InkJet Microdeposition

White Paper

Markets & Strategic Approach of Dimatix

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InkJet Microdeposition is a New Technology for On Demand Manufacturing & Fluid Processing

InkJet grew up in its first age and popularized cheap, convenient method of printing information & pictures on paper. In its second age InkJet is now realizing a new vision as a means of microcontroling the deposition of fluid materials within manufacturing & testing processes. Deposition and patterning may be achieved in a single process at a level of on-demand drop-by-drop control in picoliter quanta (1 picoliter = 1 trillionth of one liter – 10^{12}). That is a new and dramatic usage of InkJet technology and it is beginning to affect real markets.

The range of chemistries to which this process may be applied is probably very wide and the core InkJet or deposition technology, while at a relatively early stage of development today for industrial applications, shows the realistic probability of being dramatically scalable.

Major Applications for InkJet Microdeposition

There are three major separate sectors in which the application of InkJet Microdeposition is predicted to have an optimistic future:

- **Printed Electronics**
  where the generation today of micro conductive channels and in the near future layered semiconductive components are important.

- **Life Sciences**
  where fluid testing systems and tissue building systems are important;

- **Manufacturing**
  where the generation of 3D structures such as microlenses and nanostructures are important

Each sector is sizeable and strategically affected by the new technology, but the Printed Electronics sector probably holds the earliest promise as seen from today's perspective.

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Dimatix Strategy for Development of Microdeposition Markets

Each sector is technically very demanding and calls over time for the exacting development of customized systems. Furthermore InkJet technology itself is undergoing a process of scaling with growing demand. These facts call for a flexible technology offering during the first phase of the market. That translates to the need to provide users and developers now with experimental tools and a scalable customizable approach to development at a low cost.

The model in particular of Dimatix is to seed the market with very affordable small scale but highly functioning systems backed by credible support for the development described. This will be a breakthrough of importance after the failed efforts of a number of companies to go straight to high-level customization at a time when neither the investment environment nor the assured proven level of development of InkJet technology have permitted that approach.

The Potential by Segment of InkJet Microdeposition Markets

Printed Electronics

Definition

Printed electronics has a narrow and a broad definition, both of which are inexact, though usable:

Narrow Definition

In a narrow sense Printed Electronics technically refers for some observers to the ability to generate field-effect transistors or complex electronic components by sequentially laying down chemistry using a process which may actually involve utilizing familiar analog or digital (InkJet) graphic printing technologies, or else involve a more industrial process like vacuum deposition sometimes referred to as a form of 'printing' by the same observers. It is presented as a specific alternative to the Integrated Circuit (IC) because it would be much cheaper than making ICs, not least because of the relatively low investment in plant and would consequently open up consumer and other markets to electronics, which are not open to ICs. 'Printed' semiconductors will not match the functionality of ICs. But the market for printed semiconductors will be a new and different one requiring no substitution and only needing lower functionality.

Broad Definition

In a broader sense Printed Electronics is used by other observers to refer to the manufacturing of products utilizing electric or electric effects, which have some combination of the following characteristics. This is not an exhaustive list and probably can be added to:

- Deposition of electrically active layers thinner than 100 microns by any method, including conventional printing
- Capable of electronic or electric functionality without requiring an IC
- Utilizing some kind of conductive chemistry including carbon, copper, silver or conductive polymer chemistries
- Offering, or promising to offer electric or electronic functionality on flexible substrates using conductive or semiconductive chemistry both inorganic or inorganic

Value Proposition for InkJet

Future 'Printing' Manufacturing Technology Context

It should be noted that within the electronics industry the term 'printing' is sometimes used as a catch-all term referring to number of distinct technologies some of which are already in use today, some of which are proposed for future use and some of which are fundamentally dissimilar to 'print' as understood in the graphics and digital print industries. They may be categorized as follows:

- **Hybrid 'Analog' Gas, Solid and Liquid Deposition Technologies**
  These include such technologies as etching, vacuum deposition, epitaxy, electrolysis, electroless plating, metal reduction among others. These tend to dominate manufacturing today in the high volume applications described below at low *running* costs. But these are the existing technologies which true analog or digital printing as described below are intended to substitute for in the new markets. Many of them are wasteful subtractive processes where true printing would be a more environmentally friendly and economic additive process.

- **True Analog Printing**
  This refers to Roll-To-Roll offset, flexo, gravure or screen printing as practiced in the graphics industry. The well-founded hope is that these technologies already adapted to large scale manufacturing and also somewhat scalable (though much less scalable downwards than InkJet) , will be capable of relatively simple adaptation to printing of the conductive and semiconductive chemistries necessary for the new generation of flexible plastic or printed electronics. These new chemistries seem largely adaptable to functioning within analog print technology plant.

  In fact screen printing is already used in the manufacture of electronic circuits, and has been for decades – hence the term 'printed' circuit – but this form of analog printing is highly specialized and an auxiliary technology in this format rather than a primary manufacturing technology. Still, this background gives true analog printing a significant credibility entry point to the new market.

- **Direct Digital Printing (InkJet)**
  This refers in practice to InkJet alone as a non-contact (read: simplified and less problematic substrate interface as opposed to true analog printing which is all contact printing) method of direct deposition of liquid chemistry. Inkjet would offer all the benefits of true analog print technology with the added incalculable benefit for the microprecision-oriented electronics industry that it is directly controllable down to the level of the picoliter drop. If InkJet proves its ability to scale up in the future it will simply become the preferred form of depositing chemistry to create the new flexible plastic or printed electronics. This renders InkJet the logical and reliable long-term bet as the core enabling technology for the new markets.

Unique InkJet Characteristics
InkJet has the following main characteristics, which individually and in combination make it unique as a manufacturing technique in application to electronics manufacturing:

- It is a scalable technology (meaning it can be set up to produce very small quantities and sizes and has the promise in the future of being able also to print very large quantities and sizes as well). This is an advantage against true analog printing technologies as well as against hybrid deposition technologies.

- It is an on-demand technology (meaning it can be switched on and off on-demand and does not have minimal run lengths)

- It is a relatively cheap technology by comparison to current electronics manufacturing technologies such as stepped etched photolithography

- It is a modular-capable technology because of its relative simplicity, offering the significant future prospect of being able to integrate InkJet lines into product manufacturing lines

- It is an economic additive technology as against many hybrid analog technologies which employ substractive chemistry techniques resulting in waste

Unique InkJet Value Propositions
These characteristics will allow InkJet to offer the following unique value propositions to the electronics industry:

- **Generation of Ultra Low Cost Ubiquitous Consumer Electronics** through an evolution away from the unnecessarily highly functional and, in the end, threshold cost-limited IC Chip by a mass produced processing technology not requiring a manufacturing process nearly as sophisticated or complex as the IC

- **Flexible Electronic Components & Substrates**. This is today considered one of the biggest limitations of electronic circuitry in that it is very hard to generate flexible circuits (implying flexible components on them). Printed electronics are by definition flexible. The applications of flexible circuitry have already been well thought out and discovered by a process of default in a world of inflexible circuitry. Roll-out screens are an example as are wearable electronics

- **Large Area Electronics**. Printed electronics allow components to be repeat generated en masse across a substrate of any width. This is prohibitively costly for standard IC-based electronics manufacturing. This is a basic enabler for display markets, intelligent substrates and for example large area sensors.

- **Rationalization of Multi-$B Manufacturing Processes.** The ability to print electronics offers the potential to put electronics manufacture in-line or close-to-line with the manufacture of products on which or with which the electronics are designed to function. This would greatly reduce the cost of manufacture by turning two processes almost into a single process.

- **Scalable Manufacturing & Response to Demand.** Scalability and on-demand response are not just issues of reducing manufacturing costs. They are in fact enablers of markets of new users who will require high customization on a low scale at perhaps very short notice and of course at profitable pricing levels in return for the huge convenience such an offering provides.

Application Examples

The field of electronics as a potential for InkJet is rich and a number of distinct sectors deserve separate mention:

RFID & Mobile Antennas
The market for antennas necessary for all types of mobile devices will receive a sharp boost from the expanding and large RFID sector. In particular as RFID tags (quickly) get cheaper the costs of the antenna will become more of a factor. In addition, the RFID market has a large and specialized need for flexible antenna design and prototyping, which is perfectly suited to the capabilities of InkJet.

Laminar EAS
Electronic Article Surveillance (anti-theft retail tags on products) is a mature market and is morphing into RFID. However the market gave an early boost to simple component printing and may become a substitution opportunity for digital printing in place of hybrid analog deposition technologies

Chipless Printed RFID
If success were achieved in generating complex semiconductive components allowing 126 bit+ memory to be printed then the whole logistics sector of RFID (easily the largest part at a potential for trillions of tags) would go printed. This is a realistic prospect for a commercial beginning within the next 5 years.

Simple Printed Components
Resistors, capacitors and similar simple ‘unintelligent’ electric components are printed today in bulk using for example screen printing in the generation Roll-To-Roll of battery testers. This is a step towards full circuit/component generation using printing

Semiconductive TFTC/FET
This is the holy grail of printed electronics. There is coming available a new generation of organic semiconductive chemistries, which offer what is clearly a real prospect of being able to generate layer-on-layer (hence the term ‘laminar’) Thin Film Transistor Circuits using Field Effect (Laminar) Transistors. With this capability the new electronics becomes the truly major new market the electronics industry sees as being the large scale future for their industry.

Laminar Lighting
Electroluminescent chemistry and Organic Light Emitting Diode chemistry are becoming available which directly emit light. These chemistries suggest the potential one day for lighting in general to become laminar. There are already commercial signage products in proof of the technology.

Games/Novelty
There is potential for the games and novelties market to offer ubiquitous simple mass printed circuit based gaming and novelty products with simple components. Such products have already been seen in the format of gift cards and may be extendable to ideas such as folding carton-based loudspeakers.

Laminar Batteries
The idea of creating batteries from printed layers of chemistry has already been realized and there are about 10 startup vendors worldwide developing an early market. The idea of a small flexible form factor is interesting for today's electronics and is a core enabler for the future world of flexible consumer electronics.

Active FPD Backplanes
Flat Panel Displays of different technologies are all driven by backplanes of mostly transistorized circuitry. These are mostly generated today with standard electronics industry technology involving complex & mechanically very exacting systems. The FPD industry has vested economic industry in developing any realistic potential for simplified manufacturing of backplanes. Hybrid InkJet systems are in use today to part-generate such products at least as an auxiliary manufacturing method. If the potential described below for direct printing of FPD elements themselves is realized half its value will be lost if the backplanes for such systems cannot be similarly manufactured.

Direct FPD Chemistry incl. OLED
The ability to directly deposit chemistry into the front plane or image elements of FPDs, whether color filter chemistry for LCDs or OLED chemistry for direct emissive displays, will be critical for economics if it is possible at a scaled-up level by means of printing. Digital InkJet printing as a non-contact printing technique is in this case the only possible alternative due to the 3D nature of the substrate, which would exclude any other true analog printing technology. The potential is massive as even today the suppliers strategically focus to replace all projective TV with FPD.

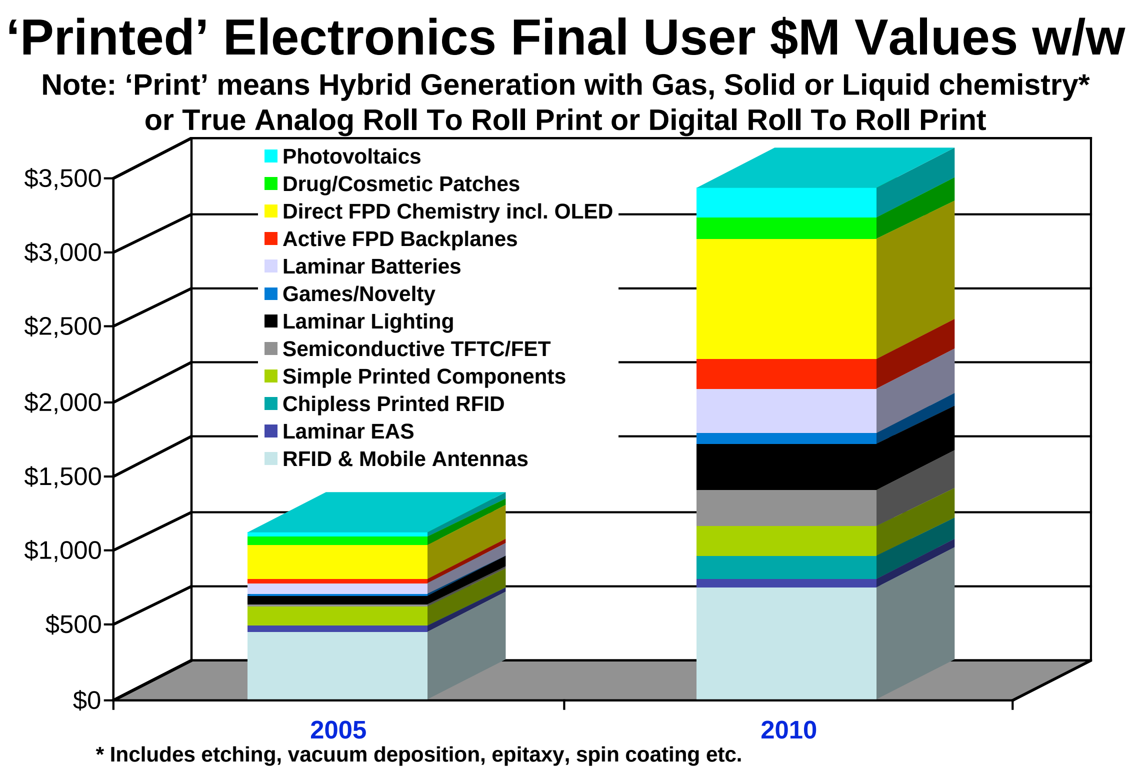
Drug/Cosmetic Patches
There is considered to be potential in using an electric current to cause a type of electrolysis on the skin causing it to absorb either cosmetic dyes or else controlled doses of drugs contained in shaped patches. It is uncertain how powerful the drivers are for this

development, but if it happens it will require precisely metered chemistry laid down onto simple circuitry.

Photovoltaics
The market for photovoltaics or solar cell technology has not ever become as large as its potential would suggest. This is partly related to the heavy and inflexible form factor of photovoltaics as well as to their high cost which is related to the combined cost of the manufacturing technique and the pricing of Silicon raw materials which are subject to commodity pricing fluctuations. It is proposed to use the new generation of organic semiconductive printable chemistry to simplify manufacturing and allow the generation of a flexible product more readily available on demand.

Market Potential

The following chart illustrates the total projected value of ‘printed’ electronics markets taking advantage of new print technology, excluding screen printing of circuits:



The following chart illustrates the approximate projected global customer base for a low-priced Dimatix prototyping industrial InkJet printer sold into the Printed Electronics segment. A simple projection is made assuming one system per year per available location (assumed as 20% of the total) in order to give a rough annual revenue expectation number for Dimatix around two years into the new project:

Sector	Potential Supplier Loc.	Potential Major Users
RFID & Mobile Antennas	120	2,000
Laminar EAS	10	500
Chipless Printed RFID	120	1,000
Simple Printed Components	350	2,500
Semiconductive TFTC/FET	500	4,000
Laminar Lighting	30	2,000
Games/Novelty	50	4,000
Laminar Batteries	25	1,000
Active FPD Backplanes	60	100
Direct FPD Chemistry incl. OLED	100	25
Drug/Cosmetic Patches	10	200
Photovoltaics	50	2,000
TOTAL	2,125	19,325
Say 20% Available =	425	3,865

Life Sciences

Definition

In a general sense Life Sciences in this context refers to the use of InkJet for very precise metering and placement of biochemistry for the purposes of chemical assays of various kinds and for the purposes of microstructural surgical engineering.

Value Proposition for InkJet

The uniqueness of InkJet within the Life Sciences relates to the following issues

- The ability of InkJet to deposit very small and precisely metered quantities
- The ability of InkJet to have a minimal effect on the sensitive chemistries used
- The ability of InkJet to deposit on to a 3D surface
- The ability of InkJet repeatedly to perform the above functions at a relatively low cost compared to existing methods of biochemical fluid handling

Application Examples

Tissue Microstructure Generation
Where, for example, there is an attempt to generate the growth of nerve fibers using chemistry which can promote such growth InkJet systems may be used to create physical structures, which both provide a physical pathway as well as contain the necessary growth-promoting chemistry to allow the process to take place. It is InkJet's ability to allow the relatively simple generation of these very small structures and place chemistry exactly where it is needed, and only there, which offers unique capability. The same principles have been applied to the generation of 3D body parts using InkJet technology.

Bio-Chemistry Assays
InkJet has also allowed the welcome miniaturization and on-demand repeatability in generating reagent trace strips on which biochemical agents may be bound, identified and quantified. Previously this has been an unnecessarily expensive, slow and complex process. Hundreds of thousands of such assays are effected daily. Assays are used for example to identify and track pathogens and antibodies as part of disease diagnosis and control and prevention (for example in the food service industries)

Proteomics
This is in principle a process which employs the advantages of InkJet described above in the processes of BioChemical assay but in the principal cause of being able in the field of pure research to study the structural and functional aspects of proteins down to the molecular level.

Drug Delivery
Another aspect of the use of InkJet is its application to drug delivery systems. For example, blood vessel stents can be coated through the means of InkJet with slow-release drugs. Capsules and pills for oral drug delivery may also be very finely controlled in their chemical content through the use of microdosing as applied on-demand through the means of InkJet. Again the advantage of Drop-On-Demand Inkjet in these processes is its ability to relatively simply and cheaply meter microquantities of chemistry on demand and on, around & in 3D substrates and objects.

Molecular Synthesis
InkkJet Microdeposition in the Life Sciences also permits a much simpler approach to the critical issue within the R&D community of experimental synthesis of DNA strauctures, Proteins, Enzymes etc.. This can also involve the use of deposition ontp pre-deposited microstructures. The significance of these capabilities extend from diagnostics to drug development and genetics.

Market Potential

The following chart illustrates the approximate projected global customer base for a low-priced Dimatix prototyping industrial InkJet printer sold into the Life Sciences segment. A simple projection is made assuming one system per year per available location (assumed as 20% of the total) in order to give a rough annual revenue expectation number for Dimatix around two years into the new project:

Sector	Potential Supplier Loc.
Hospitals	**10,000**
Private Research Est.	**1,000**
Higher Universities	**4,000**
Other	**2,000**
TOTAL	**17,000**
Say 20% Available =	**3,400**

Microstructures Generation

Definition

There is a growing interest in the use of InkJet for generation of 3D microstructures within Micro Electrical Mechanical Systems (MEMS). In a sense the use of inkJet to print conductive or semiconductive components within electronic systems as explained above under 'Printed Electronics' is a form of microstructure generation in that 3D structures are generated. But examples of InkJet microstructure generation where the 3D characteristic of the generated artifact is its predominant characteristic may include but are not limited to:

Value Proposition for InkJet

The uniqueness of InkJet as used for microstructures generation may be said to relate to almost the same issues as are relevant for the Life Sciences:

- The ability of InkJet to deposit very small and precisely metered quantities
- The ability of InkJet to have a minimal effect on the sensitive chemistries used
- The ability of InkJet to deposit on to a 3D surface
- The ability of InkJet repeatedly to perform the above functions at a relatively low cost compared to existing methods of manufacture

Application Examples

Microlenses
Extremely small microlenses may be generated on-demand with InkJet for use as indicator elements or switching elements in optronic systems. Optically pure or optimized materials are utilized in liquid form which dry or gel on deposition onto the substrate.

Waveguides
Waveguides are similar in function and type to microlenses except that they are optical tubes guiding the passage of optical signals over distance. As with microlenses, waveguides are an essential element of the growing field of optronics (Optical systems functioning to carry digital signals – an optical version of electronics) and benefit greatly by being able to be relatively simply and cheaply generated on demand by InkJet.

Market Potential

The following chart illustrates the approximate projected global customer base for a low-priced Dimatix prototyping industrial InkJet printer sold into the Microstructures Generation segment. A simple projection is made assuming one system per year per available location (assumed as 20% of the total) in order to give a rough annual revenue expectation number for Dimatix around two years into the new project:

Sector	Potential Supplier Loc.
Optoelectronic vendors	500
Private Research Est.	1,000
Higher Universities	4,000
Other	250
TOTAL	5,750
Say 20% Available =	1,150

Summarized Dimatix Revenue Opportunity

According to the rough estimates presented above for the available systems market (estimated at 20% of available sites, or over 8,000, some of which may well attract multiple sales) for the Dimatix type of product it is reasonable in our view to foresee an annual market within 2-3 years of launch as consisting of at least 4,000 systems units per year.

It should be understood that Dimatix products would come to represent a family of small-scale, sometimes lightly customized products, all of which attract follow-on revenue in heads, maintenance and chemistry.