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Introduction

Digital Fabrication has been described as the 'Third Industrial Revolution'[1]. Over the course of the Diginova project, the public profile of Digital Fabrication has increased significantly. One of the many highlights was the prominence given to 3D printing by President Obama in his State of the Union[2] address in February, 2013.

The use of computer controlled tools and processes to transform digital designs directly into products have significant implications for the structure of manufacturing. New manufacturing norms, based upon distributed manufacturing will develop. New Intellectual Property and legal structures will be required to underpin its development. The Diginova project has already identified the development of well matched combinations of advanced new material deposition tools and materials as a key success factor for Digital Fabrication. This means that Digital Fabrication will need new processes, new fabrication tools and new materials to support its development.

The world of Digital Fabrication is developing rapidly. The multi-disciplinary nature of its development can make it difficult for those interested in the area to keep up-to-date with the latest developments.

For this reason, the Diginova team and its networks are being used to monitor developments in this continuously changing landscape, so that those individuals, groups and organisations that are interested in the technology and its development can get a useful overview of the area.

This report is the second of a series of Technology Watch Reports (TWRs) that the project will publish on a regular basis, presenting key information from the relevant trade literature, conferences and exhibitions, the scientific and technological literature and the media. It is not a comprehensive review of all developments. Rather it seeks to keep the reader aware of the major areas of development and the current areas of debate and discussion within the industry.

This second report mainly focuses on the IS&T NIP/DF 2013 conference held in Seattle, Washington which is the most appropriate and well known conference in Digital Fabrication worldwide. It also reviews some other interesting articles from sources outside the conference.

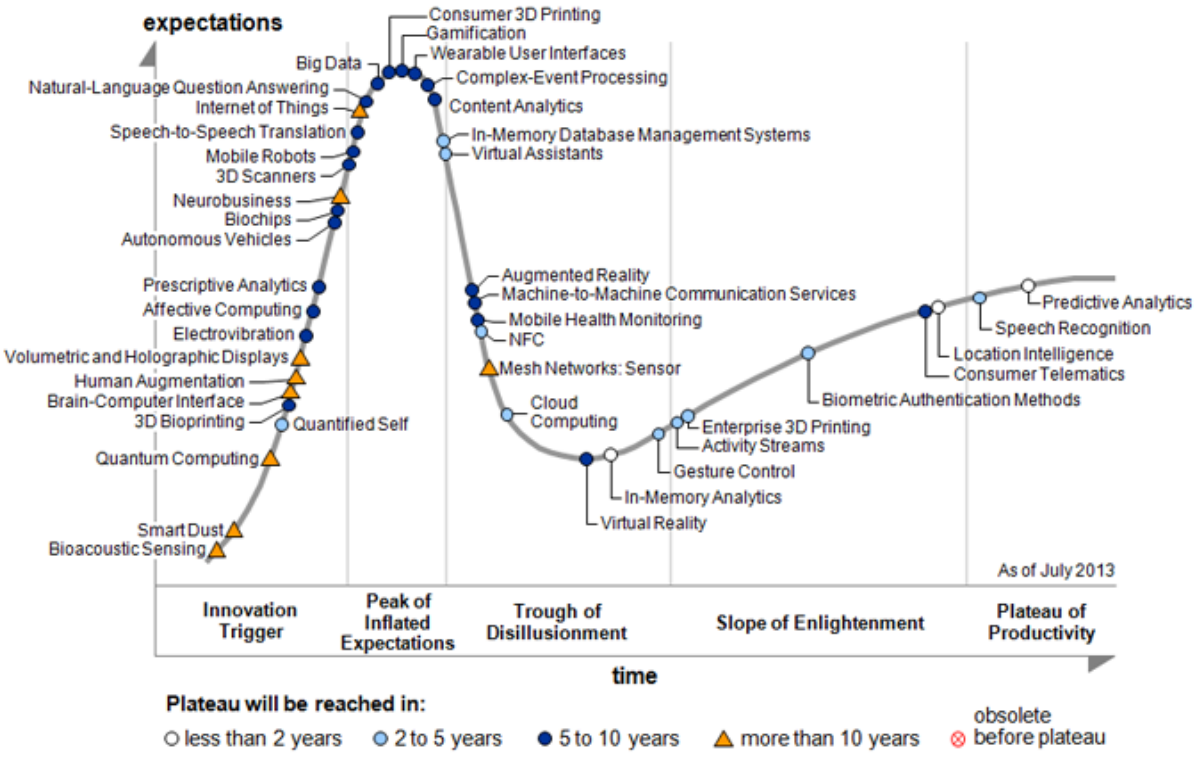
Area Covered	No. of Articles
1) Digital Fabrication in Medical and Biomaterial applications	7
2) Materials (including food packaging inks)	5
3) Roll-to-roll (R2R) Manufacturing	3
4) Embedded functionality	2
5) Aerospace	2
6) Architecture	1
7) Digital vs. Conventional Manufacturing	2
8) Retail / Consumer	1
9) OLED	1
10) Energy	1
11) Market Analysis	1
12) Standardisation	1

1 http://www.economist.com/node/21553017

2 http://printrbot.com/2013/02/13/president-obama-pushes-3d-printing-in-state-of-the-union/

The review reflects a significant and developing interest in the application of Digital Fabrication to bio and medical based applications. It also reflects the development of materials and digital techniques that can be applied to higher volume (R2R) manufacturing techniques, particularly in the area of Printed Electronics. This is in accord with the findings of the Diginova Roadmapping work, which identifies Printed Electronics and Human Applications as key areas.

Gartner have published the latest version of their 'Hype cycle' which focuses on emerging technologies. Interestingly, it is possible to see 3D printing technologies appear in a number of different areas of the cycle, dependent upon sector. So, 3D Bioprinting appears in the 'Innovation Trigger' section of the cycle, whereas 'Consumer 3D Printing' appears at the 'Peak of Inflated Expectations'. 'Enterprise 3D Printing' (or industrial application of 3D printing) is firmly in the 'Slope of Enlightenment' section of the cycle. It is possible to see a correlation between the areas reviewed in this Technology Watch Report and the different stages these areas have reached in the hype cycle. It is certainly instructive to review these papers against the background of Gartner's latest hype curve.



Source: Gartner, August 2013 (http://www.gartner.com/newsroom/id/2575515).

1) Digital Fabrication in Medical and Biomaterial applications

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	Jason Rolland, DFA, ***Paper as a Versatile Platform for Low-Cost Diagnostics***
Date	September 29 – October 3, 2013
Key learning Points	Novel technologies are needed to address the urgent healthcare requirements of patients in the developing world and other resource-limited settings. Paper and other porous media provide an attractive platform from which to build devices. 3-dimensional devices formed by stacking multiple layers of patterned paper provide the ability to perform many fluidic handling operations. Diagnostics For All (DFA) is developing tests based on this platform, like • Liver function test • Multi-plexed Immunoassay • Molecular Diagnostics
Breakthroughs	A novel platform based on patterned paper microfluidic devices is presented.

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	Niklas Sandler et al., Abo Academi University ***Fabrication of printed drug-delivery systems***
Date	September 29 – October 3, 2013
Key learning Points	The aim of this paper is demonstrate the combined use of inkjet and flexographic printing to fabricate pharmaceutical solid dosage forms with controlled release properties of drug substances. The use of printing technologies to deposit drug substances onto porous cellulose substrates is a promising approach in the production of solid medicines with distinct characteristics, tailored release behavior and dose precision.
Breakthroughs	This approach allows personalization of the doses accurately.

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	K. Borchers at.al, Fraunhofer IAP, Germany ***Bioink Development for Additive Manufacturing of Artificial Soft Tissue***
Date	September 29 – October 3, 2013
Key learning Points	Development of material systems that are printable and photo-crosslinkable , either based on bio-polymers or fully synthetic resins
Breakthroughs	Complex soft tissue substitutes can be generated by bio-based and synthetic precursors

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	D. Reyna et.al., University of Texas, USA, ***Inkjet Bioprinting of Solid Peroxide Microparticles for Constructing Oxygen-Generating Scaffolds***
Date	September 29 – October 3, 2013
Key learning Points	Inkjet bioprinting technology is a novel fabrication approach, in which the bioprinter can deposit biomaterials precisely in a designed path. This technology has been applied in this study to construct oxygen-generating scaffolds.

Source of Information	3Dprintingindustry.com
Reference	http://3dprintingindustry.com/2013/11/08/bioprinting-vascular-systems/
Date	Retrieved on November 11 2013
Key learning Points	Scientists of the Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB) in Stuttgart have succeeded in developing suitable bio-inks for this printing technology. The transparent liquids consist of components from the natural tissue matrix and living cells. The substance is based on a well-known biological material: gelatin. Gelatin is derived from collagen, the main constituent of native tissue. The researchers have chemically modified the gelling behaviour of the gelatin to adapt the biological molecules for printing. Instead of gelling like unmodified gelatin, the bio-inks remain fluid during printing. Only after they are irradiated with UV light are they crosslinked and cured to form hydrogels. These are polymers containing a huge amount of water like native tissue but remain stable in aqueous environments and when being warmed up to a physiological temperature of 37 °C. The researchers can control the chemical modification of the biological molecules so that the resulting gels have differing strengths and swelling characteristics enabling imitation of the properties of natural tissue — from solid cartilage to soft adipose tissue.
Breakthroughs	ArtiVasc 3D will provide a micro- and nano-scale based manufacturing and functionalisation technology for the generation of fully vascularised bioartificial fatty tissue. The artificial vascularisation will, for the first time, allow a connection to the natural tissue enabling entire nutrition and metabolism. By combining the fatty tissue with a dermal and epidermal cell layer a 3-layered skin equivalent will be developed.

Source of Information	NIP29 and DF 2013 Technical Programme Proceedings
Reference	***Bioink Development for Additive Manufacturing of Articficial Soft Tissue*** K. Borchers, C. Bierwisch, S. Engelhardt, et al. NIP 29 and Digital Fabrication 2013, Technical Programme Proceedings, 223.
Date	Sep 29 - Oct 3, 2013.
Key learning Points	They develop printable and photo-crosslinkable material systems form either biopolymers or synthetic resins. They then use e.g. (meth)acrylation of the precursor polymers to achieve photocrosslinkablility. Further chemical modifications and additives are applied in order to achieve inkjet-printable resin viscosities. Inkjetprinting combined with UV laser or two photon-polymerization (TPP) in inert atmosphere is developed for 3D material structuring. They generated some example tubular systems that could potentially be used as blood vessels.
Breakthroughs	The viscosity of the materials was tailored to the inkjet-printable range and the E-modulus of the crosslinked synthetic materials can also be adjusted. Modelling and computational fluid dynamics allowed for prediction of the correlation of structure and function, e.g. for biomimetic bifurcations with optimized wall shear stress for endothelial cell growth in blood vessel like systems. Gelatin-based biomaterials constitute both printable non-gelling precursor solutions and crosslinked hydrogels with tunable physico-chemical properties. Such bioinks can be used for 3D encapsulation of cells
Comments	Additive manufacturing can be opened up for processing both, bio-based and synthetic precursors for future generation of complex soft tissue substitutes.

Source of Information	NIP29 and DF 2013 Technical Programme Proceedings
Reference	***Inkjet Printed Structures for Smart Lab-on-Chip Systems*** E. Beckert, O. Pabst, Z. Shu et al. NIP 29 and Digital Fabrication 2013, Technical Programme Proceedings, 224.
Date	Sep 29 - Oct 3, 2013.
Key learning Points	Digital fabrication (inkjet) using printed conductives, piezoelectrics and pH sensitive polymers to create multi functional elements for lab-on-a-chip (LoC) devices. These elements include heaters for fluid temperature control, capacitive fluid presence detectors, electrodes for free-flow electrophoresis, chemosensors for pH detection and pumps for fluid distribution.
Breakthroughs	No specific breakthrough, but the elements described will allow the development of, for example, enhanced functionality for a LoC device is the already mentioned polymerase chain reaction (PCR) that is widely used for the amplification of DNA sequences in order to search e.g. for salmonella in food or for specific antibodies in the human blood to make the use of drugs more safe.
Comments	Inkjet printing is used to print a variety of elements that can be combined to give functionality in LoC applications.

2) Materials

Source of Information	Printed Electronics World
Reference	http://www.printedelectronicsworld.com/articles/researchers-build-3d-structures-out-of-liquid-metal-00005627.asp?sessionid=1
Date	16 Aug 2013
Key learning Points	Researchers from North Carolina State University have developed three-dimensional (3D) printing technology and techniques to create free-standing structures made of liquid metal at room temperature. They've found that a liquid metal alloy of gallium and indium reacts to the oxygen in the air at room temperature to form a 'skin' that allows the liquid metal structures to retain their shapes. The researchers developed multiple techniques for creating these structures, which can be used to connect electronic components in three dimensions. While it is relatively straightforward to pattern the metal "in plane" - meaning all on the same level - these liquid metal structures can also form shapes that reach up or down. One technique involves stacking droplets of liquid metal on top of each other, much like a stack of oranges at the supermarket. The droplets adhere to one another, but retain their shape - they do not merge into a single, larger droplet. Another technique injects liquid metal into a polymer template, so that the metal takes on a specific shape. The template is then dissolved, leaving the bare, liquid metal in the desired shape. The researchers also developed techniques for creating liquid metal wires, which retain their shape even when held perpendicular to the substrate. The team is currently exploring how to further develop these techniques, as well as how to use them in various electronics applications and in conjunction with established 3-D printing technologies.
Breakthroughs	Creation of stable liquid-metal structures at room temperature using 3D printing techniques.
Comments	This is a materials curiosity with no real market pull identified, though the team hope to find such pull.

Source of Information	Printed Electronics World
Reference	http://www.printedelectronicsworld.com/articles/inkjet-based-circuits-at-fraction-of-time-and-cost-00005971.asp?sessionid=1
Date	12 Nov 2013
Key learning Points	Use of ink jet technology to produce conductive circuits with equipment costing no more than US$ 300 using a technique called 'Instant Inkjet Circuits'
Breakthroughs	Related to the material: using recent advances in chemically bonding metals to create silver nanoparticle inks that do not require sintering. Application would be rapid prototyping of electrical circuits.
Comments	Interesting application of advanced materials to established digital fabrication techniques.

Source of Information	NIP29 and DF 2013 Technical Programme Proceedings
Reference	***Patterning of Functional Ceramic Oxides on Metallic Substrates by Inkjet Printing*** M. Vilardell, X. Granados, S. Ricart, A. Calleja, A. Palau, T. Puig and X. Obradors. NIP 29 and Digital Fabrication 2013, Technical Programme Proceedings, .
Date	Sep 29 - Oct 3, 2013.
Key learning Points	The paper covers the implementation of Chemical Solution Deposition (CSD) in combination with drop on demand (DoD) inkjet printing technology. When simple additive processing is implemented in continuous reel to reel systems with novel low-cost materials, the potential to further decrease the production costs of the whole manufacturing process is immense. The paper gives a summary of functional ceramic oxides patterning by combining CSD and inkjet printing methodologies onto different single crystal, polycrystalline and textured substrates. The present work demonstrates a powerful method of fabricating multifilamentary YBCO patterned coatings for low losses coated conductors (CC's) and LSMO magnetoresistive analogue encoders for position sensing.
Breakthroughs	The authors show that it is possible to control the patterning of low ac losses superconducting coated conductors in only one production step. Also, more complex functional ceramic patterns have been demonstrated and tested.
Comments	An interesting paper on the potential for inkjet printing when combined with functional inks.

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	D. Illsley et.al., Sunjet, Bath, UK ***Low Migration UV-Curable Inkjet for Food Packaging***
Date	September 29 – October 3, 2013
Key learning Points	UV-curable inks for single pass (web) inkjet printing with low migration potential and suitable for the printing of food packaging have been developed and optimized.
Breakthroughs	

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	R. De Mondt, J. Loccufier, Agfa-Gevaert N.V., Mortsel, Belgium, ***Key Innovations that allow Low Migration Digital Printing with UV-curable Inks***
Date	September 29 – October 3, 2013
Key learning Points	Intrinsically low migration UV inks do not exist, especially for inkjet. The newest generation of high speed, high resolution printheads requires lower viscosity inks. Even lower viscous monomers have to be used, increasing the migration risk. This paper covers specific innovations in terms of chemistry to be able to combine low viscosity and low migration.
Breakthroughs	Use of a primer to capture any migration monomer molecule.

3) Roll-to-roll (R2R) Manufacturing

Source of Information	NIP29 and DF 2013 Technical Programme Proceedings
Reference	***Towards High speed Inkjet Printed Electronics - Technology Transfer from S2S to R2R Production*** P. Teunissen, E. Rubingh, T. Van Lammeren et al. NIP 29 and Digital Fabrication 2013, Technical Programme Proceedings, 484.
Date	Sep 29 - Oct 3, 2013.
Key learning Points	An economically successful implementation of printed electronics technologies in industrial production processes requires high throughput and large scale compatible manufacturing techniques. Roll-to-roll inkjet printing and photonic sintering of metal-based conductive inks on flexible plastic substrates is a promising approach in this respect. It is, however, currently mainly applied on a small scale sheet-to-sheet basis, and technology transfer towards roll-to-roll production has proven to be challenging. Presented here is a stepwise strategy, starting with rather basic, laboratory scale equipment and using small amounts of materials. Based on the outcome of these tests, the experimental scale is successively enlarged and the process conditions continuously optimised, until finally industrial applicability is convincingly demonstrated on a pre-pilot roll-to-roll production line with manufacturing rates of up to 20 m/min. Following this stepwise approach, the authors were able to scale up the production speed by several orders of magnitude in a purposeful and thus cost and labour efficient way.
Breakthroughs	Again, no breakthrough, but R2R inkjet printing in combination with photonic sintering has a promising potential to be applied to the production of printed electronic devices on an industrial scale. In order to achieve a reliable, stable and fast manufacturing process, which is an indispensable prerequisite for successful commercial application, intense process optimisation has to be carried out.
Comments	This is an interesting study on the challenges faced in moving a digital fabrication technique through the scale up process.

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	Pit Teunissen, Holst Centre – TNO, et al., ***Towards High Speed Inkjet Printed Electronics – Technology Transfer from S2S to R2R Production***
Date	September 29 – October 3, 2013
Key learning Points	Roll-to-roll inkjet printing and photonic sintering of metal-based conductive inks on flexible plastic substrates. Industrial applicability is demonstrated on a pre-pilot roll-to-roll production line with manufacturing rates of up to 20 m/min.
Breakthroughs	R2R sintering of inkjet printed metal-based conductive inks.

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	Jolke Perelaer, Friedrich-Schiller-University Jena, et al ***Low Temperature Sintering of Inkjet Printed Metal Precursor Inks for Organic Electronic Applications***
Date	September 29 – October 3, 2013
Key learning Points	This paper presents recent results in the sintering of inkjet printed metal nanoparticle dispersion on cost-effective polymer foils. In order to sinter the particles at speeds that are compatible with roll-to-roll speeds, combinations of innovative sintering methods have been used. Conductivity values between 40 and 60 % were hereby obtained in a few seconds to minutes by using either photonic or plasma pre-sintering followed by microwave flash sintering.
Breakthroughs	The presented sintering methods represent a step towards roll-to-roll production of printed electronic applications.

4) Embedded Functionality

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	Steven Ready et al., Palo Alto Research Center, ***3D Printed Electronics***
Date	September 29 – October 3, 2013
Key learning Points	Taking advantage of both 3D printing and printed electronics, PARC is currently developing a printing system capable of integrating electronic functionality into 3D objects. This system uses both ink-jet and extrusion methods, enabling a wide range of structural and functional inks to be used. Photonic curing allows for a continuous, automated, layer-by-layer approach for building up these integrated objects with embedded electronic functionality.
Breakthroughs	Two materials necessary for creating functional electromechanical parts – a structural material (UV curable polyurethane gel) and a conductor (a nanoparticle silver ink) have been integrated to make electrical connections.

Source of Information	Printed Electronics World
Reference	http://www.printedelectronicsworld.com/articles/internal-tagging-technique-for-3d-printed-objects-00005720.asp?sessionid=1
Date	9th August, 2013
Key learning Points	3D printing can be used to create objects incorporating internal tags that allow the objects to be tracked. These internal tags, which the researchers have dubbed InfraStructs, can be read with an imaging system using terahertz (THz) radiation, which can safely penetrate many common materials. The tags themselves come at no extra cost, but THz imaging, still in its infancy, can be pricey. As this imaging technology matures and becomes more affordable, however, InfraStructs could be used for a number of applications beyond keeping track of inventory or making point-of-sale transactions. InfraStructs can be made with the same layer-by-layer process used for producing the object. In some cases, information can be encoded by positioning bubbles or voids inside the object; those voids reflect THz radiation. In other cases, materials that are reflective of THz radiation might be used to encode the information or create images inside the object.
Breakthroughs	Creation of inexpensive tagging technology as a natural part of the 3D printing process, using THz technology to read the tags.
Comments	This is not commercialized, but indicates the type of functionality that can be built into an object using digital fabrication in conjunction with sophisticated reading technology.

5) Aerospace

Source of Information	Bloomberg.com
Reference	http://www.bloomberg.com/news/2013-11-12/ge-printing-engine-fuel-nozzles-propels-6-billion-market.html
Date	Retrieved on November 11 2013
Key learning Points	General Electric Co. (GE) is on the hunt for ways to build more than 85,000 fuel nozzles for its newest jet engine. Instead of assembling them from 20 different parts, it plans to create the units in one piece – with 3-D printers.
Breakthroughs	Constructing the components with lasers one layer at a time will producer stronger, lighter nozzles than with conventional machining, according to GE. That means ensuring the printers evolve into equipment sturdy enough for assembly-line production, not just tools to fashion plastic prototypes.

Source of Information	Printed Electronics World
Reference	http://www.printedelectronicsworld.com/articles/3d-printed-rocket-engine-gets-its-first-fiery-test-00005648.asp?sessionid=1
Date	26th July, 2013
Key learning Points	NASA and Aerojet Rocketdyne of West Palm Beach, Fla., recently finished testing a rocket engine injector made through additive manufacturing, or 3D printing. A series of firings of a liquid oxygen and gaseous hydrogen rocket injector assembly demonstrated the ability to design, manufacture and test a highly critical rocket engine component using selective laser melting manufacturing technology. Aerojet Rocketdyne designed and fabricated the injector by a method that employs high-powered laser beams to melt and fuse fine metallic powders into three dimensional structures. This type of injector manufactured with traditional processes would take more than a year to make but with these new processes it can be produced in less than four months, with a 70 percent reduction in cost. "Rocket engine components are complex machined pieces that require significant labor and time to produce. The injector is one of the most expensive components of an engine," said Tyler Hickman, who led the testing. Aerojet Rocketdyne's additive manufacturing program manager, Jeff Haynes, said the injector represents a significant advancement in application of additive manufacturing, most often used to make simple brackets and other less critical hardware. "The injector is the heart of a rocket engine and represents a large portion of the resulting cost of these systems. Today, we have the results of a fully additive manufactured rocket injector with a demonstration in a relevant environment." he said. "Hot fire testing the injector as part of a rocket engine is a significant accomplishment in maturing additive manufacturing for use in rocket engines," said Carol Tolbert, manager of the Manufacturing Innovation Project at Glenn. "These successful tests let us know that we are ready to move on to demonstrate the feasibility of developing full-size, additively manufactured parts."
Breakthroughs	Hot fire testing of a critical component manufactured by a digital fabrication technique (SLM), with significant savings in production time and cost.
Comments	This could have significant implications for key component manufacture in critical and harsh environments.

6) Architecture

Source of Information	Daily Mail
Reference	http://www.dailymail.co.uk/sciencetech/article-2425446/3D-printed-ROOM-looks-like-beautiful-interior-cathedral.html
Date	19/09/2013
Key learning Points	This is a really good example of the potential of digital fabrication and it can be applied to large scale. The room was produced by printing 3D sandstone blocks. The room size is 16 square metres.

7) Digital vs. Conventional Manufacturing

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	Susanne Klein et al, HP Labs UK and USA ***3D Printing: When and where does it make sense?***
Date	September 29 – October 3, 2013
Key learning Points	For 3D printing to be employed more widely and not only as a means of prototyping, the following obstacles have to be overcome: - The choice of materials has to be expanded - Printing times have to be drastically reduced. Glass manufacturing has been used here as an example. Instead of printing the whole object the authors suggest using 3D printing as a way to add features and therefore to add value to otherwise mass produced objects. Printing of a single layer, an interface for example, could be possible at speeds comparable to traditional inkjet printing.
Breakthroughs	Not really a breakthrough, but this paper is a balanced critical appraisal of the capability of 3D-printing. It uses the glass industry as a case study. It also disputes Lipson and Kurman's ten principles of 3D printing.
Comments	• Trying to understand where 3D printing and traditional manufacturing can add value to each other. • This paper discusses how 3D printing can add value to existing production processes using the example of glass container production in the UK. The case proved to be challenging.

Source of Information	Digitaltrends.com Dailymail.co.uk
Reference	http://www.digitaltrends.com/cars/urbee2-isnt-pokemon-3d-printed-car-gets-290mpg/ http://www.dailymail.co.uk/sciencetech/article-2515009/Meet-Urbee-3D-printed-CAR-makers-claim-greenest-practical-car-made.html
Date	28th November 2013
Key learning Points	The car is powered by ethanol Car body panels are created by printing a type of plastic It took three month to print the prototype but is several years away from production. Urbee car weighs around 1,200 pounds and the prototype model is expected to consume just 10 gallons of ethanol fuel on a journey across the US The shell and interior of the car are 3D printed and it has a hybrid engine using ethanol and an electric motor Designed to be eco friendly
Breakthroughs	World's first 3D printed car
Comments	An interesting example of how 3D printing is being used in the industry.

8) Retail / Consumer

Source of Information	Printed Electronics World
Reference	http://www.printedelectronicsworld.com/articles/3d-printing-retailers-get-a-piece-of-the-action-00005746.asp?sessionid=1
Date	22 Aug 2013
Key learning Points	Article on retailers who are beginning to stock 3D printers for the home market. In July, UK electronics retailer Maplin announced that it would be offering a self-assembled 3D printer priced at £699.99 in its stores. In August, Microsoft announced it would be selling Makerbot 3D printers in its stores, at a slightly pricier $2,549 but in this case ready-assembled. Makerbot itself has just opened its own retail store in New York. The main aim of these activities is clearly to stimulate the consumer market for 3D printers. The article also refers to the IDTechEx report "3D Printing 2013-2025: Technologies, Markets, Players" , which is a commercially available market analysis report.
Breakthroughs	Simply that hardware is being made available for the retail market at attractive prices. This should stimulate activity in the home/consumer -based digital fabrication market.
Comments	More evidence of the potential to adopt digital fabrication at a consumer scale.

9) OLED

Source of Information	Engaget.com / Kateeva.com
Reference	http://www.engadget.com/2013/11/21/kateeva-oled-tv-inkjet-printer/
Date	Retrieved on November 11 2013
Key learning Points	Due to the oxygen and moisture-hating nature of OLED ingredients, current OLED televisions are built with tricky vacuum evaporation and shadow masking techniques that are too inefficient and wasteful to be inexpensive. The YIELDJet, on the other hand, prints the LEDs in a pure nitrogen chamber to avoid those problems, plus it promises better film coating uniformity as well. This will also reduce costs.
Breakthroughs	"world's first inkjet printer engineered from the ground up for OLED mass production."

10) Energy

Source of Information	Printed Electronics World
Reference	http://www.printedelectronicsworld.com/articles/printing-microbatteries-the-size-of-a-grain-of-sand-00005547.asp?sessionid=1
Date	21st June, 2013
Key learning Points	3D printing can now be used to print lithium-ion microbatteries the size of a grain of sand. The printed microbatteries could supply electricity to tiny devices in

	fields from medicine to communications, including many that have lingered on lab benches for lack of a battery small enough to fit the device, yet provide enough stored energy to power them. To make the microbatteries, a team based at Harvard University and the University of Illinois at Urbana-Champaign printed precisely interlaced stacks of tiny battery electrodes, each less than the width of a human hair. The scientists realized they could pack more energy if they could create stacks of tightly interlaced, ultrathin electrodes that were built out of plane. For this they turned to 3D printing. To print 3D electrodes, the group first created and tested several specialised inks. Theseinks were designed to extrude from the inkjet nozzles and immediately harden into their final form.
Breakthroughs	Creation of a viable printed battery using the £D printing approach: development of the specialist materials required.
Comments	Again, not yet commercialized, but offering performance that is potentially similar to commercial batteries and hence relevant to MEMS, and other miniaturised devices.

11) Market Analysis

Source of Information	Printed Electronics World
Reference	http://www.printedelectronicsworld.com/articles/the-problem-with-3d-printing-00005935.asp?sessionid=1
Date	30 Oct 2013
Key learning Points	Flyer for the IDTechEX forecast report '3D Printing Materials 204 - 2025: Status, Opportunities, Market Forecasts' Predicts materials market value of $US615M in 2025. However, this is predicated on suppliers maintaining premium pricing by locking in end users to their products. If market is fully competitive by 2025, this value will drop to $US244M.
Breakthroughs	This is a commercial report that analyses the materials market for 3D printing. The interesting comments on materials suppliers 'locking' clients into their materials is presented under the heading 'The problem with 3D printing'.
Comments	The following observation of the report authors is very interesting: "Whilst hard data concerning pricing is hard to come by, some end-users have revealed both the practice and the prices, some of which are hundreds of times the commodity price for similar materials. Further, prices are being maintained at a high level long after R&D costs have been recouped. This anti-competitive behaviour is preventing the development of an efficient, competitive market for 3D printing materials and is presenting very high barriers to entry for new suppliers. Perhaps most importantly of all - it is hindering the development of new materials for 3D printing. The new IDTechEx report discusses these issues and more." This is a developing area that would should be monitored.

12) Standardisation

Source of Information	NIP 29 and Digital Fabrication 2013 Conference, Seattle, USA
Reference	Alan Hodgson, 3M, ***IEC TC119 – International Standards for Printed Electronics***
Date	September 29 – October 3, 2013
Key learning Points	This paper gives a brief overview of the International Standards process and the organisation of IEC TC119 (Printed Electronics). It looks at the proposed structure for the standardisation of Printed Electronics and surveys the areas currently being worked on.
Comments	Printed electronics need meaningful and relevant standards to aid the "lab to fab" transition.