Sidney Kimmel Institute for Nuclear Renaissance

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Anomalous heat effect (AHE) is the appearance of excess energy in the form of heat when a palladium cathode is electrolysed in heavy water, and is much less evident when light water is used. The present article describes the organization, motivation and plans of an institute formed to perform fundamental research aimed at discovering the mechanism of AHE.

Keywords: Anomalous heat effect, excess energy, hydrogen, palladium.

Introduction

THE Sydney Kimmel Institute for Nuclear Renaissance (SKNIR) was established in April 2012 as an entity within the Department of Physics and Astronomy at the University of Missouri (UM), USA, that reports directly to the Vice Chancellor for Research (VCR), Doctor Rob Duncan. The Institute was formed through negotiations between Robert Duncan and philanthropist Sydney Kimmel, which concluded on an agreement between UM and Kimmel to provide initial 5-year funding totalling US$ 5.5 million. The nucleus of the SKINR staff (Box 1) originated with the company Energetics, LLC. Energetics had carried out research since 2002 in the anomalous heat (AH) field.

The mission of SKINR laid out by Duncan 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.'

Duncan initiated SKINR projects with several UM professors. Their activities are supported and guided by SKINR and experiments are fundamental investigations into aspects related to the anomalous heat effect. The collaborators, and a short description of their experiments, are listed in Box 2.

The in-house facilities at SKINR are listed in Table S1 and Figure S1 (see Supplementary Information online), and materials fabrication capabilities are detailed in Table S2 (see Supplementary Information online). In addition, Shubra Gangopadhyay has complete VLSI capability that SKINR makes use of through strong collaboration.

SKINR collaborates worldwide with several of the foremost institutions involved in AH research. These are

Box 1. The SKINR staff

- Orchideh Azizi, Ph D (electrochemist)
- Arik El-Boher, Ph D (Research group leader, mechanical engineer)
- Jinghao He, Ph D (materials scientist)
- Graham K. Hubler, Ph D (director, physicist)
- William Isaacson (technician)
- Dennis Pease, Ph D (physicist)

Additional members include four undergraduate students at SKINR, five graduate students, two Postdocs and one research staff in collaboration departments.

Box 2. SKINR project collaborators

John Gahl: Electrical engineering: Pd(d,p); Ni(p,p), high intensity ion bombardment using MURR cyclotron, reaction cross-sections, exploding PdH/PdD wires using pulsed power.

Shubhra Gangopadhyay: Electrical engineering: carbon nanotubes and graphene oxide-based cathodes, artificially structured cathodes; Pd/Pt/Au deposition on membranes.

Helmut Kaiser: Department of Physics and Astronomy/MURR: *in situ* neutron scattering during electrolysis on the PdD system.

Kattesh Kattie: Department of radiology: *in situ* Pd nanoparticle deposition on Pd cathodes.

Scot Kovaleski: Electrical Engineering: piezoelectric ion sources, low-energy ion bombardment.

Mark Prelas: Nuclear engineering: PdH/NiH films deposited on diamond particle detectors; neutrons from thermally shocked TiDx.

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detailed in Figure 1 that shows the timeline of involvement by the collaborators, the US funding sources (depleted as of 2013), and also the path of Energetics Inc. from a company formed in Israel, to moving to Missouri, and to being incorporated into the UM system as an Institute in 2012.

Sorting out which experiments will bear fruit is the most difficult task for SKINR. Due to limited resources we cannot pursue many of the experiments we deem would help elucidate the mechanism of anomalous heat. New experiments that we consider important, a few of which we are currently pursuing, include the following.

Nuclear mechanism

- Real-time detection of low energy emissions with thin membrane system.
- Move materials to Ge cave detector a few 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.
- Systematically study effects of polarizing (pulsed) magnetic field.
- Stimulate AH 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 perturbed angular correlation hyperfine magnetic field measurements during heat production at CERN (in discussion).
- Hydrogen permeation kinetics studies using two cells separated by Pd membrane.

Solid state theory

- Density functional theory for electronic band structure of D in Pd and its alloys.

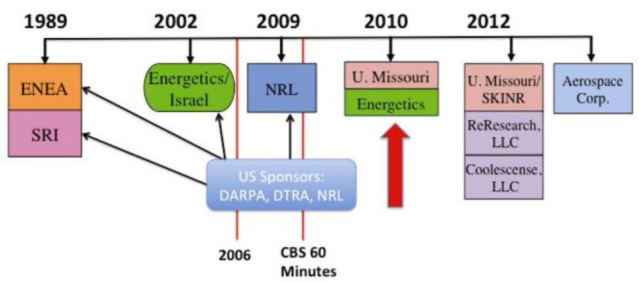

Figure 1. Timeline of anomalous heat research in the Sydney Kimmel Institute for Nuclear Renaissance, USA.

Cathode development (many choices)

- Self-assembled Pd nanoparticle cathodes.
- Pd-coated carbon nanotube/graphene oxide cathodes.
- Artificially structured Pd cathodes.
- New alloy compositions.
- Understanding the metallurgy of Pd in the process of cold rolling and thermal annealing.

As an example of a new experimental method, Figure 2 schematically shows the thin membrane experiment being carried out at SKINR and ENEA, Frascati Laboratory. The thin membrane allows transmission of X-rays down to 1 keV, alpha particles over ~20 keV and radio frequency (RF) out of the electrochemical system to be sensed by the appropriate detectors in air. Most calorimeters have power sensitivity in the range 1–10 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 this power output. 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}. While the AH 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[1–4]

- [100] texture of polycrystalline grains.
- Laser triggering.
- Magnetic polarization (from Mitch Swartz, Dennis Cravens and Dennis Letts).
- D loading ratio >0.9.
- Specific cathode preparation (rolling, annealing and etching – consult papers from Violante, ENEA).

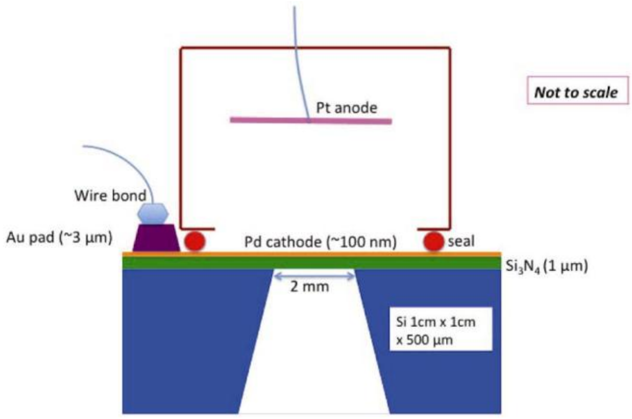

Figure 2. Schematic of membrane experiment.

Facts that do not support nuclear model

- No high-energy neutron or gamma ray emission.
- No activation of materials in electrochemical cell.

Facts describing foil cathode surface

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

Summary

SKINR owes its existence to Sidney Kimmel, Energetics LLC, CBS News and 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. We have developed extensive collaborations inside UM and with other institutions as well and we invite more collaborators. We believe in completely open research objectives, plans and publication of results. We have much optimism at SKINR that the rate of unravelling the mysteries of AH is accelerating.

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