Overview of the Sidney Kimmel Institute for Nuclear Renaissance (SKINR)

G.K. Hubler, A. El-Boher, O. Azizi, D. Pease, J.H. He, S. Gangopadhyay

Abstract: The Anomalous Heat Effect (AHE) is the appearance of excess energy in the form of heat when a Pd cathode is electrolyzed in heavy water (D_2O) and is much less evident when light water (H_2O) is used.[1-4] This paper describes the organization, motivation and plans of an institute formed to perform fundamental research aimed at discovering the mechanism of the AHE.

Introduction

The Sidney Kimmel Institute for Nuclear Renaissance (SKINR) was established in April 2012 as an entity within the Department of Physics and Astronomy at the University of Missouri (UM) that reports directly to the Vice Chancellor for Research. The Institute was formed through negotiations between Dr. Robert Duncan and philanthropist Sidney Kimmel. Mr. Kimmel provided initial 5-year funding totaling \$5.5 M. The nucleus of the SKINR staff originated with the company Energetics LLC. Energetics had carried out research since 2002 in the anomalous heat field.

The MISSION of SKINR is "to find the origin of the Anomalous Heat Effect (AHE) with a sound materials science approach and with no preconceptions as to the origin of the phenomenon. To publish findings in the open literature and to openly collaborate worldwide with researchers in the field and in cross disciplines."

The SKINR staff is composed of:

- ◆ Orchideh Azizi, Ph.D. (Electrochemist)
- ◆ Arik El-Boher, Ph.D. (Group Leader, Mechanical Engineer)
- ◆ Jinghao He, Ph.D. (Materials Scientist)
- ◆ Graham K. Hubler, Ph.D. (Director, Physicist)
- ◆ Martin De Stefano (Technician)
- ◆ Dennis Pease, Ph.D. (Physicist)

Additional members include four undergraduate students at SKINR, three graduate students, two Post-Docs and two research staff in collaborating departments.

Dr. Duncan initiated SKINR projects with several UM professors. Their activities are supported and guided by SKINR. The experiments are fundamental investigations into aspects related to the Anomalous Heat Effect. The collaborators, and a short description of their experiments, are listed below:

- ◆ Prof. John Gahl, Electrical Engineering: Pd(d,p); Ni(p,p), high intensity ion bombardment using MURR cyclotron, reaction cross-section and exploding PdH/PdD wires using pulsed power
- ◆ Prof. Shubhra Gangopadhyay, Electrical Engineering: Carbon nanotubes (CNT) and graphene-oxide based cathodes, nanoparticle deposition on cathodes, artificially structured cathodes and Pd/Pt/Au deposition on membranes
- ◆ Prof. Kattesh Kattie, Dept. of Radiology: *In situ* Pd nanoparticle deposition on Pd cathodes
- ◆ Prof. Mark Prelas, Nuclear Engineering: PdH/NiH films deposited on Diamond particle detectors and neutrons from thermally shocked TiDx

SKINR Experimental Instruments

Sidney Kimmel Institute for Nuclear Renaissance, University of Missouri

Electrochemical systems:
- -9 open/hybrid cells in isoperibolic calorimeters
- -1 closed cell differential isoperibolic TEM calorimeter
- -2 closed cell isoperibolic TEM calorimeters (from TSEM, Italy)
- -2 open cell mass flow calorimeters (MFC) with ultrasound stimulation
- -1 open testing cell, no calorimetry
- -2 open cell with thin membrane, no calorimetry
- -1 dual electrochemical cell hydrogen permeation system
- -3 SS closed cell mass flow calorimeters
- -1 laser triggering cell with calorimetry on loaded cathode
- -1 cell allowing stress on loaded cathode
- -1 Gorsky Effect cell

Gas systems:
- -1 High Temperature gas reactor with mass flow calorimetry

Diagnostic systems:
- -2 X-ray detectors
- -Gamma detector
- -Neutron detector
- -RF spectrum analyzers (1 kHz-13 GHz)

Materials characterization:
- -SEM
- -Power spectral density
- -AFM
- -X-ray diffraction
- -X-ray texture
- -Electrochemical impedance spectroscopy
- -Hydrogen permeation kinetics
- -Charging protocols

Glow Discharge:
- - 2 Pd-D2 Low Temp. Ion Bombardment with MFC
- - 1 Ni-H2 High Temp. Ion Bombardment with MFC

All systems equipped with National Instruments data collection and control hardware and LabView software

SKINR, ENEA, TSEM have robust collaboration with National Instruments who has furnished hardware, software and training

Table 1. SKINR experimental systems.

The facilities in-house at SKINR are shown in Table 1 and in the photographs. Our materials fabrication capabilities are detailed in Table 2. Dr. Gangopadhyay has a complete VLSI capability that SKINR makes use of through our strong collaboration.

SKINR collaborates worldwide with several of the foremost institutions involved in AHE research. These are detailed in Figure 1. It shows the time-line of involvement by the collaborators, the U.S. funding sources (depleted as of 2013), and the path of Energetics Inc. from a company formed in Israel, to moving to Missouri, to being incorporated into the UM system as an institute in 2012.

Sorting out which experiments will bear fruit is the most difficult task of SKINR. Due to limited resources, we cannot pursue many of the experiments we believe would help elucidate the mechanism of anomalous heat. Anomalous heat is fundamentally a solid-state-physics problem requiring new information about the local environment around Pd and D atoms (and Ni and H atoms). New experiments that we think are important, a few of which we are pursuing, include:

Nuclear Mechanism
—Real time detection of low-energy emissions with a thin membrane system
—Move materials to Ge cave detector ~ minutes after MJ heat event
—Try to detect ^{4}He in closed cell by mass spectroscopy

General Mechanism
—*In situ* neutron scattering during heat events (in discussion with several groups)
—Systematically study effects of polarizing (pulsed) magnetic field
—Stimulate AHE using a femtosecond laser in the structured palladium deuteride system
—Stimulate by tuning acoustic frequencies to resonate with defect processes in cathodes
—Fabricate surface-structured cathodes
—Perform *in situ* perturbed angular correlation (PAC) Hyperfine field measurements during heat production at CERN (performed May-July 2015, to be published)
—Perform *in situ* Mossbauer (in discussion)
—Hydrogen permeation kinetics studies using two cells separated by Pd membrane[5]

Solid State Theory
—Density functional theory for electronic band structure of D in Pd and its alloys

Cathode Development (many choices)
—Self assembled Pd nanoparticle cathodes
—Pd coated carbon nanotube/graphene oxide cathodes
—Artificially structured Pd cathodes
—New alloy compositions
—Understand the metallurgy of Pd in the process of cold rolling and thermal annealing[5]
—Understand the role of electrolyte impurities on the ability to obtain high D/Pd fractions

High Temperature Gas Loading of Ni-H System
—Use SKINR gas reactor to explore heat production in Ni powder/LiAlH up to 1200°C

As an example of a new experimental method, Figure 2 shows schematically the thin membrane experiment being carried out at SKINR and ENEA.[6] The thin membrane allows transmission of X-rays down to 1 keV, alpha particles over ~20 keV and RF out of the electrochemical system to be sensed by the appropriate detectors in air. Most calorimeters have power sensitivity in the range of 1 to 10 mW. Suppose that the anomalous heat mechanism is active much of the time but at the micro-, nano- or pico-Watt level. The calorimeter is insensitive to such low power outputs. If, for example, in the membrane experiment we detect a 1 keV X-ray at a rate of 1 Hz, the corresponding power is 0.2 femtowatts, an excess power sensitivity improvement of 10^{12}.

This experiment was run for over a year with null results.[6] It is running now, improved by depositing a Pt resistor temperature sensor over 100 nm Al_2O_3 directly on the air side of a 50 µm thick Pd membrane. That arrangement provides a very fast, sensitive thermal measurement.

Table 2. SKINR materials fabrication capabilities.

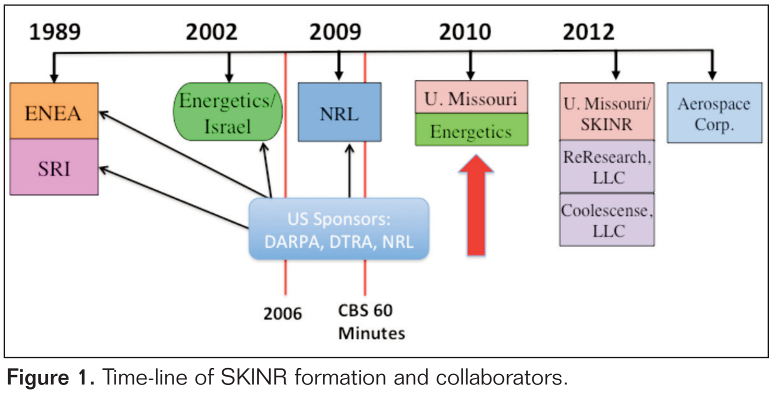


Figure 1. Time-line of SKINR formation and collaborators.

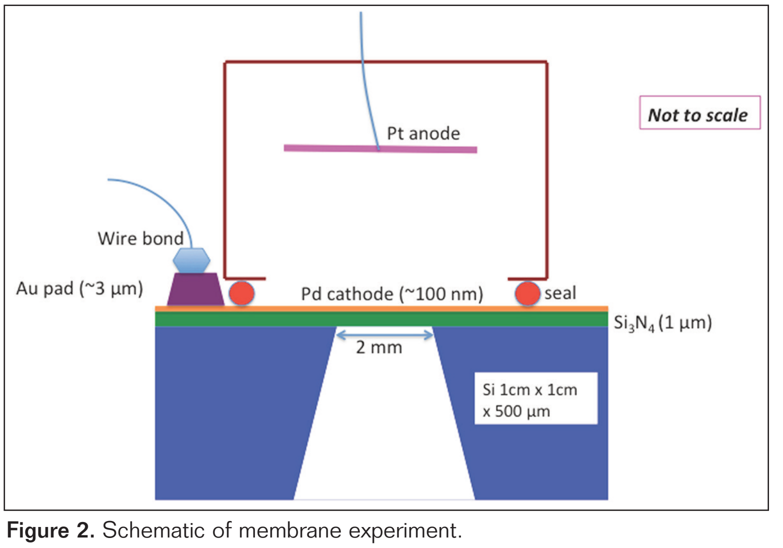
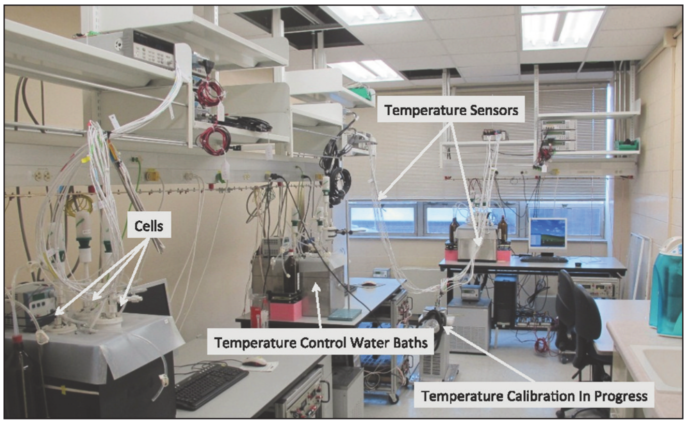
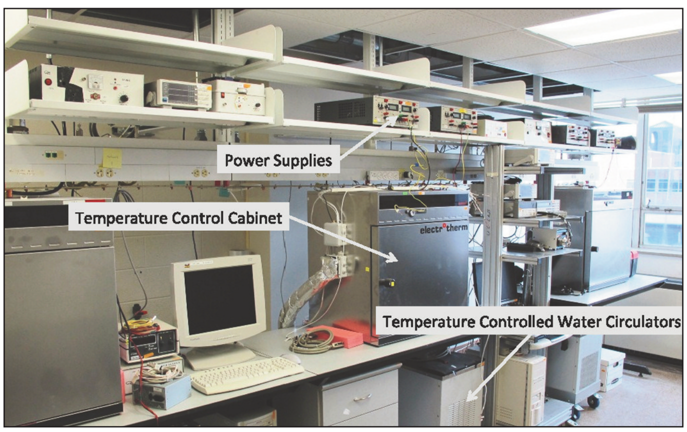


Figure 2. Schematic of membrane experiment.

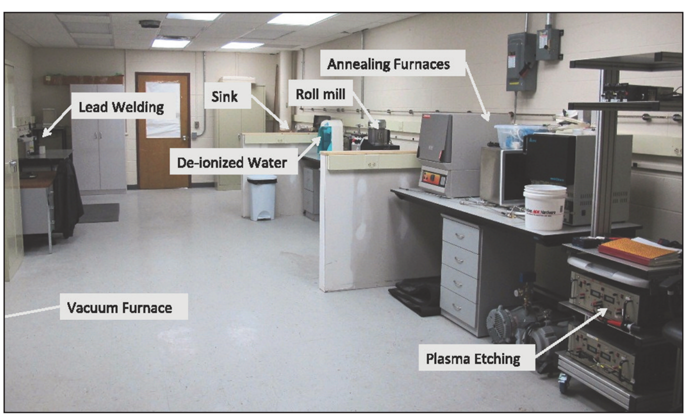


MU Engineering Building West Lab-139,
electrolytic open cell experiments.

MU Engineering Building West Lab-137,
hermetically sealed closed electrolytic experiments.



MU Engineering Building West Lab-137,
ultrasonically excited electrolytic experiments.



MU Engineering Building West Lab-135, sample preparation room.

While the AHE mechanism is not clear, certain facts have become apparent regarding features of cathodes that will produce excess heat. Here we list these facts that have been collected for years.

Facts that support generation of excess heat

—[100] texture of polycrystalline grains[2,4]
—Laser triggering
—Magnetic polarization (from Mitchell Swartz, Dennis Cravens, Dennis Letts)
—D loading ratio > 0.88
—Specific cathode preparation[2,4]

Facts describing foil cathode surface

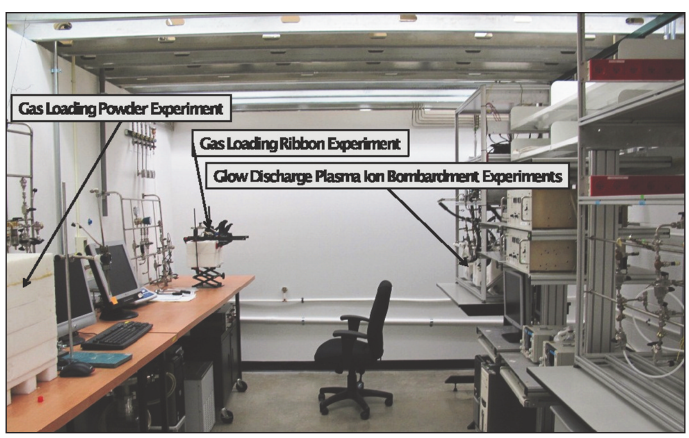
—Surface contaminants important (Pt, Ni, Fe, Si, Al, other?)
—Labyrinth morphology promotes excess heat[2,4]
—Peaks in power spectral density correlated with appearance and amplitude of anomalous heat[2,4]
—Strong RF emission from heat producing cathodes

Summary

SKINR owes its existence to Sidney Kimmel, Energetics LLC, CBS News and Dr. Rob Duncan. We are studying both electrochemical and gas loading experiments in palladium deuterium/hydrogen systems, but with main emphasis on the electrochemical method where we have had all of our positive results. Our near-term goals are increasing reproducibility in electrolysis experiments, and mechanistic studies that may lead to improved understanding of the origin of anomalous heat. Results from more fundamental experiments are needed to be able to formulate a working model for the FPE. Extensive collaborations were developed inside UM and with outside institutions, and we invite more collaborators. We believe in open research objectives, plans and publication of results. We have much optimism at SKINR that the rate of unraveling the mysteries of the AHE is accelerating.

References

1. Hubler, G.K. 2007. "Anomalous Effects in Hydrogen-Charged Pd: A Review," *Surf. Coatings Tech.*, 201, 8568.
2. Violante, V., Castagna, E., Lecci, S., Sarto, F., Sansovini, M., Makris, T.D., Torre, A., Knies, D., Kidwell, D., Grabowski, K., Dominguez, D., Hubler, G.K., Duncan, R., El Boher, A., Azizi, O., McKubre, M. and La Gatta, A. 2013. "Excess of Power During Electrochemical Loading: Materials, Electrochemical



MU Physics Building Lab-301.

Conditions and Techniques," *Proc. 18th Inter. Conf. on Cold Fusion*.
3. Azizi, O., El-Boher, A., He, J.H., Hubler, G.K., Pease, D., Isaacson, W., Violante, V. and Gangopadhyay, S. 2015. "Progress Towards Understanding Anomalous Heat Effect in Metal Deuterides," *Cur. Sci.*, 108, 565.
4. Violante, V., Castagna, E., Lecci, S., Sarto, F., Sansovini, M., Torre, A., LaGatta, A., Duncan, R., Hubler, G.K., El-Boher, A., Azizi, O., Pease, D., Knies, D. and McKubre, M. 2015. "Review of Materials Science for Studying the Fleischmann-Pons Effect," *Cur. Sci.*, 108, 540.
5. Azizi, O., He, J., Paterson, D., El-Boher, A., Pease, D. and Hubler, G. 2015. "Effect of Cathode Pretreatment and Chemical Additives on H/D Absorption into Palladium via Electrochemical Permeation," *Proc. ICCF19*, April 2015, Padua, Italy, to be published.
6. Pease, D., Azizi, O., He, J., El-Boher, A., Bok, S., Mathai, C., Gangopadhyay, S., Katti, K., Katti, Kav. and Hubler, G. 2015. "Search for Low-energy X-ray and Particle Emissions from an Electrochemical Cell," *Proc. ICCF19*, April 2015, Padua, Italy, to be published.

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