

MRS (Materials Research Society) Fall Meeting: December 1-5, 2008, Boston, USA

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A) General Summary

The MRS Fall meeting 2008 comprised no less than 45 technical symposia on latest news in materials science and technology held in parallel. Within the week, a total of more than 4700 academic papers (oral and interactive) were given. Thus, priorities had to be made by the EOOE correspondent based on the personal research interests related to Organic and Large-Area Electronics (OLAE)¹. Based on the selection, the following conclusions were drawn:

1) Dawn of Modern Nanotechnologyⁱⁱ: nanostructured materials (semiconductor, oxide, metal nanoparticles of all thinkable sizes and shapes) become more and more building blocks for the device engineers. First applications like the QD-LEDs presented by Vladimir Bulovic (Massachusetts Institute of Technology) are in place. Much attention was paid to carbon-based hybrid materials: nanotubes (CNTs) in first place but also exfoliated graphene sheets instead, embedded in or adjacent to polymer materials.

2) With that, the commitment of OLAE and flexible electronics not to attack silicon electronics is no longer true. Keynote talks by John A. Rogers (Northwestern University), Ohseung Kwan (PowerFilm Inc. and Hewlett-Packard Inc.) and Ali Javey (UC Berkeley) indicated tendencies that it is the clear goal to beat the performances of solid silicon by nanostructured silicon. According to these speakers, we are at the dawn of flexible electronics based on silicon and silicon-oxide nanostructures. Alone, industrial-scale production and handling of these materials has to be shown or improved.

3) For inorganic materials, solid-state R2R technologies are seen favourable to the detriment of solution-based R2R. In this number, self-aligning imprint lithography (SAIL) and a flexo-type contact printing approach were mentioned in keynote talks as suitable alternative for a dry forward transfer of underetched silicon nanostructures in R2R configuration. The compromise of ILAE is still: either high local order but grain boundaries all over the place or a low or random order uniformly distributed over a large area.

4) For organic materials, solution processability is still very important and roll-to-roll (R2R) was even referred to as 'the holy grale'. Classical printing (gravure, inkjet, flexo) is still an issue, as is the quest for tailored drying and annealing processes. However, alternative deposition techniques are in place (e. g. spray pyrolysis, mist deposition, electrospinning, laser-assisted indirect forward-transfer writing, electrohydrodynamic jet printing) which of course all are about to prove their industrial relevance. As these approaches are to date not followed by classical printers, the integration of these into the classical printing workflow seems a tempting and worthwhile challenge.

5) For hybrid materials in (organic-inorganic) large-area electronics, the similar question does not apply yet. Key issue here: the structure-property (functionality) relationship awaits still a sufficient investigation to be understood and controlled during the production process, both on the milli-, micro-, nanometer length scales. Drying and annealing have to be paid a particular attention here, many talks came forward with widespread details. Hydrogen-bond-assisted techniques are potentially seen to solve the related challenges.

6) In summary, the way from the materials to the device goes via the structure, and the manufacturing process has to provide it. In this case, to the evaluation of the correspondent, understanding and models is crucial, with self-assembly seen as a key issue. Opinions went as far as Christiana Honsberg (Arizona State Univ, USA) pointed out in her photovoltaics tutorial that only a quantum leap putting nanotechnology into solar-cell business can serve the human energy demands in 2050 pushing up the photovoltaic efficiency to its theoretical limits (replacing contemporary silicon).

7) A pronounced particular attention was seen in a number of papers devoted to a characterisation of the flexible devices under mechanical stress and with respect to their lifetime and how mechanical stress affects the lifetime.

8) Further on, the replacement of ITO as transparent conductive oxide (TCO) was seen as in full progress, without a clear runner-up be identified.

A lot of papers dealt with investigating properties of particular alternative materials, e.g. [In][Sn][Ga]ZnO in almost unthinkable stoichiometries and carbon-based materials.

B) MRS Awards, Lectureships, and Medals

Von Hippel Award

The Materials Research Society's highest honor, the Von Hippel Award, is conferred annually to an individual in recognition of outstanding contributions to interdisciplinary research on materials. This year, the award was given to Herbert Gleiter, Forschungszentrum Karlsruhe, for "his imaginative experiments on the role of defects that have led to new insights into the importance of length scale in materials and have resulted in many new applications." Gleiter's award presentation was titled "Nanoscience and Nanotechnology – the Key to New Materials as Well as to New Studies in Other Areas of Science". (mrs)ⁱⁱⁱ

Turnbull Lecture Award

The Turnbull Lecturer Award recognizes the career of a scientist who has made outstanding contributions to understanding materials phenomena and properties through research, writing and training, through education and lecturing in the laboratory, classroom, and conferences. This year, the award went to David N. Seidman, Northwestern University, for his research on point defects and the role they play in radiation damage and phase transformations, e.g. his unique studies of interfacial segregation, and especially for the development of atom probe spectrometry. His public lecture was titled "On the Genesis of Nucleation and Phase Decomposition on an Atomic Scale". (mrs)ⁱⁱⁱ

Fred Kavli Distinguished Lectureship in Nanoscience

Moungi Bawendi, Massachusetts Institute of Technology, Cambridge, USA, has been selected to receive the Fred Kavli Distinguished Lectureship in Nanoscience. Bawendi's exemplary research probes the chemistry and physics of semiconductor nanocrystals. In his public lecture titled "The Importance of Excitons in Science and Technology of Semiconductor Nanocrystals" he highlighted the need for understanding the elementary, in part structure-related nanoscale interaction properties of these building blocks to gain best revenue for the future electronic devices. (mrs, tb)^{iv}

MRS Medal Award

The MRS Medal Award recognizes a specific outstanding recent discovery or advancement that is expected to have a major impact on the progress of a materials related field. Two scientists have been selected to receive the 2008 MRS Medal for their "fundamental contributions to the materials science of oxides that underly [contemporary] and future electronic devices." Medalist James F. Scott, Cambridge University, responded with a talk on "Some New Properties of Ferroelectrics: THz Emission, Nanodomain Switching, Finite Size Effects, and Ferroelectrically Induced Ferromagnetism", medalist Darrell G. Schlom, Cornell University, conferred about "Oxides beyond SiO₂ and the High-K Materials Revolution". (mrs, tb)^{iv}

C) Remarkable Contributions⁴

N0.1	Christiana Honsberg (University of Arizona, USA)	In her tutorial on next-generation nanostructured photovoltaics , Prof. Honsberg pointed out that only a quantum leap in technology considering nanoscale effects in materials can push up the photovoltaic efficiency to its theoretical limits, which is necessary to serve the human energy demands in 2050.
G1.1	John A. Rogers (University of Illinois, Urbana-Champaign, USA)	In a visionary keynote lecture, Prof. Rogers outlined trends and tendencies other than Moores law with respect to using single-crystalline inorganic semiconductors for unusual-format, i. e. flexible and large-area electronics .
F1.3	Peter Reiss et al. (CEA Grenoble, France)	For bulk-heterojunction solar cells, the prevalence of a designed band alignment is crucial. However, for solution-processed hybrid materials, phase separation dynamics inevitably lead to changes in the local chemical constitution, with local variations of the electrical properties encountered. Focusing on thin films of side-functionalized poly(3-hexylthiophene) P3HT and thymine-capped CdSe NCs, Dr. Reiss addressed how hydrogen-bond-assisted layer-by-layer (LBL) assembly allows an improved control over the morphology in these solar cells, resembling molecular recognition.
G11.4	Ali Javey et al. (UC Berkeley, USA)	Prof. Javey presented a R2R approach of structured and self-aligning contact printing of inorganic nanowires . On a revolving cylinder, wires are grown by CVD. Pressing the cylinder on a patterned and moving substrate, the wires lay down in parallel if the substrate is prepared in a way that the hydrogen bonds are strong enough to strip a number of wires from the cylinder. As not all wires are taken, each place of the cylinder can be used multiple times, tilting cylinder and substrate with respect to each other.
G2.1	Ohseung Kwon et al. (PowerFilm Inc. and Hewlett-Packard Inc., USA)	Dr. Kwon reported on self-aligned imprint lithography (SAIL) . SAIL consists of three steps: a) deposition (e.g. gravure, inkjet, coating), b) imprint at 5 m/min, c) self-aligned etching with the mask distorting with the substrate. Unlike photolithography, no clean room is necessary. Objectives of SAIL are large-area, high-resolution, low-cost. As an example he showed a fully R2R manufactured tent prototype bearing full solar-panel functionality for military use.
G11.1	Vladimir Bulovic (MIT, Cambridge, USA)	Prof. Bulovic gave a review from the first ideas at MIT till the launch of quantum-dot LEDs based on semiconductor nanocrystal arrays.
KK3.1	Marie-Claire Hermant (TU Eindhoven, NL)	Mrs. Hermant reported on tuning the conductivity threshold of CNT-based devices when adding polymers in small wt-% to the dispersions. She developed a mathematical model based on percolation theory and concluded that the change in properties is due to a coating-like deposition of the polymer on the CNTs and a subsequent change in the mean tunneling distances relevant for charge transport.
G13.8	Nick Kattamis and Craig B. Arnold (Princeton University, New York, USA)	Mr. Kattamis evaluated three direct and indirect methods of laser-assisted forward transfer writing of small-molecule OPV materials with respect to both the functionality and the chemical constitution of the resulting deposited structured layer. Whereas the immediate functionality turned out to be quite unaffected, encountered long-term stability problems could be clearly related to H misconfigurations induced during the (direct) writing process. Purely mechanical indirect writing, mediated by a thermally expanding polyimide foil, turned out to be able to overcome these problems.
G6.1	Antonio Facchetti (Northwestern University, Evanston, Illinois, USA)	Mr. Facchetti reviewed the synthesis of classes of n-type conducting small molecules at Northwestern University and reported on successful gravure, inkjet, and flexo printing attempts to fabricate flexible TFTs from these materials. The work included the electrical characterisation of the fabricated devices under mechanical stress (AFM, SEM) and lifetime considerations.
G13.6	J. Park and John A. Rogers (University of Illinois, Urbana-Champaign, USA)	Dr. Park reported on electrohydrodynamic jet printing (e-Jet) . This technique uses nozzles with a diameter of 400 nm or below (etched fibres like for SNOM) and allows drop diameters even smaller. The material transfer is mediated by a pulsed electrical bias voltage applied between the grounded substrate and the conductive tip. Constraints with respect to the printable materials were not given.

G13.7	M. Singh and Ghassan Jabbour (University of Arizona, USA)	Dr. Singh reported on inkjet printing Ir(iii)-based macromolecules incorporated as guest molecules in a binary polymer-based ink containing one p-conducting polymer poly(9-vinylcarbazole) (PVK) and one n-conducting polymer 2-(4-biphenyl)-5-(4-tert-butyl)-1,3,4-oxadiazole (PBD) as a solution-processable OLED material . In this project, the morphology anisotropy related to the Gibbs-Marangoni effect could be quantified using white-light interferometry.
T1.10	Christina Peabody and Craig B. Arnold (Princeton University, New York, USA)	Mrs. Peabody introduced a quantitative method to characterise the performance of OE devices , in her case Li-ion batteries, under recurrent mechanical stress . Characterisation comprises the domain-resolved viscoelastic behaviour (at neutral axis vs. in upper and lower part), strain-stress-analyses of hysteresis effects. The mechanical description is done in the Voigt-Kelvin model.
G13.4	James C. Sturm (Princeton University, New York, USA)	Prof. Sturm put the degradation aspect of OTFTs and OLEDs into focus of his talk. He presented phase diagrams of performance vs. stress time derived from literature reports. Authors are requested for any technique and material to report to him performance time series.
G2.2	Piero Cosseddu (University of Cagliari, Italy)	Dr. Cosseddu reported about the influence of mechanical deformation on the electrical performance of OTFTs .
G13.3	Jürgen Daniel (Palo Alto Research Centre, California, USA)	Dr. Daniel gave a review issuing the basic challenges of functional printing that a hydrophobic surface is required whenever a degree of order is required for the functionality. Thus the functionality assumes compromises with the scalebar of the degree of order. Exemplary, he named silver inks that ever have to retain a certain roughness to the detriment of conductivity whenever a superlayer requires contact-line pinning. From his research in engineering he stated further that the approach of SAM never worked in a satisfying manner.
G13.2	Alex Guite et al. (Imperial College, London, UK; IMEC, Leuven, Belgium; Asulab Ltd., Marin, Switzerland; MateriaNova, Mons, Belgium)	Dr. Guite reported about EU FP6 project CONTACT where polymer TFTs were manufactured at a speed of 30 m/min by gravure printing . Strategy was to put the process in first priority and do the adjustments rather on the materials side.
G13.1	Gerwin Gelinck et al. (Holst Centre and PolymerVision, Eindhoven, NL; IMEC, Leuven, Belgium; University of Kentucky, USA)	Dr. Gelinck reported on a study how a number of polymer TFTs were laid out on a 360° plate with a rotational symmetry and manufactured by dip-coating of the master plate at once into a solution bath. The film-morphology and the device performance were found to be critically depending on the dipping angle and the drying speed. Figures about the performance dependence were given.
I3.1	Gyoujin Cho et al. (Sunchon National University and Printed Electronics Research Center, Sunchon, South Korea)	Dr. Cho reported about all-gravure-printed 13.56 MHz RFID tags . Information depth: 1 bit - Reading distance: 2.5 cm - Goal price: 1 ct per item - Resolution: 100 µm - Registration accuracy: 10 µm - Used pilot line: 7 color units at 20 m/min max velocity - Actual speed: 5 m/min in order to provide heating for 5 sec. Antennae were made from Ag nanoink as curable below 150 °C in 5 sec. The TFTs at 10 V DC were made from single-wall CNTs as metallic behaviour could be suppressed by surface functionalization. Rectifiers were made from hybrid ZnO. Goals: commercialize all-printed 1 bit RFID in March 2009, have a 96 bit RFID tag ready latest September 2009.
F2.7	Ari Alastalo et al. (Technical Research Center of Finland, Espoo)	Dr. Alastalo reported on an advanced rapid electrical sintering method for metal nanoparticles. Examples about the working principles were given.
I6.1	Kurt A. Schröder (NovaCentrix Inc., Austin, Texas, USA)	Mr. Schröder briefly introduced a conjecturally rapid UV annealing technique commercially launched (PulseForge), without giving details about working principle and the constraints of usage.
B10.6	Tim Emory et al. (Hewlett-Packard Inc., USA)	Mr. Emory presented a conjectural approach for low-T R2R manufacturing of TFTs using Indium-Zinc-Oxide (IZO), Tin-Zinc-Oxide (TZO), Indium-Gallium-Zinc-Oxide (IGZO) and Hafnium-Oxide (HfO ₂) as electrodes. No details were disclosed.

ⁱ Related to the topic of this contribution, the following symposia were attended:

Symposium B: Transparent Conductors and Semiconductors for Optoelectronics

Symposium F: Low-Cost Solution-Based Deposition of Inorganic Films for Electronic and Photonic Devices

Symposium G: Organic and Hybrid Materials for Large-Area Functional Systems

Symposium I: Reliability and Properties of Electronic Devices on Flexible Substrates

Symposium KK: Transport Properties in Polymer Nanocomposites

Symposium N: Next-Generation and Nano-Architected Photovoltaics

Symposium T: Mobile Energy

ⁱⁱ To the knowledge of the correspondent, the era of Modern architecture at the beginning of the 20th century is based on the availability of architectural details (ornaments etc.) on large scale in the wake field of the industrial revolution that took place in Europe in the course of the 19th century. In contrast to preceding eras such as the Founding Époque, movements of Modern architecture had the aim to put these details into a clear functional relationship with the building as a piece of arts ('form follows function'). Alike this scenario, the production of nanomaterials has to date in part reached industrial scale, and this fact seems to open up horizons to generate new functionalities far beyond just assembling them for the sake of beauty or representation.

ⁱⁱⁱ mrs: from MRS Web Site, <http://www.mrs.org>, accessed Dec. 9th, 2008

^{iv} mrs, tb: modified after MRS Web Site, <http://www.mrs.org>, accessed Dec. 9th, 2008

^v As attended by the correspondent, mentioned in arbitrary order. Financial support by the German Science Foundation in terms of a travel grant (grant no. BL 1075/1-1) is kindly acknowledged.