**MAT: Integrated circuit devices for logic and memory**

**PROBLEM STATEMENT**

Optimum performance of integrated circuits relies on speed, density and power capabilities of logic and memory devices. Improvements in logic and memory devices require balanced consideration of multiple aspects of these devices. Such consideration spans numerical simulation, compact modeling, device design, process technology, device characterization and reliability assessment. Numerical simulation, for example, provides important physical insights into new materials, devices and physical phenomena to support analysis and informed decision-making. Advances in logic devices are needed to extend CMOS technology to and beyond the 5-nanometer node. Of particular interest are development of (i) alternate channel materials and gate dielectrics for metal oxide semiconductor field effect transistors (MOSFETs); and (ii) reduction of device parasitics. New materials and devices for nonvolatile memory cells are sought to enhance density scaling. Of particular interest are (iii) two-terminal, non-charge-storage cell capable of multi-bit performance; and (iv) efficient selection devices for cross-point arrays.

You are the Chief Technology Officer of the company that specializes in development, fabrication and testing of materials, devices and systems relevant to logic and memory devices for integrated circuits. Your CEO believes that the company’s expertise in micro to nanoscale materials, processing, and devices could provide a research and development path to pursue logic devices for 5-nanometer node CMOS technology or memory devices to enhance density scaling. Your job is to identify, design, and develop an element or suite of elements in the above areas of interest that draws from the specific expertise and resources in your organization to provide an innovative platform that contributes in a meaningful way and has significantly enhanced properties and performance relative to competitors’ state of the art capabilities. Important considerations include cost, power consumption, interconnectivity, manufacturability and reliability. Your job as CTO is to deliver a complete proposal with your plan for the company to compete in this area to your CEO by your Tuesday morning, January 16, 2018 deadline.

### **YOUR DELIVERABLE**

Your task is to write an internalproposal for your corporate officers describing your idea for research and development. The proposal should include the following:

* Executive summary (one page)
* Risk assessment roadmap form (one page)
* Full proposal (15 pages maximum)
* Appendix A: List of references (no page limit)
* Appendix B: Ranked list of intellectual property documents examined (no page limit)

**Most Importantly** – The significance and novelty of your creative solution, one that moves the boundaries of knowledge outward, will be the primary assessment focus of your review panel. The list below is just a minimum list of issues you might consider. There may be many more. The point is that your proposal ***should contain the evidence*** needed to make an effective and compelling case to your CEO in order to insure that she/he makes the right decision.

**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 use quotes for 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 technology better than existing technologies? What technology attribute(s) make it likely to penetrate the market and be purchased by electronics manufacturers for use in their commercial products? 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 technology reaches mature 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 IP documents affecting your approach 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.

**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?

*Reference the 2018 PhD Candidacy Exam Guidelines document for general instructions.*