

University of Arkansas Microelectronics-Photonics Graduate Program

PhD Candidacy Exam – March 2005

Microelectronics Area of Emphasis Exam

PROBLEM TO BE SOLVED

You are the chief engineer of a company that produces a variety of consumer and aerospace microelectronics products. Your company has become increasingly interested in the emerging market for high temperature electronics. Your job is to study the various requirements and to select the most appropriate technologies and circuit architecture to meet these requirements. Your Director of Marketing wants you to first address product solutions that will operate at 300 C ambient temperatures, and to then consider how to migrate these solutions to support space missions to the planet Venus, which is known to have surface temperatures of about 460 C.

Your job is to evaluate the benefits and limitations associated with applying various high temperature electronics technologies. You should clearly (but briefly) explain the opportunities with wide bandgap semiconductors, how they work, and current technology limitations that may cause difficulties in implementation. You should provide a comprehensive survey of competitive technologies, along with analysis of strengths and weaknesses of each approach. Specifically, you must address the separate requirements of providing for 5 volt logic; providing control voltages in the 10 to 50 volt range (for example, gate turn-on voltages for power devices); and providing high efficiency power switching devices. For these purposes, assume that you can presently purchase 5 volt logic circuits based on silicon-on-insulator (SOI) technology that will operate at 300C but not at higher temperatures. Also, assume that you can purchase power switching diodes, junction FET and static induction transistors that will operate at 460 C. Now make specific recommendations on technology investments that will result in the ability to provide for control voltages at 300 C, and both control voltages and 5 volt logic at 460 C. Also, you need to evaluate the required equipment, infrastructure and the resulting cost of implementing the chosen technology(s).

Make specific recommendations on how to provide the following circuit functionality at each of temperatures 300 C and 460 C, meeting the additional specifications:

- Operating frequency of at least 100 MHz
- Ability to switch 2.0 amps at 1,000 volts
- Better than 95% efficiency
- Operating life of 10,000 hours at the specified ambient temperature
- Sales price of less than \$1,000 in volumes of 10,000 units per year

YOUR DELIVERABLE

Your task is to write an internal proposal for your corporate officers describing your approach to this issue. Be sure you address all of the following:

Current Technology - What is already being done in this area by other researchers, companies and governmental institutions? The current state-of-the-art for both the science and the implementation should be described, making use of diverse resources such as science literature, journals, conference proceedings, the internet, patents or other sources of existing public knowledge. Be sure to cite all references used.

Your Proposed Implementations - Describe in detail how where you plan to use these devices and how they will benefit these applications. Include both the scientific/engineering basis and method of applying this to a workable solution.

Manufacturing Flow - Detail the step-by-step procedure for making these structures in a form useful in manufacturing.

Testing and Qualification - Describe a set of tests and demonstrations that you will use to demonstrate the effectiveness of your approach.

Cost Analysis - Perform a cost analysis that includes, at least, acquisition of raw materials, labor rates, costs per operation, etc. assuming quantities of 10,000 parts per year. You may exclude from your analysis possible additional costs in such infrastructure areas as human resources, facilities engineering, janitorial and grounds, upper level management, etc. You must include all direct manufacturing costs, both startup and continuing; and you must discuss explicitly space and personnel requirements to set up a stand-alone product line. Generic per process costs for various manufacturing methods can be used, as long as they are rationally applied.

Intellectual Property - List all IP sources that were consulted while formulating the answer, and include the full list of examined documents as an appendix to this exam. (The full list will not be counted as part of the 15-page limit.) From this list, identify the three that are the most significant threats to the IP you have created in your solution.