

University of Arkansas Microelectronics-Photonics Graduate Program

PhD Candidacy Exam – March 2005

Materials and Processing Area of Emphasis Exam

PROBLEM TO BE SOLVED

Your company has become aware of a growing demand for automotive in-cylinder pressure sensing as a means of providing information on torque, start of combustion, 50% burn rate, peak pressure, knock, misfire, and partial burn. Such information can be used in computerized control algorithms in order to further optimize engine efficiency as well as to provide early warning indicators of malfunctions. Your company currently manufactures and sells a set of silicon-based products including temperature, pressure and magnetic field sensors. Your team has been assigned the task of making recommendations on the best approach to either adapt current silicon-based technologies or develop entirely new silicon-based technologies to directly sense the pressure cycles of an internal combustion engine.

Your job, as chief engineer of this company, is to design a package and insertion method for a silicon-based sensing system. The maximum operating temperature for the silicon sensing element and associated circuitry is 125 C, so your design target is to minimize any temperature excursions above 95 C. The required time response of the sensor is based on a maximum of 8,000 engine revolutions per minute, with each cylinder having one combustion cycle per every two revolutions. You must have at least 2.0 angular degrees of resolution. Therefore, the sensor must be in reasonable proximity to the cylinder.

For reference, the internal combustion engine system has the following characteristics:

- Cast iron block
- Recirculating water as coolant, with head gasket formed from composite materials
- Alloy steel piston heads
- One spark plug per cylinder
- One intake valve and one exhaust valve per cylinder
- Overhead camshaft
- Peak instantaneous temperatures during combustion of 820C
- Mean exhaust gas temperature of 80 C
- 8:1 compression ratio

Any planned sensor must meet the following requirements:

- Connector with three terminals for 5 V power, ground, and output
- Output voltage ranging from 0.5 to 4.5 volt output over the range from 0 PSI to 1000 PSI (pounds per square inch)
- Sales price of less than \$15.00 in volumes of one million units per year
- Meets the highest quality and reliability standards
- Minimal conversion costs to retrofit your sensor to a current engine

YOUR DELIVERABLE

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

Current State-of-the-Art - 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 Solution - Describe in detail your solution to this problem, including both the scientific/engineering basis and method of applying this to a workable solution. You must address all pertinent aspects of the materials and processing of this device. This should include materials of construction, how they are assembled, their reaction to their environment, etc.

Manufacturing Flow - Detail the step-by-step procedure for making this product.

Testing and Qualification - Describe a set of tests and demonstrations that you will use to demonstrate the effectiveness of your approach. These should include tests that show that the device can work as intended with your protection scheme in place.

Cost Analysis - Perform a cost analysis that includes, at least, acquisition of raw materials, labor rates, costs per operation, testing and qualification etc. assuming quantities of 1,000,000 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.