Research Needs Document: Nanomanufacturing Materials and Processes

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Background

This document is prepared to accompany the Call-for-White-Papers for the thrust of Nanomanufacturing Materials and Processes (NMP). The research needs in this area are very broad. We present here selected areas of high priorities as identified by our sponsor members.

There is no doubt that nanomanufacturing is getting increasingly difficult. Feature sizes are already approaching 10 nm or less in production; accordingly, research must be directed towards 5-nm node generation and beyond. For lithography, 193-nm wavelength may not be capable of producing the desired feature size in a cost-effective manner. As such, opportunities exist for a major paradigm shift. Related to this, metrology and defect detection are critical and their effectiveness must be improved in order to ensure that capable solutions exist in a timely and cost-effective manner. For unit processes, new materials are sought after for logic and memory devices. These material options must be paired with manufacturable deposition and patterning techniques. In addition, functional diversification calls for a wide range of other devices, such as required by analog applications and the Internet of Things. For interconnects, the reduced size (thickness and linewidth) introduces additional scattering such that resistance is increasing much faster than the inverse of cross sectional area, and at the same time, reliability problems increase. Interlayer dielectrics also have increasing difficulty in further reducing the dielectric constant.

For an overview, we divide nanomanufacturing into four major groups: patterning, front-end processes (FEP), back-end processes (BEP), and common areas of interest that are applicable to all three. It should be noted that the boundary between FEP and BEP is not clearly defined in the industry, due to the increasing kinds of devices fabricated between the semiconductor substrate and the first metal level. Here we simply put FEP as processes for devices of all kinds, including memories, passives, TFT, sensors, etc., and BEP as those for interconnects and interlayer dielectrics.

Research Needs

The research needs for nanomanufacturing are obviously very wide. In this call, due to limited resources, we have gone through some discussions and identified what our members have considered to be the most critical items for university research. We have identified 12 topics among the 4 groups. The list of topics are shown as follows:

Patterning

1) Selective deposition, growth, and removal as an enabler of self-aligned patterning strategies.
2) Design for manufacturing (DFM) for patterning materials – Process and defect-aware models and design rules for DSA with BCPs or other novel patterning strategies of sub-20 nm pitch.
3) New self-aligned, complementary options to enable patterning, scaling, and process control (i.e. not spacer-based multi-pass patterning, DSA with BCPs, or selective deposition).

Front-End Processes

4) Emerging/hybrid research materials for logic devices.
   - Materials for improved mobility and electrostatics, including gate stacks.
   - Materials for beyond-CMOS devices.
5) Emerging research materials for memory devices.
6) Functional diversification on CMOS platform – Processes to support heterogeneous or SOC system integration. Examples; TFT, passives, MEMS/NEMS, sensors, and power devices.

7) Novel deposition and removal processes to realize new 3D device architectures.
   - Selective growth and deposition.
   - Passivants.
   - Atomic layer etch and cleans.

Back-End Processes

8) Low-resistance interconnects – Line and via resistances. Interfacial/contact resistance.
   - Cu scaling extension and barriers.
   - Alternate/novel concepts for interconnects – Beyond-Cu interconnects.

9) Low-capacitance isolation – Low-K dielectrics extension. Air gap.

10) Interconnect reliability – Fundamental understanding. Electromigration. TDDB.

Common areas

11) Metrology and analytic techniques.
   - 3D imaging – Examples; CD-SAXS, TEM, Electron and X-ray tomography.
   - Functional imaging: combining imaging and material property probing. Example; STEM with EELS.

12) Novel patterning metrology techniques – To assess DSA (3D), selective deposition/growth. Design, modeling, emulation and simulation of unit processes.

13) Other topics – Outside the above twelve focus areas. All submissions will be considered for outstanding concepts.

When submitting the white papers, researchers are asked to indicate the topics (in number) what their research topic can best fit in.

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