Annual report to SNEAP – 2006

Ferguson S. M., Kayani A. and Kern A.
Dept of Physics – MS 5252, Western Michigan University, Kalamazoo MI 49008-5252, USA

The most important change at the WMU accelerator laboratory this past year was the retirement of Steve Ferguson, who served as accelerator physicist for more than 31 years. He was replaced by Asghar Kayani, who came to WMU from a post-doc at Montana State University. He received his PhD from Ohio University. Steve officially retired at the end of March, but volunteered part time until Asghar took over on the first of July.

The Physics Department took advantage of this personnel change to persuade the university to change the accelerator physicist position from Professional and Administrative staff to Faculty Specialist. This means that Asghar was appointed to a tenure track faculty position with the provision that he heads the accelerator lab instead of teaching classes.

Asghar Kayani is a condensed matter/surface science physicist. His expertise is in the science of advanced materials, and he is a specialist in ion beam analysis of materials. His research projects are related to the development of solid oxide fuel cells (SOFCs) and hydrogen storage materials as a step towards decreasing dependence on fossil fuel with the implementation of a hydrogen economy.

Briefly, the SOFC is a device to produce electricity through the chemical process of combining hydrogen and oxygen to make water. SOFCs operate at a high temperature, typically 800-1000 ºC, where the oxygen ions can readily diffuse through the solid oxide electrolyte material (zirconia). The voltage of an individual cell is relatively low, about 0.7 V, so for an application requiring several volts such as a computer or electrical instrument, individual cells are stacked together with a metal plate between each cell. Metal is the desirable material so as to keep the cost of the cell low. However, a metal plate in this mixed oxygen, hydrogen, and water environment at high temperature quickly corrodes and fails to transfer electrical current from one cell to the next. One of Kayani's research projects is focused on improving the performance of these metal plates.

A second problem with the metal plates between cells arises when they are fabricated from low-cost steels. Chromium oxide forms on the surface of the steel and evaporates from the surface during cell operation. This chromia vapor then moves through the cell to the critical triple phase boundary region where it poisons the electrochemical process. Kayani uses ion beam analysis to study the mechanism by which the chromia vapor poisons the SOFC operation, in this case, to track oxygen incorporation into the zirconia electrolyte of the SOFC. The process uses isotopes of oxygen, much like chemists use isotopes of carbon to track important processes at the atomic scale. Tracking oxygen diffusion in an oxide material is difficult, but can be accomplished by using ion beam techniques.

Achieving the goals of the hydrogen economy requires improving the ability to store large quantities of hydrogen and to reversibly and quickly charge or discharge hydrogen from the storage medium. This project consists of basic research to understand and improve the kinetics of the hydrogen absorption/desorption process for new materials using plasma coating or surface modification treatments. The program is designed from the outset to accommodate industrial scale production. Specifically, the storage capacity and charging/discharging kinetics of hydrogen in bulk novel materials is characterized, and contrasted to the performance of similar materials synthesized with nanoscale coatings deposited using magnetron sputtering and a filtered arc plasma deposition process. This research allows Kayani to better understand the dependence of the hydrogen absorption/desorption kinetics on material microstructure, composition, and impurities/dopants by means of optical and electron spectroscopy and ion beam analysis techniques.

All of the projects mentioned above involve use of ion beams. A complete picture of materials elemental composition and structure can be obtained using Rutherford backscattering (RBS), nuclear reaction analysis (NRA), ion channeling and Particle induced x-ray emission (PIXE)

To pursue an ion beam analysis program we will have to increase the intensity of our He beam. Therefore, we have designed a sodium vapor oven to take the place of the hydrogen exchange canal in the duoplasmatron ion source.

We have a two-axis precision goniometer that was used for channeling measurements in crystals many years ago. We modified it for use in an experiment involving the transport of electrons through a micro-channel plate. Since the goniometer had to be placed at the center of the large electron scattering chamber, we had to redesign the drive mechanism. The two stepping motors were placed on a flange outside the chamber with their shafts pushed into the vacuum through sliding O-ring seals. The shafts were connected to the goniometer via universal joints and variable length drive shafts. An ICP DAS I-7050 digital I/O module (7 in, 8 out) was connected to the goniometer stepper motor controllers and a Lab VIEW application was developed. I-7000 data acquisition modules employ differential 2-wire half-duplex RS-485 protocol. The data acquisition rate is fairly slow (10Hz), but the modules are inexpensive (I-7050 - $125). Up to 256 modules can be put on one network.

We also developed a Lab VIEW application with an I-7050 interface to read out an Ortec 776 counter.

We added a vacuum control panel to the negative ion source (NIS). Two highschool students who are enrolled in the Kalamazoo Area Math and Science Center mentorship program, Jesse Denardo and Jeremey Liggett, designed and built this panel. They followed our usual practice of placing the switches and indicator LEDs on a diagram of the vacuum system.

A system to detect leaks in the lab chilled water system was installed. The system will be interfaced to Lab VIEW. When personnel are not present, notification of trouble will be via automated phone messages.