

University of Arkansas Microelectronics-Photonics Graduate Program

PhD Candidacy Exam – March 2008

Electronics Section of the Exam

PROBLEM TO BE SOLVED

High dielectric constant (K) capacitors are essential in the electronic packaging industry, and the dielectric constant is used to determine the ability of an insulator to store electrical energy. The dielectric constant is the ratio of the capacitance induced by two metallic plates, with an insulator between them, to the capacitance of the same plates with air or a vacuum between them. High K capacitors can be realized by a combination of unique design and novel material(s).

Your company's CEO feels that recent work in nano-structured materials points to the possibility of engineering capacitors with higher K-values. She has asked you to examine the possibility of developing such a high K-value capacitor using a novel scheme (*not published in the literature so far*). Because she has risen to her role of CEO through her early reputation as a leading technologist, she has been quite detailed in her initial assignment.

YOUR DELIVERABLE

Your job is to develop and evaluate *in detail*, (*note the stress on – “in detail”*), a nano-structured material system based upon a structure-property relationship for high K-dielectrics.

Your 15 page maximum length internal report will be shared and critiqued by your CEO and your fellow corporate officers. Be sure to address at least all of the following in your report:

Current Research - What is already being done in these areas by other researchers, companies and governmental institutions? The current state-of-the-art for the underlying science must be described, as well as an elaboration of the detailed scientific rationale for your proposed nano-structured high K dielectric. This state-of-the-art must be described in detail using numbers, making use of diverse resources such as science literature, journals, conference proceedings, the internet, patents or other sources of existing public knowledge. Do not forget to describe conjecture of upcoming technologies that could affect the competitive position of the material system or device concept that you propose to investigate. **Be sure to cite all references that you use and to quote any word-for-word transfer to your report.**

Specific Material Systems – Carefully describe the material system that you plan to use by including any difficulties that you may expect during fabrication and how you will monitor and overcome them. Be sure to address both the material and engineering issues of any proposed device concept, while carefully explaining performance considerations and any cost-performance tradeoffs. You should specifically address the following technical issues:

- (1) Describe the proposed assembly, if necessary, of the nano-structured material to achieve high K values
- (2) Describe the candidate(s) for metal electrodes and describe their compatibility with the high K-selected material

Characterization – The characterization of your new material system will create critical information used to decide the direction of future company investments. Your work must describe the details of your:

- (1) Design of the capacitor and related test vehicle (TV) for fabrication
- (2) Systematic process flow diagram for the TV fabrication

Testing and Qualification – Characterization of the material must then lead to testing of devices fabricated using these new material systems.

- (1) Present material and electrical tests that will be necessary to test the performance of the newly fabricated nano-engineered capacitors (NECs).
- (2) List relevant descriptions of 2 key reliability MIL Standard tests necessary to validate the proposed NEC

Device Concepts – Be sure to give the underlying science behind all device concepts that you propose as well as the specifications you expect to reach. You must also:

- (1) Present a list of various scientific and engineering reasons (2 each) why NECs may not work, along with a risk assessment and potential solutions
- (2) Provide two compelling applications, with clear technical rationale, where such a NEC could be applied today.

Cost Analysis – At least in qualitative terms, describe the factors that will enter into the cost analysis for researching the integrated material system as well as for integrating it into current device fabrication facilities. Use this as an introduction to then discuss your expectations of the method by which your company will harvest the value of your high K dielectric nanostructured system product and what would be the expected return on investment, fully explaining your assumptions.

Intellectual Property - List in rank order of importance all commercial, academic, and governmental IP sources that were consulted while formulating the answer, including key important reference data as an appendix to this exam. For instance, if the IP source is a patent, include the patent number, title, inventor name, and assignee name. (The full list will not be counted as part of the 15-page limit.) The most competitive materials and device concepts should be discussed within the 15-page document, making comparisons of strengths and weaknesses of these materials systems or device concepts relative to your own.

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 ensure that she makes the right decision.

Hint - Your report should read like a story – one logical step followed by another. This will help you stay focused! Re-read along the way to be sure that you have one logical step followed by another.