NOVEL SENSORS R&D LEADING TO CURRICULUM DEVELOPMENT

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Abstract

Under the umbrella of the NSF Center for Industrial Sensors and Measurement (CISM), a multidisciplinary research and development program for harsh environment sensors is being actively pursued at Ohio State University. Efforts are now underway to embrace the field of biosensors and microfabrication. The objective of this program is to exploit CISM research advances in sensors for implementation of an innovative classroom and industry-oriented curriculum. The program will target undergraduate and graduate students and utilize an interactive approach emphasizing the importance of problem solving, group work, communication and use of state-of-the-art technology. Technical education will be expanded to include business, management, administration and law with advice of our colleagues from the Colleges of Business, Education, and Law. The goal of this program is to ensure that students understand and can communicate the impact of their research and education to the broader community. An educational environment where students can continually assess how their research progress is achieving the stated goals will help develop skills useful for future careers. CISM with its existing organizational structure is ideally suited to implement such an education project. It already provides an infrastructure in which scientists, engineers and business leaders from the university, government and industry are working together. Plans are underway to establish an incubator company that will translate CISM research into sensor products. Students will get the opportunity to be active participants in this process. Several programs are planned to integrate the curriculum with the non-OSU community. In particular, distance learning to bring off-site participants into the program will be implemented. Ohio State College of Engineering in cooperation with the Ohio Aerospace Institute (OAI) has a significant investment in distance learning program in place. In this program, we will target collaboration with Indiana University at Fort Wayne and the NASA Space Technology Development and Utilization Program (STDP) to implement distance learning schemes. In addition, a "living" course that continually adapts to new advances via the Internet will be established.

VISION, GOALS AND OBJECTIVES

Recent technological breakthroughs at Ohio State University (OSU) on the development of novel sensors have led to a major multidisciplinary initiative. Activities include: (i) a Center for Industrial Sensors and Measurements (CISM), equally funded by the National Science Foundation, the State of Ohio and an industrial consortium, and (ii) a CMR Scholar, tenured senior-level faculty position, awarded to CISM by the Center for Materials Research (CMR) at OSU. Faculty from disciplines ranging from basic science (Chemistry and Physics) to applied engineering (Aerospace, Chemical, Electrical, Industrial Design, Materials and Mechanical) now direct research at CISM in close collaboration with industry.

CISM faculty, working together over the last two years have noted that mentoring in an interdisciplinary environment presents new opportunities and challenges. The objective of this program is to develop an innovative curriculum, a structured research program and a highly communicative environment. Team-taught lecture and laboratory courses will serve to introduce the students to the sensor and business training areas. The curriculum will focus on an interactive approach emphasizing problem solving, group work, communication, and the use of technology for in-class demonstration. These courses will target upper level undergraduate and starting graduate students. Given the interdisciplinary nature of the topic, these courses should attract students from various disciplines ranging from basic science to applied engineering, including those engineers and scientists from industries and national laboratories. Special efforts will be made to encourage enrollment of women and minority groups through distance learning (in cooperation with OAI through the On-Site Graduate Engineering Program), a close working relationship with the NASA STDP consortium: North Carolina A&T State, New Mexico Highlands University, Central State University, Southern University, Jackson State University, and Tuskegee University, and the National Science Teachers Association (NSTA).

Under the CISM umbrella, research areas focus on Basic, Innovative, Applied and Industry-oriented projects. Each student has a primary advisor in his/her field of specialization and a co-advisor from a different field. There is enough flexibility to ensure movement of personnel between these research efforts, determined primarily by the students' interests and programmatic aspects. Communication among students, rapid dissemination of research results, feedback from the CISM staff and industry as well as flexibility to alter direction is a central theme of the program. The specific research under this program will focus on fundamental studies of the gas-solid interface and should have an impact on all on-going CISM projects.

We believe that major improvement in engineering education is possible if students understand the impact their research education is having on the community. This will allow students to see a universal picture and any positive or negative reinforcement of their research programs will come from a wider perspective. Such an environment will accelerate their progress and will also help develop skills useful for future careers. CISM's existing organizational structure is ideally suited to implement such an education program. It provides a framework for direct interaction of scientists, engineers, and business leaders in the university and industry, and can readily support an educational system capitalizing on change.

The 21st century worker must have all the tools necessary for management, leadership, and ethics. The students' technical education would be expanded to include business, management, administration, and the law. We plan to incorporate courses in business and law that address such issues as product design and liability, problems created by new technologies, protecting intellectual property, technology transfer, and the relationship to the Internet. Clearly, the time-honored method of placing highly competent technical people into positions requiring a working knowledge of accounting, human resources, business planning, and law must evolve.

RESEARCH THEME AND MAJOR RESEARCH EFFORTS

A continuing need exists for measurements in industrial processes and products. Where sensor technology has been applied many benefits have resulted, including improved energy efficiency, better quality, lower scrap or off-specification products, and reduced emissions. Considerable activity exists in the development of new sensor technology. Unfortunately, much of this is fragmented and not always directly applicable to making reliable measurements in the harsh industrial environments found in the aerospace, steel, heat treating, metal casting, polymer, glass, ceramic, pulp and paper, automotive, utility and power industries. Also, since most of the sensor development efforts are based on empirical and/or trial-and-error methods, a fundamental understanding of the sensing and degradation mechanisms is lacking, and this makes the optimization of the sensing behavior a formidable task.

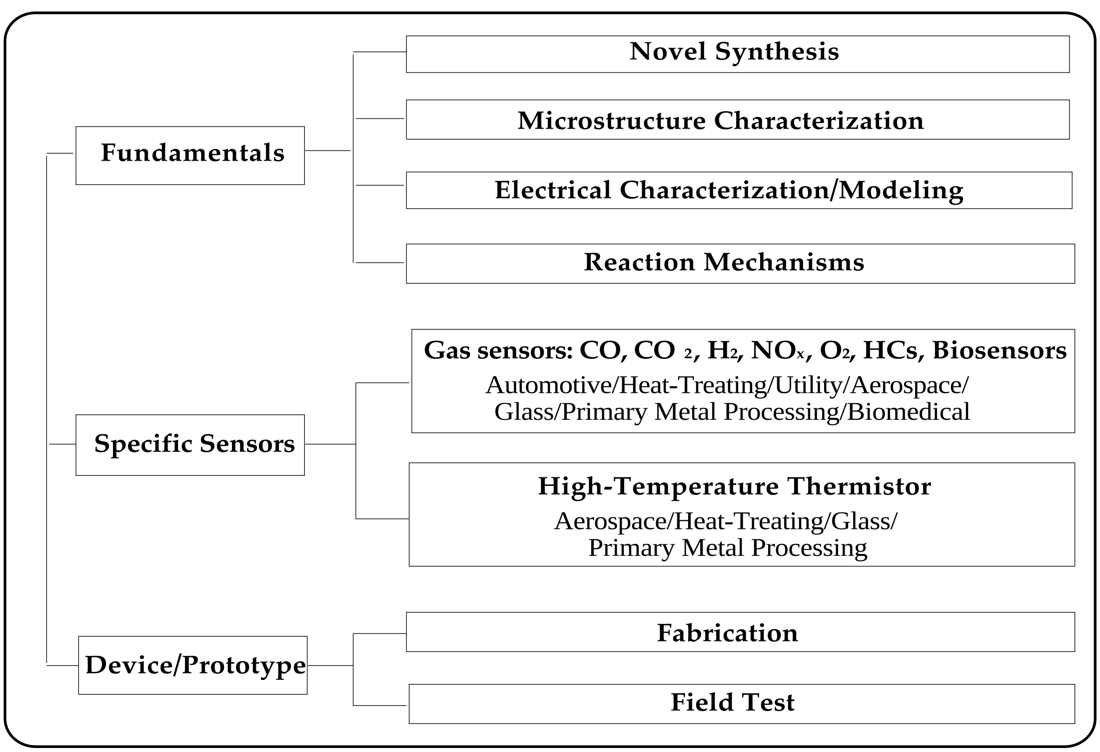


Fig.1 On-going research on ceramic sensors for hostile environments at CISM.

While low-temperature sensors have been commercially successful, less success has been achieved with their high-temperature counterparts. This is due mainly to the problems associated with sensitivity, stability and reproducibility at higher temperatures. Based on our recent studies, it has become apparent that the optimization of sensor performance requires a detailed knowledge of the surface and interface chemistry, the influence of atmosphere, temperature and additives on the defect structure, and an adequate understanding of transport processes across grain boundaries and device interfaces.

Research under CISM represents collaborative efforts among various faculty groups from Chemistry, Physics, Materials Science and Engineering, Electrical Engineering, Industrial Engineering, Mechanical Engineering and Chemical Engineering. As summarized in Fig.1, the primary tasks of the on-going research are: (i) understanding the fundamentals of sensing and degradation mechanisms, (ii) development of specific sensors for targeted applications, and (iii) designing prototypes/devices and conducting field-tests in real-life environments. The research represents a comprehensive approach starting from the development of new sensor materials to the understanding and optimization of sensing behavior to device fabrication and field tests in real-life environments.[1-5] Clearly, it represents a multidisciplinary approach involving faculty members from basic science and applied engineering disciplines, and their close interaction with involved industries. The collaboration strategy is presented in Fig.2. CISM consortium members participating in the on-going research represent a wide range of interests, and it is expected to grow in the future, especially with emphasis on biochemical sensors and integration of sensors in MEMS by Marc Madou (CMR Scholar).

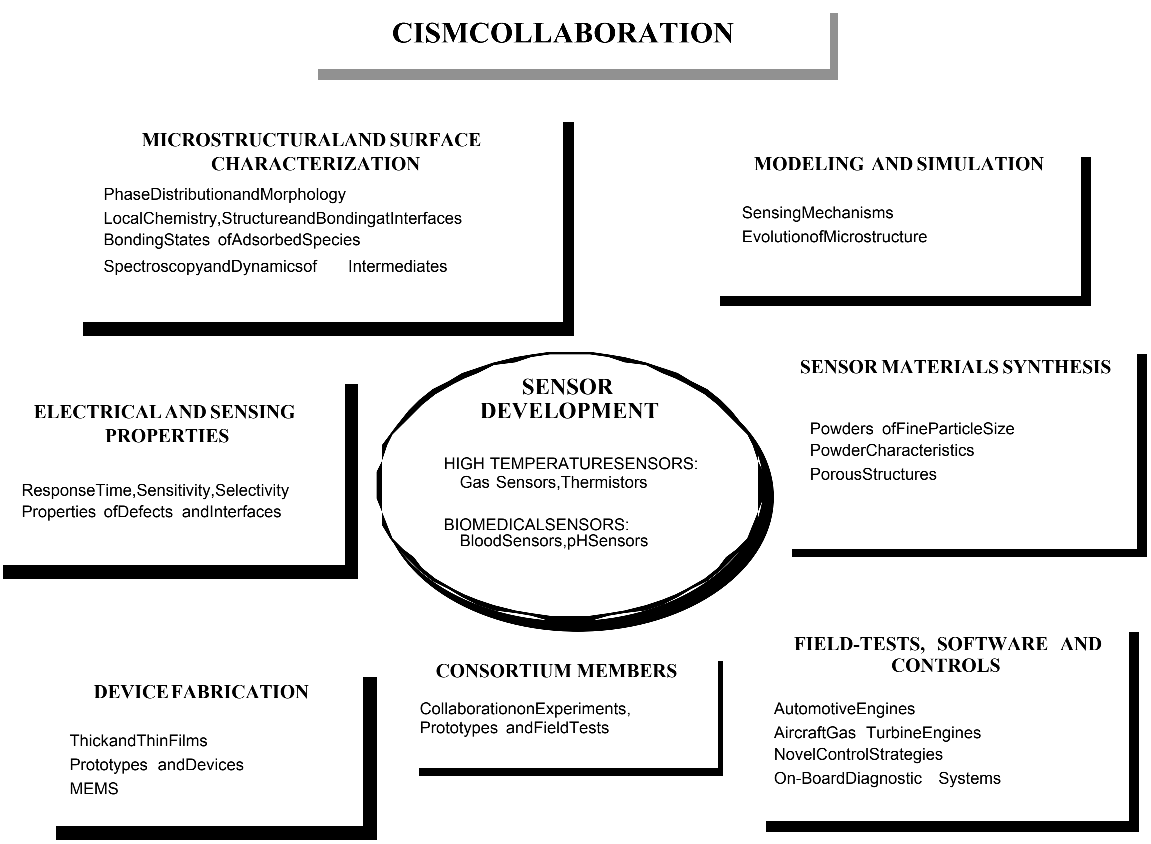
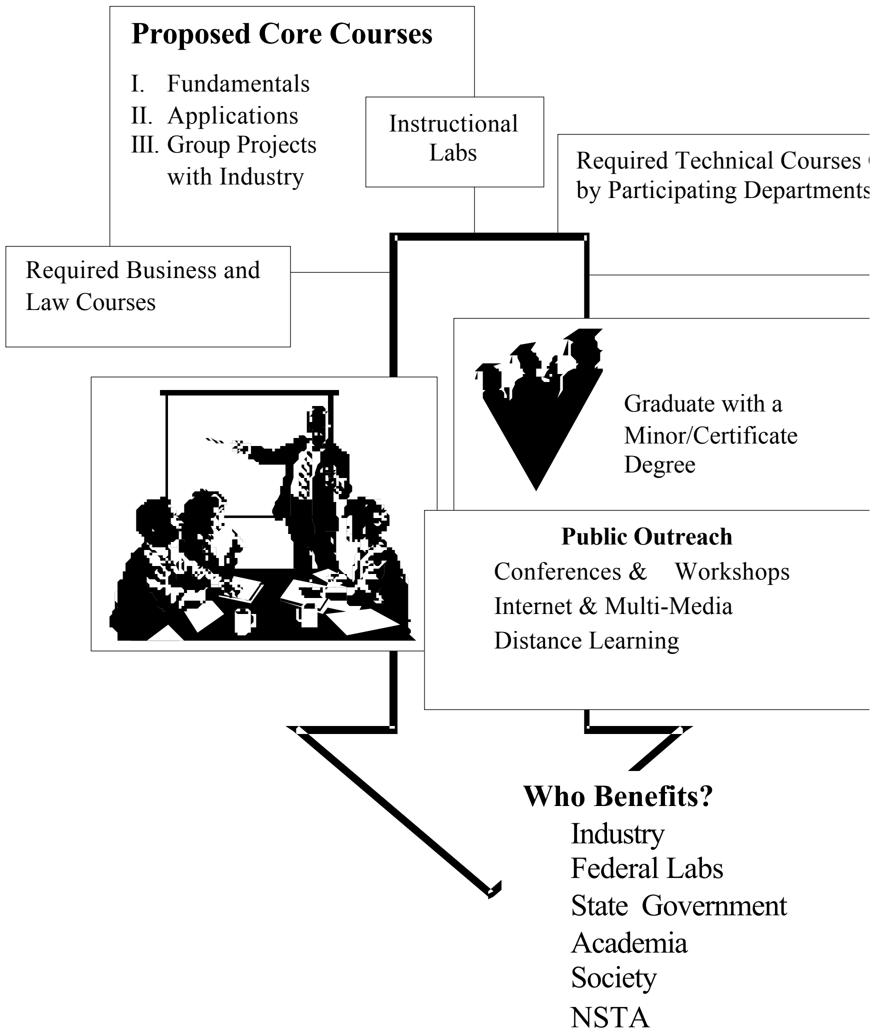


Fig.2 Schematic showing CISM focus groups.

CURRICULUM DEVELOPMENT

Course Development

A three-course sequence (9 credit hours) in sensor materials including instructional laboratories with industrial experience for senior undergraduate and starting graduate students will be developed. Two of the three-course sequence will cover the basic scientific principles, applications, and related technological issues. Each course will have a laboratory component. The third course will be group projects with participating industries. Students entering these courses will have senior or graduate standing in science or engineering. Students taking this sequence along with 11 credit hours of relevant courses in participating departments including Business and Law will have the option to receive a minor or certificate degree program in "Sensors and Measurements". The proposed courses under this program will be designed around the multidisciplinary approach of CISM, and will be team-taught by faculty members from a wide range of disciplines. Non-technical pursuits with emphasis on technical management, communication, protection of intellectual property, ethics and law will be chosen in consultation with colleagues from business and law. The flow chart below summarizes essential components of the proposed curriculum.



The laboratory component of the courses will have two major parts: (i) core experiments in a dedicated laboratory and (ii) demonstrations in various PIs research laboratories. The core experiments will demonstrate fundamental aspects of sensor fabrication, characterization and sensing mechanisms. For the demonstration part, students will have access to the current CISM laboratory facilities (located within CISM complex) including a semi-cleanroom which houses the "electronic nose", and individual PI research laboratories. CISM facilities include powder processing and heat treating, gas sensor measurement setup, thick film deposition, wide range of electrical measurements & testing capabilities, semi-clean hybrid electronics lab and electronic nose (donated by Alpha MOS Co.) with software for artificial intelligence and pattern recognition.

Group projects will involve targeting specific industries, identifying a sensor need, developing a prototype and performing field-tests. The faculty member will ensure that the knowledge and methodology developed in his/her laboratory are implemented in the design of the project. Each project will be a team effort involving multiple students working in close collaboration with an industry partner. An essential component of these group projects will be an ***Industry Internship*** involving students spending an extended period at the industrial sites performing field tests.

Minor/Certificate Program

Students will have the opportunity to get a minor or certificate degree program in "Sensors and Measurements" by combining the proposed courses with relevant existing courses in participating departments. Qualifying for a minor/certificate program will need a minimum of 20 hours of graded courses from a selected list. The business and law courses will be chosen in consultation with colleagues from Colleges of Business and Law.

Assessment Plans

Both the CISM University Policy Committee and the CISM Industrial Advisory Board will evaluate the program. They will advise and guide the PIs during the project development. An external committee consisting of representatives from academia, national laboratories and industries will also review the curriculum. A statistical survey done by specialists (i.e., from the OSU School of Education) will track students in the program. Students will be asked to complete a questionnaire, designed by an evaluation team, aimed at determining the success of the program in preparing them for their careers.

Dissemination Plans

The results of this project will be disseminated through three mechanisms. The first is the presentation and publication of papers describing the curriculum and its philosophy, together with a description of sample capstone design projects, and the participation of industrial sponsors in these projects. Papers will be presented by the PIs at the Frontiers in Education Conference, and at other professional society meetings and symposia.

The second means of dissemination is through a workshop held at the end of the project. The objective of the workshop will be to gather faculty and industrial participants to discuss the findings of the project and the impact and value to education.

The third means will be the establishment of an Internet site for computer-aided instruction and distance learning. Video and multimedia instruction will be developed and used as teaching tools. Moreover, the existing OSU distance learning system that connects classrooms to off-site participants will be used. This interactive television originating live from specially equipped classrooms is videotaped and will be disseminated among participating universities.

Special efforts will be made to encourage enrollment of women and minority groups. In fact, the OSU campus has a large minority student population (~ 7,000) and is rising steadily. This group will be targeted with incentives such as Undergraduate Research Scholarships through the Office of Research and the Women in Engineering program. Other minority groups will be targeted through distance learning and outreach programs. Initially, the STDP universities will be targeted. Systematically, the program will expand to other schools. Activities of the outreach program will be coordinated through the contact person who will also take an active role in the development and teaching of some of the special topics. It is recognized that students learn differently, by utilizing multi-media it is anticipated that women and minorities may have a more "class room friendly" and better learning environment. This could lead to better recruitment and retention of these groups. Course materials will be made available through Internet, videotapes and animation CDs. Some of these materials may appeal to the NSTA.

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