Nanomanufacturing Science and Technology Focus Topic
Room: 16 - Session NM+MS-TuM

All Invited Session: Challenges of Nanomanufacturing from an Industrial Perspective
Moderator: S. Butler, Texas Instruments, B.R. Rogers, Vanderbilt University

8:00am **NM+MS-TuM1 Challenges of Nanomanufacturing from an Industrial Perspective**, ***A. Sekiguchi***, Tokyo Electron Limited **INVITED**

In the semiconductor industry, we have been able to benefit from cost reductions associated with physical scaling of memory and logic devices for decades. By reducing the physical dimensions of our devices from generation to generation, we have been able to drive bit cost of memory and processing power cost of our logic devices with ease. Today however, challenges associated with atomic scale manufacturing and control are daunting, to say the least. Dimensional controls are in the single nm range, six sigma, for lateral scales, and in the sub-Angstrom range for critical film thicknesses. The talk will describe the device level challenges that we face in this era of nano-scale manufacturing, explore options that we have in terms of patterning at 1x nm node and below, and discuss process options that will be needed in the next generation of devices.

9:00am **NM+MS-TuM4 PRINT® Nanomanufacturing Technology-Precisely Engineered Particles for Life Science Applications**, ***M. Hunter***, Liquidia Technologies, INC. **INVITED**

Nanomedicine, an offshoot of nanotechnology, refers to highly specific medical intervention at the molecular scale for treating and curing disease or repairing damaged tissues, such as bone, muscle, or nerves. At this size scale – about 500 nanometers or less –biological molecules and structures operate inside living cells. The pharmaceutical industry continues to evaluate the potential of these new technologies to alleviate the burden of rising research costs, improve the speed and efficiency of the discovery process, and create high-value new generation therapeutics. While nanotechnology is widely seen as having huge potential, the pharmaceutical industry remains skeptical that success at the bench scale can successfully be translated into high volume products.

Liquidia's PRINT® technology (Particle Replication in Non-Wetting Templates) is one example of a breakthrough in micro- and nanoparticle manufacturing that allows complete control over particle size, shape and chemical composition. Since its inception, Liquidia has been addressing nanoparticle manufacturing scale-up by adapting the PRINT particle fabrication process to merge the high-volume production methodologies of roll-to-roll processing and the high precision fabrication methods of the microelectronics industry. Using PRINT technology, Liquidia has the ability to rapidly scale up cGMP manufacturing of particles with unprecedented control over the composition and geometry. This creates the unique ability to manufacture high volumes of complex micro- and nanostructured objects in a number of particle geometries and a variety of materials in a cost paradigm that is very attractive. Using manufacturing methodologies developed and proven in other industries including the printing, film and medical device industries, Liquidia plans to scale its particle manufacturing capabilities to supply commercial quantities for a variety of industries, including diagnostics, vaccines and therapeutics.

10:40am **NM+MS-TuM9 High Productivity Combinatorial R&D Technologies for Cost-Effective Nanomanufacturing**, *D. Lazovsky*, ***C. Hunter***, Intermolecular, Inc. **INVITED**

Nanomanufacturing is inherently more challenging than the production of micron-scale and larger device structures, as interface effects increasingly dominate device performance for nano-scale devices. Theoretical understanding of such effects lags the results of practice, so empirical experimentation is necessary to simultaneously co-optimize multiple critical elements. Such co-optimization using traditional research and development (R&D) methods is typically inefficient, slow and expensive.

Cost-effective nanomanufacturing starts with the development of an optimized device structure, which depends upon our ability to learn about material interactions. For example, while a basic photovoltaic (PV) cell can be made with just 4 layers (n- and p-regions, two contacts), thin-film PV cells designed for optimum efficiency today use additional 10-50nm thick layers to modify band-gaps, optimize light reflection, and extract maximum current.

Even if an optimized nanodevice structure has been identified, it cannot be trivially transferred to high-volume manufacturing (HVM). Different tooling alters process conditions, which generally results in non-optimal final device performance as well as manufacturing yield losses. As an example, while the champion Cu(In,Ga)Se_2 (CIGS) cell from a lab has reached >20% conversion efficiency, the best reported from HVM lines today is only ~14%.

Once a nanomanufacturing line is running, experiments are needed to enhance device performance and improve line yield. However, it is inefficient to do R&D using the production line since the experiments must compete with manufacturing runs, and the HVM tools are generally not ideal for experiments. With inefficiency in R&D learning cycles, improving yield is slow and expensive.

A more efficient approach uses a high productivity combinatorial (HPC™) platform—such as that developed by Intermolecular—to dramatically accelerate R&D by 10-100x relative to traditional methods. With unique combinatorial process tools, throughput-matched characterization, and an informatics analysis and data management system, in less than a year we developed a world-class 17.7% active-area efficiency CIGS PV cell using a two-step sulfur-free process flow.

Intermolecular’s HPC platform is purpose-built for the R&D of semiconductor and clean-energy products, and is used in Collaborative Development Programs (CDPs) with a growing number of customers. For example, leading-edge semiconductor memory chips today use dielectrics and metal electrode layers that are only 1-10 nm thick, and HPC technology has accelerated R&D learning-cycles and time-to-market for our customers producing such memory chips.

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