Project Acronym: DIGINOVA

Project full title: " Innovation for Digital Fabrication "

Grant agreement no: 290559

NMP3-CA-2012-290559

Funding scheme: Coordination and support action

Coordination (or networking) action

D5.2 Draft Roadmap for Digital Fabrication

This document is an excerpt of the deliverable D5.2.

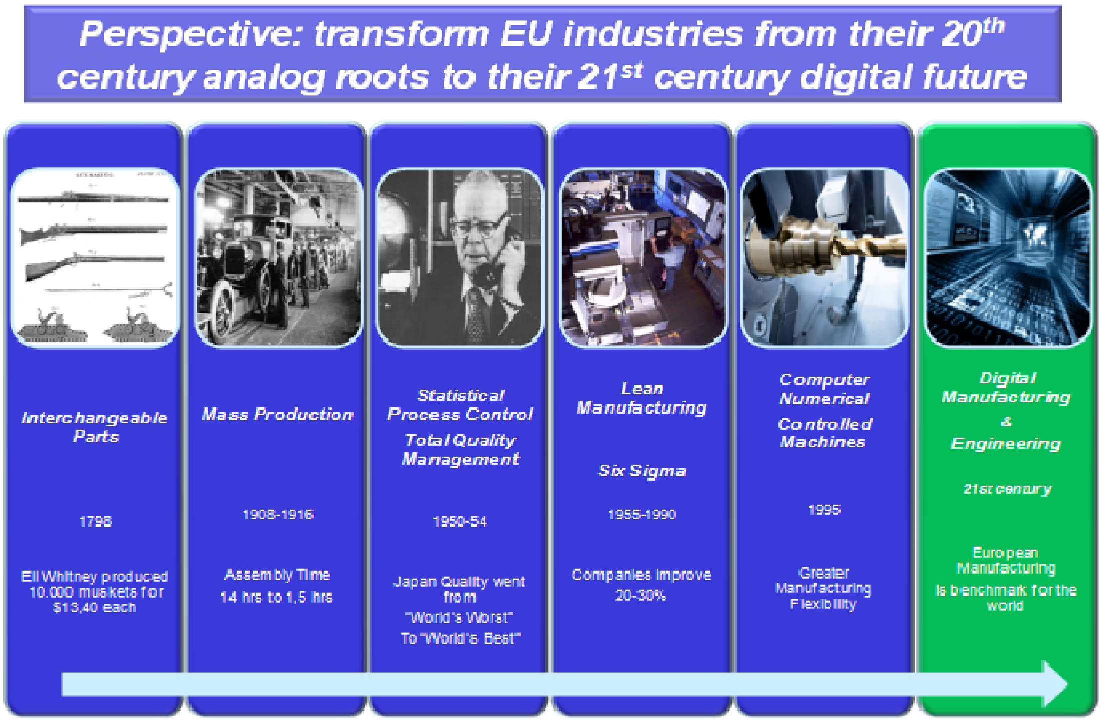
The content given is not the final result that will be described in D5.3.

The project Diginova has received funding from the European Community's Seventh Framework Programme [FP7/2007 - 2013] under grant agreement no. 290559 in theme NMP.2011.2.3 - 3

Executive Summary

This paper presents the draft version of the DIGINOVA roadmap for digital fabrication. The aim of this draft roadmap is to facilitate discussion between major stakeholders in digital fabrication, gather their feedback and based on this produce a final version of the DIGINOVA roadmap gaining wide support and acceptance in industry, academia and commerce.

Digital fabrication can generally be defined as a new kind of industry that uses computer-controlled tools and processes to transform digital designs directly into useful physical products. This includes technologies that make use of digital material deposition methods to create two-, or three dimensional products i.e. both modern digital printing technologies (2D digital fabrication) and additive manufacturing technologies (3D digital fabrication). Complementary technologies may be used to supplement these digital technologies in order to deliver full production systems. In the present state-of-the-art, development of well-matched combinations of advanced new material deposition tools and materials is emerging as a key success factor for digital fabrication. When matched with fully developed production systems, this will enable a change of paradigm in the manufacturing industry, and bring a new generation of products to the market.



Our vision is that within the next ten-twenty years, digital fabrication will increasingly transform the nature of global manufacturing, with an increasing influence on a wide range of areas in our everyday lives. Traditional mass-manufacturing will evolve from worldwide distribution of physical products towards becoming a global distribution of digital design and specification files that will form the basis of local production. The economical advantage of large scale production will decrease, which makes smaller series production increasingly competitive and customized products affordable to an increasing number of consumers. New possibilities of combining different materials and forming geometries that have not been practical to manufacture in the past will stimulate innovation and enable new types of products for a vast array of applications to be created. This will transform the nature and flexibility of manufacturing, for example we can have fully automatic "around the clock" factories. The combined possibilities brought on by digital fabrication will generate new business models, new markets for new types products and services.

The project Diginova has received funding from the European Community's Seventh Framework Programme [FP7/2007 - 2013] under grant agreement no. 290559 in theme NMP.2011.2.3 - 3

Diginova

Increasingly, end-users participate and contribute to the design and manufacturing of the products by easy-to-use computer programs. Transformation to digital fabrication contributes to the decrease of resource consumption and resource-intensive production in many ways, targeting to low-carbon and zero waste manufacturing. For society, to reach all these advances of digital fabrication, issues related to standardization, safety and intellectual property rights needs to, and will be, solved. This paradigm change in manufacturing opens up great opportunities for a new type of production and new material development in Europe.

Digital fabrication technologies are already used in a wide variety of application areas. Health care, consumables, food production, electronics, vehicles and the general production of spare parts are all areas that to some extent already are benefited, and in the future could be expected to gain increasing benefits from the advantages identified for digital manufacturing. Table 1 examines some of these applications in more detail. There are mixes of applications, ranging from those already in existence to those that are expected to develop. Some will lead to the development of business opportunities in the short term; others will have more impact in the long term. For some applications the technology is already available, but manufacturing is not currently feasible. To identify the most promising applications for European digital fabrication business, DIGINOVA project reviewed the wide range of opportunities. On the base of defined criteria (sustainability, market potential, feasibility, etc.), twenty one most potential applications were identified.

Table 1. Examples of applications for digital fabrication.

Application area	Short term	Long term
Human health	Hearing aids, surgical guides, decorative printing on food items, orthopaedic, prosthetic/ orthotic, dental implants	Medical microfactories, personalised diagnostics and drug delivery systems, tissue engineering scaffolds, treatment planning tools (”organ-on-a-chip”), personalised food supplements, whole food products, personalised drugs
Machines and vehicles	Power generators and transmission, durable goods, airframes, cabin parts, automotive parts, personal protective equipment and armour, tooling and casting for several applications	Energy storage, personalised products and gadgets with functional and integrated properties, micro-vehicles, on-demand wear and spare parts
Electronic	Displays, smart windows, sensing, integrated electronics, printed circuit boards, tapestry, wireless devices, antennas, solar cells, semiconductor	OLED lighting and displays, thin heating elements, printed sensors (”lab-on-a-chip”)RFID tagging, thin batteries, stretchable substrate drivers, switching membranes
Consumer products	Jewellery, toys, game figures, customised interior/ exterior design and decoration	Intelligent clothes and smart fabrics, personalised products, shoes, functionalized design and decoration
Printing and decoration	Digitization of traditional printing industry, packages, textiles, digitally fabricated garments, advertisements, signage, ceramic tiles, security, identification markings, surface treatment, traffic signs, labels, books, newsprints	Display graphics, personalised products, on-demand journals, magazines with intellectual features

We see that the most promising opportunities for European manufacturing business can be found from the area of Graphics and communication, Additive manufacturing, Electronics, Healthcare and Mega-scale digital fabrication. Whilst these are in themselves broad areas, we believe the following activities within each area hold the greatest promise for European Digital Fabrication:

The project Diginova has received funding from the European Community's Seventh Framework Programme [FP7/2007 - 2013] under grant agreement no. 290559 in theme NMP.2011.2.3 - 3

Graphics and communication
1. Digitisation of Traditional Printing Industry
2. Decoration of Products & Surfaces
3. Packaging
4. Digital Textiles
5. Display Graphics

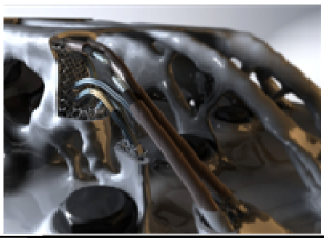
Additive Manufacturing
1. Durable goods
2. Integrated Electronics
3. Sensing
4. Power Generation & Transmission
5. Energy Storage

Electronics
1. OLED Lighting and Displays
2. Smart Windows
3. Printed Sensors
4. Thin Heating Elements
5. Smart Textiles (2D)

Healtcare
1. Medical Microfactories
2. Personalized Diagnostics & Drug Delivery
3. Tissue Engineering Scaffolds
4. Treatment Planning Tools ("Organ-on-a-Chip")
5. Digitally fabricated garments (3D).

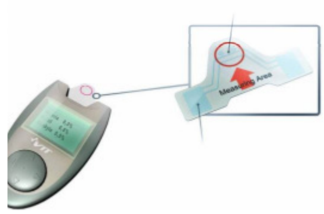
Mega-scale Digital Fabrication
1. Digital building and construction

Display graphics panels at trade show
(Océ Technologies B.V.)



Topologically optimized component with embed-ded electronic tracks and cooling channels
(University of Nottingham)

Flexible displays
(VTT Technical Research Centre of Finland)



Pyramid-building
(VTT Technical Research Centre of Finland)

In order to focus development and research on the topics that will lead towards the accomplishment of the vision, we recommend the following actions.

The project Diginova has received funding from the European Community's Seventh Framework Programme [FP7/2007 - 2013] under grant agreement no. 290559 in theme NMP.2011.2.3 - 3

Table 1. Recommendations for research items for 2D digital fabrication, technical 2D printing development.

2D Digital Fabrication	
Cost	• Speed – larger printhead arrays with reduced crosstalk • Reliability – root cause analysis • Reduced Scrap – error (shortcut) repairing mechanism • Repeatability – monitoring of material ejection
Resolution	• Joint-development with system integrators and end users • Deposition systems development according to application needs • Development of ink-receiving substrates
Materials	• Joint-development with equipment suppliers • Wider range of processable materials, including micro and nano materials • Improved characteristics of functional materials • Understanding of the effects of the complex rheology of some of these materials • Complete understanding of the effect of new printhead architectures on material and fluid stability
Core components	• Joint-development with material suppliers • Deposition systems according to the needs of the new materials, e.g. larger particle sizes • Increase in material application by larger amount of materials • Better understanding of deposition • Better understanding of interface effects and strategies for compensation
Design & Concept	• Matching design and modelling concepts in collaboration with equipment suppliers • Better understanding of the process capabilities • Compatibility with other processing steps for hybrid approaches • Suitable and appealing design concepts • Tools for 2D printed products, where digital fabrication offers unique advantages
Process Integration	• Joint-development with equipment suppliers of other processing tools • New concepts 'beyond R2R' with more flexibility and modularity • Improve compatibility with other processing steps • Development of "print system building blocks" • Ability to print multilayer structures, in-line printing
Sensing & Control	• Accurate sensing and feedback systems will improve cost factors • Measure and control different deposition parameters • Error (shortcut) detection and repairing mechanism
Awareness & Training	• Creation of a comprehensive 2D / 3D community • Increase the overall awareness of 2D digital fabrication by publication of research and analysis of results • Training of skilled personnel for new flexible, modular and hybrid digital fabrication • Events based on specific industrial case studies, technology transfer support and supply chain assistance

The project Diginova has received funding from the European Community's Seventh Framework Programme [FP7/2007 - 2013] under grant agreement no. 290559 in theme NMP.2011.2.3 - 3

Table 2. Recommendations for research items for 3D digital fabrication, technical AM development.

3D Digital Fabrication	
Cost	• Speed – new approaches to scanning or sources of energy. From point-processing to line-processing to planner-processing to volume-processing • Productivity – higher volume production • Repeatability – enabling batch consistency, methodologies for consistent materials supply • Reduce scrap and improve repeatability • Faster turnaround addressing material/part/component handling • Identification of new supply chain opportunities and establishment of existing supply chains for potential products
Core Components	• New/advanced AM machines e.g. machines with multiple lasers • Improve material utilization • Joint-development with material suppliers • Multi-material hardware including process control and software • Interchange-ability of process parameters between different AM machines • Development of hybrid systems • Equipment, design rules and improved computational tools for atom by atom nanoscale manufacturing.
Process Stability	• Tools for better temperature management during processing • Improve surface finish of processed parts • Improve geometrical stability • Analyse energy consumption and development of methodologies for its reduction. • Further develop energy sources with improved efficiency and control. • Reduce residual stresses. • Increase software utilization. • Analyse stability of the AM process in order to make improvements to AM systems that will allow production components to be produced with required properties
Materials	• Joint-development with equipment suppliers - increased material processability, quality and performance • New materials e.g. biomaterials, superconductors and new magnetic materials, high performance metal alloys, ultra-high temperature ceramic composites, metal-organic frameworks, new nano-particulate and nano-fibre materials, semi-crystalline and amorphous polymers suited to different AM mechanisms. • New powder production sources or new/improved methodologies for supply chain integration, e.g. recycling of used material • Map influence of energy input and distribution on microstructure and part properties • Self-assembly and synthesis methods for nanoscale structures • Establishment of bio-tissue engineering using AM
Design	• Design tools and methodologies to empower design engineers to take advantage of AM. • Design tools for non-experts
Process & Product Quality	• Methodologies for measurement of AM products • Reducing requirements for post-processing activities • 'Streamlined' workflow for hybrid manufacturing, combining AM processes to meet geometric and surface finish requirements • Develop mechanism by which the material is processed to improve surface quality • Increase the understanding of power-beam manipulation (laser or electron beam) and material interaction(s)
Quality Control	• Closed-loop control systems • Real time Non Destructive Analysis (NDA), quality assurance and process repeatability monitoring and recording systems

The project Diginova has received funding from the European Community's Seventh Framework Programme [FP7/2007 - 2013] under grant agreement no. 290559 in theme NMP.2011.2.3 - 3

3D Digital Fabrication	
	• Increase control of process tolerances • In-process monitoring and control methodologies and systems • In-situ sensors for non-destructive evaluation and early detection of flaws/defects
Product Data	• Develop databases to allow a catalogue of materials performance information for particular applications, materials and processes. • Develop an 'online' portal of materials information for comparison and sharing.
Training & Education	• Creation of a comprehensive 2D / 3D community • Specific training modules encompassing design/ modelling, processes, materials and applications • Non-technical outreach programs on logistics, lean manufacturing and new business models • University and technical college courses • Events based on specific industrial case studies, technology transfer support and supply chain assistance • Certified training programs for industry practitioners
Standards & Certification	• Certification of AM e.g. advanced in-process inspection and quality control techniques • Industry engagement in the ASTM F42, BSI and ISO working groups on standards development • Industry advisory group focusing on AM supply chains and common areas of capabilities for Europe
Environment	• Heat sources used in AM, e.g. more electrically efficient lasers • Reduce resource usage including in-process losses • Validation and standardization of the batch-to-batch recycling of materials, especially for polymeric materials • Recycling of material after natural usage life e.g. melting of used parts, monitoring and control of material chemistry, and the atomization of material to create feedstock
Liability	• New business models stating clear rules and guidelines on the effective supply of AM produced components • Ensure product safety, but also accountability in the event of faulty or damaged parts/products
Other	• Global collaboration • Joint-development with end-users to understand the business case for using AM over other manufacturing routes • Mechanisms for taking a product into production e.g. taking proven concepts at TRL 4 and moving them to TRL 7 to 9. • Supply chain development, from material supply, reliable AM systems to post-processing

Keywords: digital fabrication; roadmap; additive manufacturing; additive fabrication; digital printing; 3D printing

The project Diginova has received funding from the European Community's Seventh Framework Programme [FP7/2007 - 2013] under grant agreement no. 290559 in theme NMP.2011.2.3 - 3