLENGES FOR INDUSTRIALISATION

Key drivers: materials
- High conductive materials (especially high current applications)
- Multimaterials for 3D printing compliant with electronic application
- Long term stability

Key drivers: process
- Integration of conductive tracks.
- Integration of electronics (actives/passives/batteries).
- Integration of Optics/MEMS/Fluidics.

Key drivers: tools
- Novel 3D printing tools.
- Pick and place on non conventional surfaces.
- First time right manufacturing solution.
3D PRINTED STRUCTURAL ELECTRONICS: BUILDING BLOCKS (1)

- **Integration of conductive tracks** - Development of high conductive (>10^6 S/m), high resolution (< 100 µm) dispensing and sintering technologies. (technologies include LIFT, high viscous jetting, flash sintering and laser sintering)

- **Integration of optical waveguides** (< 0.5dB/cm) - Development of multi-material (graded/step) integration technologies (ink jetting / photo polymerisation, self-written waveguides, selective layer removal.....)

[Images of 3D printed light guides and conductive tracks]
3D PRINTED STRUCTURAL ELECTRONICS: BUILDING BLOCKS (2)

- **Pick and place of electrical/mechanical/MEMs components** - on curved and non-uniform surfaces with higher accuracies ($< 1\mu m$) at higher throughputs (novel tool designs)

- **Integration of relevant additive/subtractive processes** - 3D printing (SLS/FDM/VAT) cutting, polishing, wet etching, surface modification.... (novel tool designs)

- **Development of novel hybrid integration tools** - First time right production, resource efficiency (in line metrology, efficient process control)

Integration of electronics

Microfluidics
2D-3D integration
(3D printing, flexible circuit placement interconnection, flash sintering)

3D Integration
(3D printing, pick and place of components (2D), metal interconnection, flash sintering)

Full 3D Direct Integration
(3D printing, pick and place of components (3D), metal interconnection, flash sintering)

Novel machine development for full 3D integration
(3D printing, pick and place of components (3D), metal interconnection, flash sintering)

Many more...

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3D PRINTED STRUCTURAL ELECTRONICS: TNO’S CONCEPT PILOT LINE

PrintValley 2020
FUNCTIONAL DEMONSTRATOR: MICROBOT
FUNCTIONAL DEMONSTRATOR: MICROBOT

3D printed mechanical parts
FUNCTIONAL DEMONSTRATOR: MICROBOT

CAD design
FUNCTIONAL DEMONSTRATOR: MICROBOT

Conductive track deposition
FUNCTIONAL DEMONSTRATOR: MICROBOT

3D printing of substrates
FUNCTIONAL DEMONSTRATOR: MICROBOT

Embedding electronics
FUNCTIONAL DEMONSTRATOR: MICROBOT

Embedding electronics
FUNCTIONAL DEMONSTRATOR: MICROBOT

Embedding electronics
FUNCTIONAL DEMONSTRATOR: MICROBOT

Embedding electronics
CONCLUSION

- 3DPSE enables complete freedom of form, fit and functionality
- 3DPSE will enable FTT of products from concept to production
- Industrialisation challenges needed to be solved for mass customisation
THANK YOU FOR YOUR ATTENTION

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