University of Arkansas Microelectronics-Photonics Graduate Program

PhD Candidacy Exam – Communications Topic – March 16, 2011

PROBLEM TO BE SOLVED

Advances in micro- and nano- technologies (e.g. materials, processes, devices, and/or systems) provide significant opportunities to meet the ever-increasing demand to fabricate larger numbers of transistors on a chip, benchmarked by Moore's law. In particular 'critical–layer lithographies' that surpass limitations of optical lithography must synthesize an understanding of physicochemical properties of interfaces and materials with advances in self-assembly, bottom-up fabrication to provide radically new approaches to pattern periodic and complex architectures on semiconducting substrates (nanocircuitry) or in nanoelectromechnical systems (NEMS).

Your CEO is interested in harnessing recent advances in materials, processes, devices, and/or systems to develop one innovative, cost-effective, specific, self-assembly technology that allows reproducible, large-scale fabrication or patterning of precise, periodic or complex nanoscale architectures < 32 nm. It should use self-assembly to produce a particular, representative product with dimensions <32 nm. Top-down approaches that rely solely on direct writing via high-energy waves (electron-beam or -projectile lithographies), probes (scanning or atomic force probes), or stamps (imprint lithographies, microcontact printing) are specifically excluded.

Examples of specific technologies that could be developed using novel materials, processes, devices and/or systems could include self-assembly of low dimensional materials such as nanotubes, nanowires, or other nanoparticles or macromolecules; self-folding 'origami' approaches that produce 2D or 3D structures due to local variations in modulus and intrinsic or extrinsic stress; directed or thermodynamically-driven self-assembly of materials like block copolymers using chemically nanopatterned substrates; sequence-directed assembly of organic nanostructures like β peptides, peptoids, or DNA; or other self-assembly approaches

Examples of specific products to fabricate include nematic liquic crystals or opto/electronic elements like lenses, filters, gratings, detectors, lasers, light emitting diodes (LED's), electronic storage, transistors, integrated circuits, or multi-dimensional electromagnetic metamaterials.

Your task is to use your background in nano to micro materials, devices and processing to develop *one* cost-competitive, innovative technological approach in *one* of the above (or closely related) areas to fabricate *one* specific product with critical dimension <32 nm. Your solution should consider material, process, device, and system aspects of the technology and product.

YOUR DELIVERABLE

Your task is to write an internal proposal for your corporate officers describing your approach to this issue. The proposal should include the following:

- Executive summary (one page)
- Risk assessment roadmap form (one page)

- Full proposal (15 pages maximum)
- Appendix A: Bibliography (no page limit)
- Appendix B: Ranked list of intellectual property documents examined (no page limit)

At a minimum, be sure you address all of the following:

Current Science and Technologies - What is already being done in this area by other researchers, companies and governmental institutions? Describe the current state-of-the-art for both the science and the implementation. Use diverse resources such as science literature, journals, conference proceedings, the internet, patents or other sources of existing public knowledge. ***Cite all references you use and quote any word-for-word transfer to your report.***

Your Design Approach – What is the basis for your design approach to the problem? Why is your product better than existing products? What product attribute(s) allow market penetration to achieve profitability? Address scientific *and* engineering aspects of these questions.

Testing and Qualification - Describe a set of tests you will use to demonstrate that your approach is effective and that your implementation of the solution will launch successfully.

Cost Analysis – Identify cost and market issues that will impact the pricing strategy of the solution you have proposed. Consider such things as: the major cost items that would impact the implementation; which elements of your implementation solution would be handled in-house versus externally-sourced; major risk elements that could drive up costs if the primary path item fails; costs of IP licensing needed, etc. Provide justification and/or reasoning behind your decisions. Estimate manufacturing cost for the total system as the product reaches mature product stage, so the marketing team can determine potential market size. Avoid subcontracting manufacture or assembly of any proprietary component outside the company, because the CEO is concerned with potential IP leakage.

Intellectual Property – In Appendix B, list in rank order of importance ***all*** commercial, academic, and governmental IP sources that were consulted while formulating the answer, including reference data. For instance, include the patent number; title; inventor name; and assignee name for a patent. Discuss the 3 most significant competitive approaches to your solution in the 15-page document. Compare strengths and weaknesses of these approaches relative to your own. Recommend how these IP threats should be handled.

Most importantly - this is just a minimum list of issues you might consider. There may be many more. The point is that your report ***should contain the evidence*** needed to make an effective and compelling case to your CEO in order to insure that she makes the right decision.

Hint – Clearly state your hypothesized solution. Identify its innovation(s) and advantages relative to state of the art. Describe both existing data, and work needed to support each aspect of the hypothetical solution. Consider theoretical, fabrication, and characterization aspects: for each, identify software/equipment and methods to use, parameters to vary, anticipated outcomes, and possible alternatives in the event of unsatisfactory results. Discuss material, process, device, and systems aspects of your solution. *Refine* your hypothesized solution as you accumulate

information and prepare the manuscript. **Remember**: clearly distinguish what is known from what is hypothesized or not known. What is needed to distinguish the important things to know?