

PRINTED ELECTRONICS USA

The aim of this article is to give readers a snapshot of this meeting . I hope that it will be of interest to people who were not been able to join us in San Francisco but who are interested in hearing what goes on in this community.

Given the scale of the meeting, with up to 3 concurrent conference tracks, an exhibition and masterclass sessions the aim is to give a personal perspective and not a comprehensive summary. Unfortunately I couldn't be in more than one place at any one time so there were hard choices to be made!

San Francisco looks to be a great venue for this meeting. In addition to having a large local community with relevant interests the climate this time of year is great. It was a real joy to leave the driving rain of Manchester (England), the high winds of Amsterdam and arrive to the clear blue skies and relative warmth of San Francisco.

1 MONDAY 12TH NOVEMBER – MASTERCLASSES

Having masterclasses on the day before a conference is a great idea. For those who are new to the field it gives a great way to come up to speed with the technology and the terminology before the conference sessions begin. For the specialists in a particular area it is good to be able to see the whole picture, presented as one coherent snapshot. It is also the first of a number of great networking events which commenced right at the start of the first session – see below.

1.1 Masterclass 1 – Introduction to Printed Electronics

This session was opened by Peter Harrop, chairman of IDTechEx. He began by getting everyone in the audience to introduce themselves which in my mind has a number of benefits. First, it gave the presenters a chance to hear right at the outset what the audience was looking for in the session. Secondly, it gave everyone a chance to put some names to faces – there were some people in the audience I wished to talk to following email conversations from my previous articles from the Alaska Digital Fabrication conference.

This session was a great introduction to the meeting as it covered the full panoply of the topic areas of the conference. The point was made right at the start that this is a huge area covering the printing of electric as well as electronic systems. As such it could well become bigger than the current silicon electronics business. No wonder this area is attracting a lot of attention!

Peter continued by giving an overview of printed electronics, particularly in comparison to silicon based electronics. Feature sizes of printed electronics are much larger than current silicon fabrication technologies achieve. However, one aspect of this that I had not realised is the advantages large features have on fault tolerance, a particular issue for aerospace and defence applications. Peter also emphasised the rise of the “new inorganics” – the world of printed electronics does not look to be set for domination by organic chemicals.

He also covered substrates which are of great interest to me and the great potential that flexible substrates offer this market. The key messages of this session? We are on the cusp of real applications and no one printing technology will do it all.

After a break Raghu Das, CEO of IDTechEx took over. His emphasis was more on the technologies rather than the applications so was a good complement to what went before. He emphasised the importance of screen printing technology as a printing application currently in use and the ways in which additive printing technologies will decrease lead times for design changes. However, the likes of Intel really have nothing to worry about (yet) as the technologies and applications look set to be complementary, rather than in competition to the output of fabrication plants.

Finally this masterclass concluded with a presentation from Gary Johnson, president and CEO of Thin Battery Technology. They have a printable system that aims to integrate with printed electronic devices based on carbon - zinc technology.

1.2 Masterclass 2 – Displays & Lighting

This took place in the afternoon and there was a choice of offerings.

For those interested in mating up investment with opportunity there was an Investment Summit planned for the afternoon – see <http://printedelectronics.idtechex.com/printedelectronicsusa07/en/vcforum.asp> for details. However, as I have neither money to invest nor technology to sell I went for the second offering, a masterclass on Displays and Lighting.

I found this class to be an interesting choice. It consisted of 6 presentations on the display and lighting theme.

The first was again from Peter Harrop and served as an introduction to the applications and technologies. What was apparent was the fact that there is still life in AC electroluminescence technologies and I look forward to seeing some of the conference papers on this. There was however a lot of (justifiable) focus on OLED technologies here. I had a particular interest in technologies using paper substrates as I am due to give a presentation on this later in the week.

The second was given by Ian Underwood of MicroEmissive Displays. He described their very small displays used for video glasses and electronic viewfinders. It is based on silicon chip technology but at this size there is no need for flexibility. They used a filtered white OLED system, sacrificing efficiency for better colour stability with device ageing. At present the POLED is spin coated but they are looking at inkjet technology as an alternative to this. Finally, I found their approach to digital drive electronics well reasoned as it gets them away from the fixed pattern noise issues in the darker scene areas.

The third was from Steven Ludmerer of Foresight Science and Technology who presented on the challenges and opportunities coming from lighting technologies. This presentation was a really good comparison of competing technologies and particularly of LED, OLED and compact fluorescent systems.

After a break for coffee and networking Devin MacKenzie of Add-Vision continued the class with an overview of flexible OLED displays. He illustrated some of the problems that existing display technologies have with flexibility and moved on to show the opportunities and challenges facing flexible OLEDs.

The 5th session from Lorenza Moro of SRI covered substrate and encapsulation challenges in display and lighting. With my interest in substrate issues this a particularly good one for me. The presentation started by looking at some of this

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issues that flexible substrates will face in some applications as they use components sensitive to air and water. Lorenza gave us a good comparison of substrates and showed some of the benefits of using multilayer films for encapsulation.

Finally, Ghassan Jabbour of Arizona State University continued the theme of encapsulation, particularly an issue where fabrication technologies utilise a reactive cathode. His talk was illustrated with some interesting examples from projects he has been involved with.

2 TUESDAY 13TH NOVEMBER – CONFERENCE DAY 1

After the introduction of the Masterclasses the conference began in earnest. It was a day split into two halves with keynote presentations in the morning and the conference splitting into 2 tracks for the afternoon sessions. Track 1 was applications but I chose to attend Track 2 which was devoted to Thin Film Transistor Circuits and Memory.

This was also the first day of the exhibition.

2.1 Keynote sessions

The session started with a presentation from Peter Harrop, chairman of IDTechEx. Looking over a very full session room he observed that as Printed Electronics doubles in market size each year, so does this conference. My guess is that they will need more space next year. The first point in his slides continued this theme with a forecast of \$300 billion by 2027 for this new post-silicon electronics. Peter also counselled getting away from defining this market by chemistry (organic vs inorganic) as it is what it does that matters. His view is that the first wave of this will not impact the market for silicon electronics but rather replace some printed output.

A presentation from Kivio announced for the first time at this conference their solution for Item Level Intelligence. Trillions of units but need to be below 5c. They have a silicon ink and are demonstrating the world's first all printed silicon transistor. The presentation featured poly-silicon inkjet printed on stainless steel to produce a 10 micron feature size. Kivio believe their technology will enable HF and UHF tags. They aim to commercialise by end 08. This announcement seems to have been featured in the Wall Street Journal today too!

Rather than the publicised presentation from Hasbro we had one from T-ink (short for Thinking ink). They are into paper related products and conventional printing, packaging with Mead Westvaco and have a lot of neat heated textile products.

We then had a presentation from Cubic on their contactless RFID solution for transport ticketing. Like many, I am familiar with their products – they do the Oyster cards for London Transport. This is a memory logic card but there is a need for intelligent products that are read/write. These are now taking volumes from magnetic systems as the costs are now comparable. Transit applications look set to be an early adopter of Printed Electronics.

After a break for networking and looking around the exhibition (see later) there was a presentation from Samsung Electronics on displays. The presenter described the advance of display technologies as consisting of 3 waves;

notebooks, monitors and TVs. The presentation then went on to look at what could constitute the 4th wave. There will be inevitably be a need for higher resolution and speed (and therefore higher TFT current) but at lower cost. Printed displays could do the latter but at the moment will struggle with the former.

A presentation from LG Philips illustrated a world first – a high resolution full colour solution processed OTFT-LCD! It illustrated the development process from glass moving to flexible plastic and was a good illustration of the use of different printing technologies for each layer, taking advantage of their relative attributes. This was a theme also brought out in Masterclass 3 on Printing Technologies.

The final presentation of the morning session came from the National Science Foundation. This was good positioning as it pulled some of the issues together. It summarised some of the market research from IDTechEx and illustrated the growth of scientific papers in Organic Electronics as a metric of activity in the field. NSF see this as a key indicator of market potential. The presenter outlined the background, aims and mission of the NSF and showed that Printed Electronics sits well within their remit. They envisage growth in their funding in future years and are already supporting a number of projects of direct relevance to Printed Electronics.

2.2 Track 2 – Thin Film Transistor Circuits and Memory.

This track started with a presentation from the Palo Alto Research Centre (PARC) who have an interest in displays and imaging sensors. Included in this talk was a large format x-ray imaging device on a flexible substrate. PARC are working on printed systems using inkjet and this sensor was patterned using inkjet on PEN. I had recently seen a reference to this work in Applied Physics Letters. The presentation showed the importance of annealing organic semiconductors to improve mobility. A further important point was also made – that mobility decreases with surface roughness. This is important particularly as we move on to printed electronics on paper substrates, the subject of my own presentation the following day.

This presentation then moved on to discuss degeneration mechanisms for these devices. It was shown that they degenerate in air in the absence of light so photochemical effects are not the primary issue. Perhaps surprisingly storage in pure oxygen did not produce a problem. Keeping away from water vapour was shown to be helpful but the main problems seem to stem from atmospheric pollutants such as ozone (1 to 10 ppm for <30 seconds) and sulphur oxides. These can be kept away from the devices by encapsulation. Given that this is a known issue with the colorants in conventional inkjet printing there is probably some knowledge to be gained from these applications.

A presentation from STMicroelectronics looked at materials for “post silicon” electronics. It concentrated on soft lithographic methods and nano-imprint lithography. The resultant devices were characterised by conventional methods. The presentation gave good examples of synergistic efforts between chemical companies, advanced tool manufacturers and end users.

ORFID Corporation presented next with a description of their vertical transistor architecture. They have designed a vertical organic semiconductor FET

(VOFET) and a light emitting version (VOLED). The layers are laid down onto glass by thermal evaporation and spin coating.

A presentation from HelioVolt described the technique of Reactive Transfer Printing. This is an impact printing method where 2 plates each containing a reactant are pressed together in a printing process. The reaction proceeds to produce the desired material. This technique was demonstrated to print CIGS for photovoltaic applications.

2.3 Track 1 – Applications

After the afternoon coffee and exhibition break I moved into the Applications track. I missed the first presentation as I got into some interesting discussions with other delegates about printing onto paper. This was a good illustration of the strengths of these meetings – it is not just about what you hear in the formal sessions!

A presentation from Motorola started with the valid point that although silicon based semiconductor development is often described by Moore's Law printed electronics can be described as "More than Moore" due to the potential for explosive growth. The presenter then went on to look at printed sensors and the trend towards wholly printed sensors and RFID tags.

We then had a presentation from Elumin8 on their electroluminescent system followed by a final session from Raghu Das of IDTechEx on smart skin patches, the 4th generation of these requiring progressively more electronics.

The day finished with a drinks reception followed by the conference dinner. A great time was had by all with a lot of conversation covering the days events.

3 WEDNESDAY 14TH NOVEMBER – CONFERENCE DAY 2

Day 2 of the conference and we split into 3 tracks covering 5 topics. I chose to spend some of my time in all 3 tracks. My only fixed point was my presentation on the use of paper in printed electronics late morning so I took the opportunity to sample what was on offer.

3.1 Track 1 – Displays and Lighting

This track started with a presentation from Cambridge Display Technology. Their vision is to displace LCD for display by 2020 - there is already a Nokia phone using their technology. However, OLED technology currently has a 2x price premium over LCD. The plus point is much lower power consumption which is particularly important for handheld applications. CDT are working towards flexible substrates but the substrate must also act as a barrier layer too.

CDT illustrated some major advances in blue OLED lifetime, with a T₅₀ of 10,000 hours. While this is not (yet) good enough for domestic TV applications it is deemed to be sufficient for mobile applications. They are evidently making advances with printing techniques too, showing some good pictures of the coffee ring effect in practice. They are exploring optical feedback systems for interlayer registration with Toppan and looking at Vitex Barix barrier systems.

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A presentation from Eastman Kodak featured display backplane technology using zinc oxide. They believe this confers transmission and efficiency advantages. It also means that the fabrication can be done in air.

After a break for some of the other sessions I returned for the presentation by the US Display Consortium (USDC). They are sponsoring a number of projects and I was particularly taken by their work on interlayer registration. They have a project on self-aligned imprint lithography that looks to be particularly interesting.

We then had a presentation by 2 people from Quantum Paper. The company is currently undergoing a name change to Nth Degree. They are initially targeting the retail point-of-purchase, direct marketing, magazine inserts and signage markets moving on to flat panel display and packaging next year. Theirs is a printing technology but there was little said on this – some is electroluminescent but “not all”.

Arizona State University have been doing some very interesting work on Printed Electronics. Included in this is a coated paper from Agfa, wall to wall solar panels and made the first demonstration of inkjet printed quantum dots.

A presentation from VTT described their work on the OLLA project and the use of gravure printing to fabricate continuous films for OLEDs. Gravure printing has the advantage that you can use the same fluid rheology as used for spin coating.

MicroEmissive Displays presented their very small displays used for video glasses and electronic viewfinders. It is based on silicon chip technology but at this size there is no need for flexibility. They used a filtered white OLED system, sacrificing efficiency for better colour stability with device ageing. At present the POLED is spin coated but they are looking at inkjet technology as an alternative to this.

The final presentation in this session was from iSuppli and looked at market drivers for flexible displays. The market was segmented by “flexibility” from slightly bendable to fully rollable. I found this a useful way to consider the issues involved.

3.2 Track 3 – Sensors and Sound

I was interested to view the BioIdent Technologies presentation and was not disappointed – it was a very slick and animated performance featuring their lab-on-a-chip system. Their inkjet based fabrication system is capable of doing 40,000 square metres of material pa and they are currently in pre-production with a number of OEMs.

3.3 Track 2 – Photovoltaics and Batteries

I attended the presentation from Enfucell featuring their Zn/MnO₂ battery technology. This is roll-to-roll printed and uses paper as the separating layer. This would be a good technology for some of the novelty applications discussed at this conference.

3.4 Track 2 – Materials and Substrates

I attended the conference as a presenter too. My contribution at the start of this session was on the role of paper in the future of printed electronics. Paper and cardboard are universally accepted media both in domestic and industrial environments. Unfortunately it is not a particularly easy substrate for printed electronics. The presentation looked at some of the early successes of paper and card and summarised the ways forward. We have to look at paper design criteria and printing techniques. For this latter point the masterclass on printing technologies is particularly useful.

This session also contained a presentation from Sun Chemicals who are leveraging their experience in conventional printing into printed electronics.

4 EXHIBITION

The 2 days of the conference also featured an exhibition from companies and organisations active in this area. Serving lunch and coffee in this area served to ensure significant foot traffic through the area and the booths certainly looked to be busy. Here is a summary of a few I visited.

I spent some time on the Cintelliq stand discussing the organic semiconductor industry. They do a well produced newsletter on this industry that made an interesting read.

IDTechEx and Printed Electronics World had booths and showed some interesting examples of printed electronics together with their library of market reports. I mark the occasion Printed Electronics World had been produced as a high quality print version too.

The Organic Electronics Association (OE-A) were giving away the 2nd edition of their brochure which is a mine of information. Their pack also included a set of organic electronic demonstrators and interactive electronic paper cards complete with reader.

RadTech are a trade association for the UV and EB curing industry and had some of their reports on show. I have an interest in their technology as I believe that it has much to offer printed electronics.

Sonoplot were showing their picolitre scale fluid dispensing system. This seemed to be an interesting alternative to inkjet for linear features and I left with a number of scientific papers to read about their system.

Unidym had samples of their carbon nanotube products on show. They are producing conductive coatings of these and seem to hold a significant number of patents in this field.

5 THURSDAY 15TH NOVEMBER – MASTERCLASS 3

On the final day of the conference I attended the Masterclass on Printing Technologies. This was delivered in 3 parts.

First of all Bruce Kahn of Printed Electronics Consulting described the systematics and principles of printing. Bruce went through the various impact and non-impact printing processes that have been developed or evolved in conventional printing. As he described these he showed with examples how these can be used to fabricate printed electronics and displays. By going through

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the advantages and disadvantages of each he illustrated where each technique may find a niche in printed electronics.

Mike Renn of Optomec then described their M³D Aerosol Jet Printing system. This is finding use in the fabrication of photovoltaics where the ability to fabricate long continuous straight conductors is of value.

Finally Susann Reuter of IDTechEx described some examples of Printed Electronics to pull the whole masterclass together. Although this is a huge topic that could certainly use more than the 3½ hours allotted it was a great introduction to the topic. I would recommend this to anyone attending a future conference.

This was a great end to a 4 day meeting. I certainly feel that I took away a great deal of valuable information from the event. I look forward to the next time!

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