

**THE NON IMPACT PRINTING (NIP) AND DIGITAL
FABRICATION CONFERENCES**

Alaska, September 2007

The aim of this report is to give readers a snapshot of these 2 conferences. I hope that it will be of interest to people who were not able to join us in Alaska for the 2007 conferences but who are interested in hearing what goes on in this community.

This meeting is ideal for those who are interested in both conventional printing and printed electronics as the 2 conferences are held on the same site. As your registration covers both conferences you can move between tracks, covering the aspects that interest you the most. This report was written in the form of a diary and originally intended as a blog so you will see how I covered the conferences.

Given the scale of the meeting, with up to 4 concurrent conference tracks, an exhibition and tutorial sessions the aim is to give a personal perspective and not a comprehensive summary. Unfortunately I cannot be in more than one place at any one time!

For those interested in joining us in Pittsburgh in 2008 more details can be found under <http://www.imaging.org/conferences/nip24/> and <http://www.imaging.org/conferences/df2008/>. I will be there again this year and I hope you can join me.

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1 SUNDAY 16TH SEPTEMBER – TUTORIAL DAY

One of the key strengths of these conferences for me is the breadth and depth of the tutorials. I now take part in these sessions both as a presenter and a monitor.

Presenting tutorials is a really interesting experience. While there is a lot of work to be done in the preparation the rewards more than make up for this for me. Quite often I find that someone in the audience has some pearl of wisdom to share on a particular issue that adds to my knowledge and gets added to the tutorial for next time.

The offerings change year on year too. New topics appear as technologies change but some of the more popular topics appear year on year. At the end of each tutorial attendees fill in a feedback form and the results are collated by the IS&T. The presenters then receive feedback on what the audience thought of the tutorial shortly after the end of the conference. You will find more details of the 2007 tutorials under <http://www.imaging.org/conferences/nip23/tutorials.cfm>.

So 7:15 am on Sunday morning found me setting up my tutorial on Industrial Inkjet. And I was not on my own either – there were 4 other tutorials running at the same time on electrophotography, toners, paper technology and the future of ink jet. Plenty to choose from and a great introduction to a topic.

I had cast the tutorial to appeal to a broad spectrum of interests, from “traditional” inkjet applications to Digital Fabrication the audience came from a variety of backgrounds. This is perhaps a good reflection of the attendance at these conferences, including students, applications engineers, researchers, technologists and academics. We had an interesting morning covering the various aspects of inkjet technology for conventional printing and Fabrication applications.

The afternoon continued at the same pace. I had volunteered to help monitor a tutorial, this time on Image Science. Again there was a wide choice on offer, from desktop inkjet, toner fusing, digital fabrication, colorant chemistry and toner additives. Image science was fun and I learnt a lot but I was definitely ready for the networking event over a beer or two that evening.

2 MONDAY 17TH SEPTEMBER – THE FIRST DAY OF NIP

An early start today with the Speaker's Breakfast at 7am. I get to go to this as I am a Session Chair today – see below. Giving a paper at these conferences is not only a good way to showcase your work but also raises your personal profile in this community. It also gets you into these most select gatherings where the discussions go on over coffee and buns.

Then off up the road for the plenary session. Anthony Federico of Xerox took us through some of the issues that digital printing technologies can address and some of the points he raised are of particular interest to our community. In particular he noted the market for packaging continuing to rise with GDP and the rapidly expanding slice taken by digital printing. Given the similar expansion in counterfeit products, particularly in the pharmaceutical sector this is a market of interest both for security printing and printed electronics solutions. Both topics are subjects for conference sessions later in the week so I look forward to these.

This signalled the start of the 3 tracks of the NIP conference. You can get some idea of scale of the meeting by looking at the agenda under <http://www.imaging.org/conferences/nip23/program.cfm>. I chose Ink Jet Printing Materials for the time up to morning coffee. One aspect that stuck me was although this was a part of the NIP conference it was just as applicable to the Digital Fabrication audience too. Good move putting this on before the start of DF! The first 2 papers covered issues of fluid / paper interaction. This is not only an issue for “conventional” inkjet printing but needs to be understood if we are to take advantage of the low cost and wide acceptance of paper for Printed Electronics. As this is a particular interest of mine I found these really useful.

The third paper looked at the issue of fluid / head interactions in a thermal inkjet head. Again this is of interest to both communities and I believe that both thermal and piezo inkjet technology will have a place in both conventional and fabrication inkjet into the future. These 3 papers also provided some useful updates for my Industrial Inkjet tutorial (see yesterday's blog).

I then swapped tracks as I was honoured to be asked to co-chair the Colour Science and Image Processing session, which as usual was wide ranging. There was some good fundamental colour science and updates on colour profiling and proofing. There is currently a lot of interest on extended range monitors and printers so it was good to have an update on this too. A number of papers devoted to document scanning would have played well at an Archiving conference! There was something here for everyone.

Nobuhito Matsushiro explained to us the background to the von Kries model of chromatic adaptation, which is now around 100 years old. However, some important issues are still to be clarified and these were discussed in this paper. Theoretical models were shown that improve the approaches to the construction of these chromatic adaptation models.

Paul Fleming III made two presentations. The first one summarised research aimed to provide consistent colour display across Windows and MacOS platforms, using the same computer hardware and LCD monitor. The results

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showed the complexity of the factors that affect monitor profiles and the issues that still remain to be addressed.

Paul's second presentation was the first of four interactive previews. This poster described some work to derive digital printed proofs for an offset press using multiple substrates.

Masao Inui described some work to evaluate wide gamut monitors and printers. Test images expanded with nonlinear functions were found to give the best subjective quality but in some cases the high chroma images were not well received by observers.

KiMin Kang presented an interesting technique to correct the images produced when thick bound books are imaged on a flatbed scanner. The problem is that the areas near the book spine are in shadow. The paper proposed a method to model this shadowing to correct the scan, something that may be of interest to our Archiving community.

Continuing this theme Shaun Love presented some work on a context based filtering technique to enhance scanned documents. This technique separates text, background and image regions in a scan in order to process these independently.

Ping Lu gave an interesting presentation on processing images of hands. This has potential application in personal authentication systems but for this application it is important to deal with shadows in the images in order to clearly define the hand shape.

Yue Qiao presented a new technique for high speed colour conversion for JPEG compressed images, using the transform rather than the spatial domain. Conversions from colour to grey scale and CIELAB to CMYK were presented.

Byong Tae Ryu showed a method to reduce the transmission time of information from computer to printer, using look up tables within the printer. These look up tables enhance both the spatial and bit depth resolution. Different methods to produce the training images were presented.

Kenneth Crouse presented some work on the suppression of automoiré in multilevel supercell halftone screen design. Automoiré can produce objectionable artefacts in print. While there are other techniques to do this the method described appears to have some advantages, reducing the lower spatial frequency components.

Kazuhisa Yanaka presented a novel technique using a sheet of hexagonal lenses to reconstruct a printed image in 3 dimensions for Integral Photography, a stereoscopic viewing system. The lens reconstructs a series of images taken radially to reproduce the 3 dimensional image. Printing is done using a standard desktop printer. The reconstructed images were most impressive and produced a lot of interest.

Finally the 3 tracks all got together for a good natured but somewhat partisan discussion on the future of inkjet and electrophotography. We only had 1 hour so I wasn't expecting any conclusions but I think a fair summary is that both technologies will survive and there are enough opportunities for us all.

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Finally, off to the IS&T VIP Reception. A beautiful evening spent in the roof function room of the conference hotel and more discussions on the future of the technologies. A long day but a great start to the conference.

3 TUESDAY 18TH SEPTEMBER - THE FIRST DAY OF DIGITAL FABRICATION

Tuesday saw the start of the IS&T's Digital Fabrication conference. You can get some idea of scale of the meeting by looking at the agenda under <http://www.imaging.org/conferences/df2007/program.cfm>. As it is co-located with the Non Impact Printing conference delegates now have 4 conference tracks to choose from. However, I chose to spend the entire day in Digital Fabrication as today's topic was Printed Electronics and Devices.

The day started with a plenary session given by John Rogers of the University of Illinois. His topic was the use of a technique known as electrohydrodynamic printing to build flexible electronics. This is an interesting alternative to the "normal" piezo and thermal drop on demand inkjet systems and has the interesting attribute that it is capable of a sort of "burst" mode where it acts more like continuous inkjet. The resolution looks good too but I am not sure how you would make a practical multi-nozzle system.

We then got into the Printed Electronics session proper. This took up a full day with 16 technical papers on a wide variety of topics in this application area. There were a good variety of authors too, from academics, students, large and small corporations. A strong showing by the Eastern nations perhaps indicates where a lot of the action is but it was good to see us Europeans well represented too!

The concept of digital printing taking some market share from conventional presses was echoed in this session with digital techniques providing the route to personalised electronics. There was some emphasis placed on the fact that inkjet is an additive process and thus is perceived to have environmental and materials (cost) benefits.

So what was new this year? There were some simple demonstration circuits such as ring oscillators being fabricated as proof of principal. Optical feedback techniques are being used to help interlayer and front to back registration. And there was a lot of confidence that Printed Electronics was really happening by non-impact printing.

Various ways of sintering metallic inks were discussed. One was the use of laser sintering of the conductive inks which delivers heat where required and thus reduces the total heat load on the other components and the substrate. Another was the use of microwave heating. These methods certainly hold promise for the future but the issues do not seem to be resolved yet.

As you would perhaps expect from a conference co-located with NIP there was a lot of inkjet in this session. One feature of inkjet is that it prints thin layers. However, when thicker layers are needed, such as those needed for significant conductivity in photovoltaics this means multiple passes to secure lower resistance. In addition to the issues this raises of vertical layer registration one paper noted differentiation of the layers, presumably due to drying in between passes. Hybrid printing techniques were another feature of this session and it does look to be the way forward. Electrostatics and screen printing have a lot to offer too.

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It is easy to dismiss thin layers as simply a result of the relatively small drops that inkjet currently produces. However, there is rather more to this to do with the dynamics of ink/media interaction so there are still tricks we can play. However, if you want really big drops a paper on inkjet by ultrasonic drop production may have the answer!

So where are we going next? Printed sensors looks to be a big one for the future and these will incorporate printed electronics. There was a paper on textile sensors at this meeting, continuing on from work I saw presented at a conference in the UK. This and another paper featured electrodeless plating, a technique to increase the conductivity of metal tracks from a plating solution.

Issues? Yes, it isn't going to be plain sailing. We are going to have to do some more work on some elements of the system. As we move into more exotic fluids, such as those containing nanowires the issue of fluid management will need to be solved as some of the components will just fall out of suspension if you let them. And we need to do more on substrates for these applications.

Key points? Inkjet is not going to be the only technology. In inkjet, it isn't all piezo technology. There are some interesting opportunities arising for substrates.

As if all that wasn't enough, the day finished with an interactive discussion on Intellectual Property. As I do some work as an Expert Witness I was looking forward to this. On the positive side, we had a couple of very interesting presentations of fostering innovation and the interpretation of the term "originality". However, considering that this was an international conference the rest of it was rather disappointing with a pronounced US law, big company litigation bias. Rather missed the mark for me.

Tuesday was also the first day of the conference exhibition, but I will cover that one below.

4 WEDNESDAY 19TH SEPTEMBER – NIP AND DIGITAL FABRICATION!

This was another day with 4 concurrent tracks to the 2 conferences. As a result I did a lot of moving about between rooms to catch the tastiest bits of both meetings. This is a great feature of running these meetings in parallel as your delegate registration covers both meetings. Rather like the session on Monday (see earlier blog) it illustrates just how much there is in common between these two meetings, particularly in the field of printed electronics.

The start of another busy day with another Speaker's Breakfast at 7am. This time I am a Session Chair for the Security and Forensic Printing session – see below. Although this session currently resides in the Non Impact Printing conference I can see us having a substantial Printed Electronics component in the future as this technology will be a great addition to the security printing ecosystem. Although the primary function of the Speaker's Breakfast is to arrange the sessions for the day it is also a great place to exchange information on the topics for the day as you get to spend quality time with the prime movers on these subjects.

I started the day in the Digital Fabrication conference at a session devoted to Industrial and Commercial applications. This was a great opportunity to take a look at some real applications happening now. This session contained 4 sessions featuring some very different technologies but interestingly all using inkjet.

The first paper examined alignment issues for multilayer fabrication by inkjet. Both single sided and double sided coating of a substrate was covered together with a machine vision system to monitor registration. The author was achieving ± 5 microns placement accuracy between layers on the same side of the substrate with a few extra microns tolerance between the two sides. Not bad!

The second paper described a rather novel fabrication technique for silicon solar cells. Although this was a photovoltaic application I imagine that this method could find application elsewhere in printed electronics. They used inkjet printing technology to jet a plasticiser onto a resist layer. This makes these areas of the resist permeable to an etching solution allowing the formation of openings to the underlying layer for metal contacts. This method also has the intriguing possibility that these steps can be repeated, generating multiple contact patterns.

The third paper was a good example of a manufacturing solution where device fabrication incorporated into a packaging line is an interesting option. A sensor has been designed that is inkjet printed and exhibits a colour change depending on the environment. Although this sensor is designed to be used as is for applications such as food packaging it could be envisaged that this could become an enabling technology for a printed electronics sensor in conjunction with OLED elements for electronic systems.

The final paper described roll to roll inkjet printing of a cholesteric liquid crystal display. The system is currently capable of fabricating a colour display of a size suitable for a mobile application.

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While my afternoon was devoted to the Security and Forensic Printing session I managed to sneak out to see two rather interesting papers in the Media for Digital Printing session.

The first dealt with surface modification of a substrate designed to receive toner. The interesting part to this paper is that methods to modify the surface structure of the substrate were described. This is an unusual system in that it uses a multilayer substrate more commonly associated with inkjet products, which is a technology that I believe is essential for some future advanced fabrication applications.

The second paper continued this theme but this time describing a multi-layer inkjet product. In this case it described the optical properties of the product – a technology that is good to have in the toolbox for some high end printed display applications.

The Security and Forensic Printing session took up a full afternoon with six papers. First on was Steven Simske, one of the other co-chairs of this session. He cast product security not as a technology but as an ecosystem which was an interesting concept. It could equally well be described as a journey where each individual technology introduced is but a stopping point. As the counterfeiters catch up it is time to move on to another technology. As usual, Steven had some impressive solutions for security printing to show.

Sunjoo Suh and colleagues have a method for printing information with 600dpi dots that is compelling on the digital paper space.

Detlef Schulze-Hagenest overviewed a differential gloss (analogue) watermarking technique that uses clear toner – a nice check for inspectors / retailers.

Fariza Hasan described the use of UV absorbing materials for security thermal printing applications. As a result the image content is not revealed on scanning or copying. In addition complementary colourless compounds that colour on heating were described. Fariza also described the production of disappearing images and 'delayed appearance' images that can remain invisible from 2 days to months. The latter can be useful for preventing unnoticed expiration of a product.

Pei-Ju Chaing described an EP process to embed extrinsic signatures into the halftoning of documents by modulating the intensity of the writing laser with the capability of embedding 5 bits per half inch. The work described aims to place the modulation below the human visual perception threshold and included a section on model valuation. An interesting application of stenography on real hardware!

Jason Aronoff presented some work on the use of conductive inks in variable data printing processes. Conductive inks raise the possibility of reading the data in several different ways – multi-modality reading. In addition the use of metallics also enhances the aesthetics of the print. One case study presented illustrated the difficulty of modifying screen print inks for thermal inkjet. The paper also showed some early work on conductive inks on fibrous and non-porous surfaces.

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This was also the second day of the exhibition. A wide variety of companies exhibited this year and I found it useful to get a snapshot of the technologies on offer. The exhibition hall certainly seemed busy whenever I called in. The exhibitors seemed well satisfied with the interest being generated and given the quality of the audience attracted by these conferences I feel sure it will have been a worthwhile visit for them. You can find a list of the exhibitors under <http://www.imaging.org/conferences/df2007/exhibitors.cfm>.

At the end of a long day we had the conference reception, held at the Anchorage Museum of History and Art. A stunning venue holding some fascinating pictures provided the backdrop for one of the best networking events of the conference.

THURSDAY 30TH SEPTEMBER

The 5th day of this meeting in Anchorage. The theme of this day for me was future technologies and applications, with a lot of relevance to Printed Electronics.

The day started with a short IS&T Honors and Awards presentation. This provided me with the first learning point of the day – the importance of Imaging Science in Printed Electronics and particularly in displays. I will give a further example of this later.

The IS&T Fellowship award is given to members for outstanding achievement in imaging science or engineering. One of the recipients in 2007 was Prof. Ralph Jacobson, then President of the Royal Photographic Society. Unfortunately Ralph could not attend the meeting in person to collect the award and I was honoured that he had asked me to represent him at this ceremony. Well done Ralph!

The presentations were followed by a plenary session entitled “Engineering Challenges in Biofabrication”. This covered an inkjet application aiming to fabricate biological structures. As such the “bioinks” need to be water based so as to assemble materials in layers without killing living cells in the bioink or the layers below. There is also a need for absorbable materials for the scaffold.

There was some discussion of the relative attributes of thermal and piezo print heads. The author expressed some preference for thermal units which work well for biological compounds of high molecular weight ($>10^5$) and have cost and flexibility benefits for nozzle sizes >50 microns. This community seems to take consumer desktop inkjet cartridges and adapt them for this purpose. Despite some pointed questioning from members of the audience with a commercial interest in piezo heads for this application he stuck to his preference.

This is an excellent example where non-impact printing is ideal as it reduces the possibility of interlayer contamination and eases the problems of sterility. It was shown that after printing the cells seem to act in a normal fashion. It is believed that the shear stress is too short ($\sim 10\mu\text{s}$) for the cells to get stressed.

So where are the applications? It looks like early applications will be in drug screening and cosmetic testing with organ building to come in the future. Is this important for Printed Electronics? Not yet, but watch for the future. As we get more into printing sensor systems biological membranes will become a key component in some assemblies.

One interesting aspect to this application was the very high value treated paper substrate used in this application. There are obviously options for high value added substrates (glass, plastic, paper) in this market.

It was then time for the conference sessions. Today I shared my time between the Image Permanence and Printing Systems Engineering and Optimisation sessions in the Non Impact Printing (NIP) conference and the New and Novel

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Direct Write Methods session at Digital Fabrication. This involved a lot of moving back and forth which worked well as the session chairs kept their papers pretty much to time.

As always the Image Permanence was an interesting session and this year I was able to relax and drink in the papers from the audience having been a session chair this time last year. Although this session has no direct relevance to Printed Electronics at this time the models being developed are going to be applicable to applications prone to environmental degradation processes, particularly printed displays. There is an International Standards group working on these models and as Principal UK Expert on this I am interested in following this up.

In the Printing Systems Engineering and Optimisation session a paper from Chemnitz University of Technology examined to move of industrial printing from conventional colour printing into Printed Electronics. The work points out that although the capabilities of these printed devices will be well below that currently available from silicon based fabrication technologies the types of presses in use are capable of 4 orders of magnitude greater productivity with a commensurate decrease in cost per unit. The authors believe that from conventional printing technologies flexo, offset and gravure are suitable for printed electronics and will be joined by inkjet and toner based digital systems. Gravure printing systems have the advantage of a simple inking system that will probably ease adaptation to the new fluids required. However, the high set up time may limit application to long print runs or high quality applications. By way of contrast setting up an offset press is comparatively easy but the fluid formulation is likely to be more difficult.

This session also contained a very interesting paper from Hewlett Packard on heat transfer issues in an inkjet print head. While our first thoughts may be that this is only an issue with thermal inkjet the point was made that external heating sources such as UV curing units and driers may be equally important. Temperature changes can influence the rheology of inks and even prompt the nucleation of bubbles that can block the ink channels. With increasing levels of miniaturisation and nozzle densities this is set to become a more important topic and HP deserve credit for the level of work they have evidently done on this.

Although these 2 papers were in the NIP conference they would be equally at home in both conferences. Once again it shows the close fit between the Non Impact Printing and Digital Fabrication conferences.

I spent most of the afternoon in the New and Novel Direct Write Methods strand of the Digital Fabrication conference. We were treated to a broad spectrum of methods and applications. This served to further underline the fact that piezo actuated inkjet is not the only game in town!

A presenter from Waseda University showed an electrostatic inkjet system for printing electronic conductors. Although this is a single nozzle system it is capable of jetting highly viscous liquids that are effectively pastes so can cope with very high metal loading inks yet still produce fine lines. Still early days for this technology but one to watch for those difficult to print "fluids".

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A presenter from Atotech showed an interesting method of applying a resin coat to a metal foil. This is an element of the production process of multilayer PCBs for devices such as mobile phones. Typically these layers are solvent coated and require long oven lines to remove the solvent. The aim of this work was to investigate the use of electrostatic technology to powder coat the resin layer, thus avoiding the use of solvents. Again, the work appears to be in early stages of development but it will be interesting to see if this printing technique can be modified to produce a patterned coating, just as in conventional electrostatic printing.

Another presentation from the Chemnitz University of Technology dealt with the construction of micro membranes patterned using inkjet technology. Rather than use inkjet to build the membrane material the fluid drops are used to repel the membrane construction to provide the location and size of the pores. In addition to biological applications this technology could well find application in the fabrication of printed electronic sensor elements.

Finally, a presentation from Hitachi explored the use of electrophotography for printing conductive features of around 10 μ width. Although once again at the experimental stage this paper shows the potential of electrophotography as a digital fabrication technique that could well be more productive than inkjet in some applications.

The conference day finished with the interactive poster session. Here delegates display a poster describing their work and then stand by the side of it to discuss it with passers by. This is a really good forum, particularly for work in progress.

I have already described a lot of this work as it was previewed within the conference sessions. However, 2 papers stood out, both on topics of great interest to me. The first was on coating papers for use as substrates for printed electronics where the authors were using technology originally developed in the photo industry. I presented a paper at the Digital Fabrication conference in 2006 on this topic so it was good to see the theme continuing. The work showed that polyethylene coated paper was as good a substrate for PEDOT printing as polyester base.

The second paper was previewed in the Print and Image Quality section of the Non Impact Printing (NIP) conference and covered the optical properties of printed images, in particular attributed related to sharpness. As such one would not expect this to be of particular relevance to printed electronics. However, a closer look at the technical content of this paper revealed the potential relevance to the investigation of image quality in printed displays. I have to admit this was easier for me to spot as I did a paper on a similar topic at the NIP conference in 2006!

Overall, an interesting and full day. It was very apparent that there are a number of technologies under development that will be of use in Printed Electronics in the future. Watch this space!

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