Low Energy Nuclear Reactions

An Energetics Revolution for ALL of NASA's Missions

and

A Solution to Climate Change and the Economic Meltdown

J. M. Zawodny - August 12, 2009

LENR History

- 1989 Pons & Fleischmann announce Cold Fusion from an electrochemical cell containing PdD
- Physics community promptly discredit the claim
- The problem was their attribution to D-D fusion
  - Energetics of overcoming the Coulomb barrier
  - High energy neutrons not observed
- P&F experiment did produce excess heat and He
- Difficult to reproduce, experiments took 100 days
- Investigation of excess heat and transmutation of elements in electrochemical cells has continued worldwide.

LENR since P&F

- Today, there are many groups around the world working on LENR, 20+ in the US alone.
- Abundant evidence for excess heat and element transmutation with both Deuterium and Hydrogen metal hydrides with increased reproducibility
- Wide range of successful experimental methodologies (PdD, NiH, liquid & gas phase, …)
- Nearly every group has developed their own theory (all requiring “New Physics” or Miracles)
- All theories are based on the Strong Nuclear force and are variants of Cold Fusion
- … except for one new theory

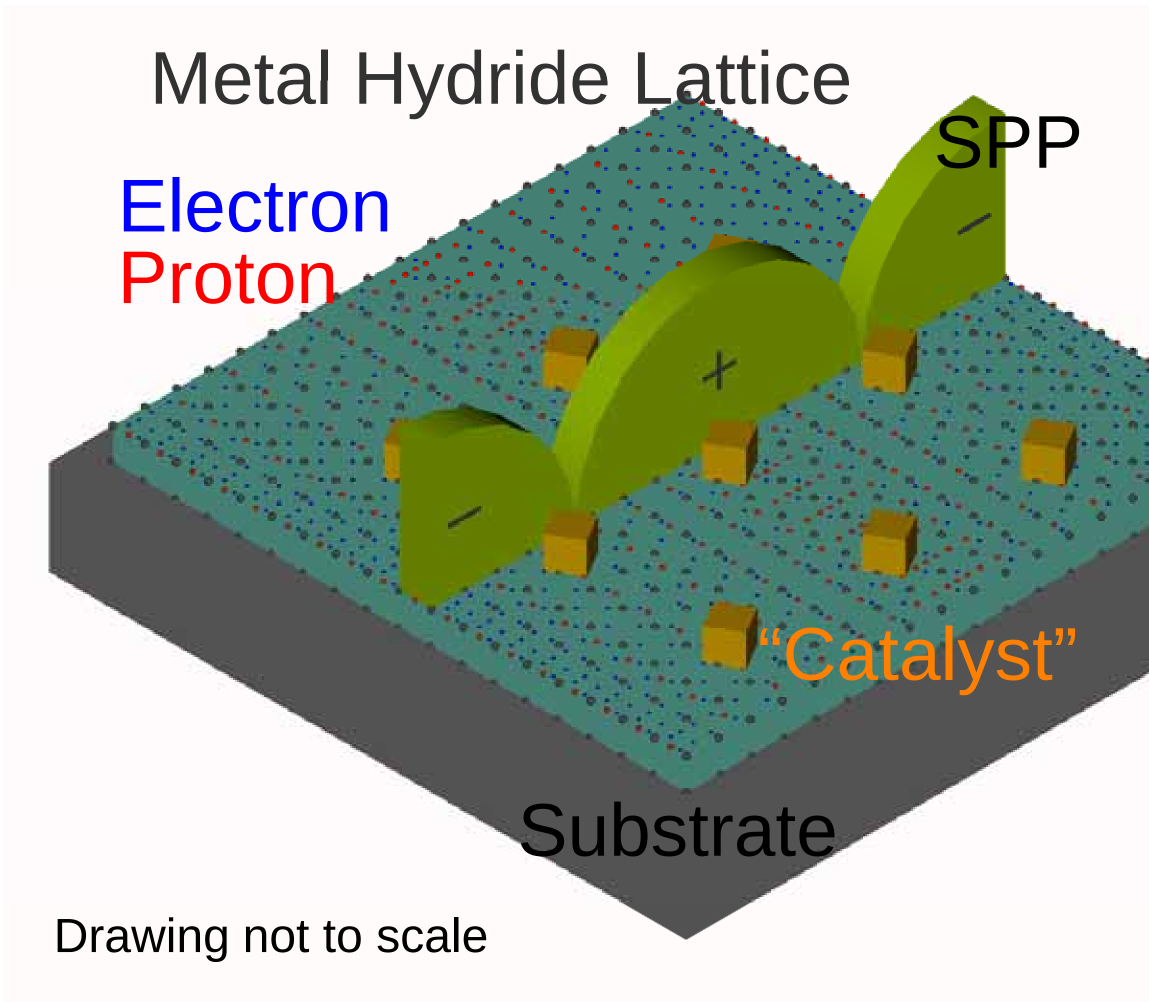
Widom-Larsen Theory

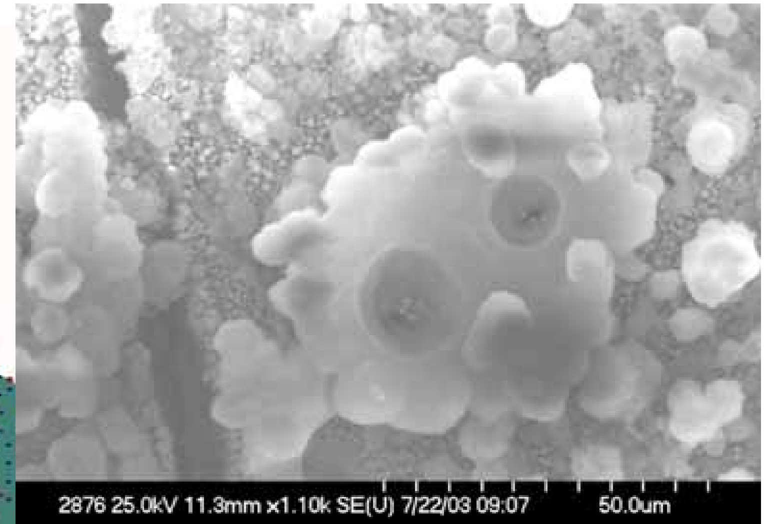
- Lewis G. Larsen developed a theory of LENRs (WLT) that explains ALL the evidence and along with Dr. Alan Widom published their theory in Eur. Phys. J. C (2006)
- WLT is 1st theory to not require "New Physics".
- It relies on the Weak Nuclear force which:
  - Produces a neutron via electron capture
  - Does not have a Coulomb barrier to overcome
- The theory combines QED, Condensed Matter, Nuclear, and Plasma Physics
- We (NASA) now understand this theory.

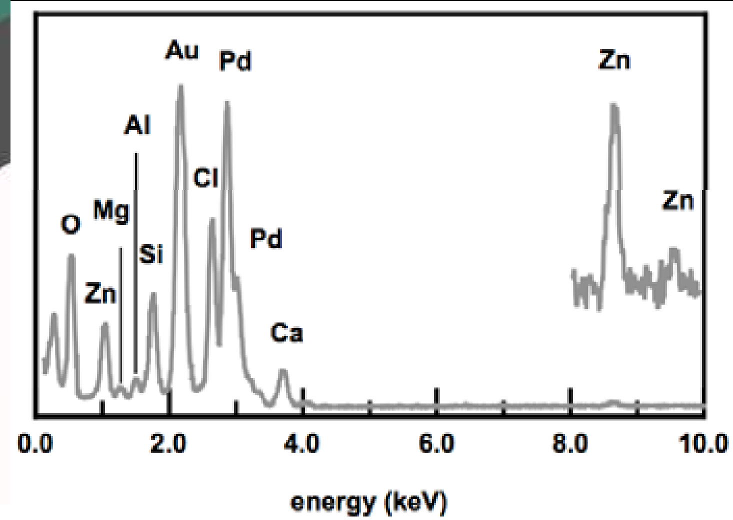
WLT Overview

- $p + e^* \Rightarrow n + \bar{\upsilon}_e$ Inhibited by 0.78MeV
- e* is a "heavy electron" allowed by QED - requires high electric fields (~10^{11}V/m or 10V/Å)
- High fields result from a breakdown of the Born-Oppenheimer Approximation via a coupling of Surface Plasmon Polaritons to a collective proton resonance in the metal hydride.
- The result is an Ultra Low Momentum Neutron which is rapidly absorbed by nearby nuclei.
- Subsequent decays release significant energy.
- Select impurities/catalysts determine the overall energetics

Diagram, Image, and Data







WLT Predictions

- Reaction rate is related to the SPP amplitudes near the proton resonant frequency
- Reactions are sporadic on smooth or randomly patterned devices driven by broadband SPPs
- Reaction rate should increase for patterned / resonant devices
- Reaction rate should increase when driven at the proper frequency

WLT Energetics

- An example of the Li-Be-He cycle energetics
  - $p + e^* \Rightarrow n + \bar{\upsilon}_e$ Inhibited: 0.78MeV x6 = ~5MeV
  - $^6Li + n \Rightarrow {}^7Li$
  - $^7Li + n \Rightarrow {}^8Li$
  - $^8Li \Rightarrow {}^8Be + \beta + \upsilon_e$
  - $^8Be \Rightarrow {}^4He + {}^4He$ ~27MeV released to this point
  - $^4He + n \Rightarrow {}^5He$ This cycle runs twice
  - $^5He + n \Rightarrow {}^6He$
  - $^6He \Rightarrow {}^6Li + \beta + \upsilon_e$ ~3MeV x2 released here
- In this cycle 6 protons and 3 electrons are converted to a ^6Li and 9 (anti)neutrinos with a net release of ~28MeV (other cycles exist)

Energy Density Comparison

- Fission - Strong nuclear force - 3% Efficient
  - $^{235}U + n \Rightarrow {}^{92}Kr + {}^{141}Ba + n + n +$ ~200MeV
  - 88,000,000 MJ/Kg or 1,900,000 times chemical
- Fusion - Strong nuclear force - ~5% Efficient
  - $^{2}H + {}^{3}H \Rightarrow {}^{4}He + n +$ ~18MeV
  - $^{2}H + {}^{2}H \Rightarrow {}^{3}H + p +$ ~4MeV
  - or $\Rightarrow {}^{3}He + n +$ ~3MeV
  - 337,000,000 MJ/Kg or 7,300,000 times chemical
- LENRs - Weak nuclear force - TBD% Efficient
  - $6p + 3e \Rightarrow {}^{6}Li + 6\ \bar{\upsilon}_e + 3\ \upsilon_e +$ 28MeV
  - ~370,000,000 MJ/Kg or **8,000,000 times chemical!**
  - W-L conservative estimate - 4,000 times chemical

Ramifications

- Nuclear-like energy densities **Scalable** from mW to GW
- Little or no need for radiation shielding - **Portable**
  - Adaptable to the full range of transportation systems
  - Wholly obviates the reasons (weight, safety, attendant costs) fission is not used
- **Revolutionizes Aviation and Access to Space**
  - No GHG (CO_2, H_2O, aerosols, …) concerns
  - Decouples energetics from reaction mass
  - Fuel mass essentially goes away for air-breathing applications, reduces total mass
  - Fuel is very cheap (electrolysis of H_2O)
- **Total replacement of fossil fuels** for everything but synthetic organic chemistry

Example: Aircraft

The impact LENR would have on commercial, military, and civilian/personal aircraft

- Essentially no change in mass from takeoff to landing (1% LENR efficiency would allow **2Kg** H_2 to fuel a 747 on 9800km flight)
- No harmful emissions
- Increased safety
  - Non-flammable
  - Excess power (High thrust/weight)
- Increased performance
  - Payload
  - Speed
  - Altitude

Example: ETO

The impact LENR would have on Space Access

- Significantly reduced launch mass
  - Collect reaction mass on the way up
  - Collect reaction mass during aero-capture/aero-breaking
  - Collect reaction mass during reentry
- Improved Safety - non-flammable
- Potential for high ISP
- Low fuel mass (burn rate) may enable horizontal take off. No need to throw mass straight up initially. Better integration with existing infrastructure.

Example: Surface Transports

The impact LENR would have on Surface Transportation

- Elimination of emissions
- Safety - non-flammable
- Extended range
- Increased power
- If you can build a rocket or plane using this, you can certainly power just about any other form of transportation.

Example: Energy & Climate

- LENRs could replace Coal, Oil, Natural Gas fired power plant heat sources with minimal impact to the extant generation and distribution infrastructure
- Similarly, LENRs could be drop-in replacements for conventional nuclear reactor heat sources in nuclear power plants
- LENRs could co-generate electricity and useful heat for on-site commercial (ore processing, thermoforming, cement, …) and consumer heating (furnace & hot water) needs
- LENR powered desalination plants could produce fresh water while simultaneously producing power (H_2) and converting dissolved CO_2 to $CaCO_3$ via electrolysis

Activities @ NASA LaRC

- System Architecture studies to assess impact on Aircraft and Access to Space
- Design and execute an independent experiment that demonstrates fundamental understanding of the theory and its practicality.
  - Devices designed and fabrication-ready
  - Novel experimental apparatus designed & being fabricated
  - Identifying risks and suitable facility
  - Seeking complementary measurements & analysis

The End

STOP

Activity in the US (partial)

1. Naval Research Laboratory
2. Space and Naval Warfare Systems Center (SPAWARS)
3. U.S. Navy China Lake Naval Weapons Laboratory
4. Los Alamos National Lab
5. Massachusetts Institute of Technology, Cambridge, MA
6. SRI International, Menlo Park, CA
7. University of California, San Diego, CA
8. University of California, Berkeley, CA
9. George Washington University
10. Purdue University
11. Rice University
12. Montclair State University, New Jersey
13. University of La Verne
14. Texas A&M
15. University of Illinois, Urbana, IL
16. Lattice Energy, LLC
17. Black Light Power
18. JWK Technologies Corporation
19. JET Thermal Products
20. Kiva Laboratory, LLC
21. Coolescence, LLC
22. Infinite Energy Magazine and Research Systems, Inc

New Energy Times Comment:
This list is outdated and inaccurate

Activity Abroad (partial)

1. China Institute of Atomic Energy, China
2. Department of Physics, Tsinghua University, Beijing, China
3. Laboratoire des Sciences Nucléaires, Paris, France
4. Bhabha Atomic Research Centre, Trombay, India
5. ENEA, Frascati, Italy
6. INFN-LNF Frascati, Italy
7. EURESYS, Roma, Italy
8. University of Catania, Department of Physics Catania, Italy
9. Hydrogen Energy Research Agency Velletri, Italy
10. Energetics Technologies, Israel
11. Osaka National University, Japan
12. High Scientific Research Laboratory, Marunouchi, Japan
13. Mitsubishi Heavy Industries, Japan
14. Toyota Central Research & Development Laboratories, Inc., Aichi, Japan
15. P.N. Lebedev Physics Institute of Russian Academy of Sciences, Moscow, Russia
16. Institute of Physical Chemistry & Electrochemistry, RAS, Moscow, Russia
17. Moscow State University, Moscow, Russia
18. FSUE 'LUCH', Moscow, Russia
19. Joint Institute for Nuclear Research, Dubna, Russia
20. University Dubna, Dubna, Russia
21. Electrodynamics Laboratory "Proton-21" Ukraine
22. Kiev National Shevchenko University, Kiev, Ukraine
23. Institute of Microbiology and Virology, Kiev, Ukraine
24. Institute of problems of NPP safety, Kiev, Ukraine

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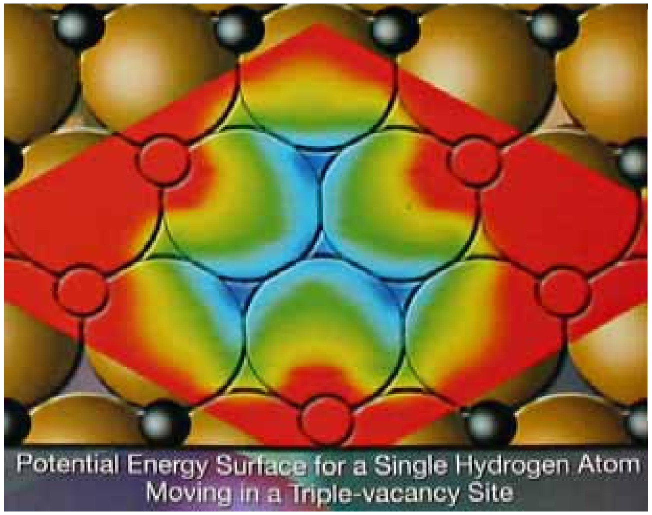
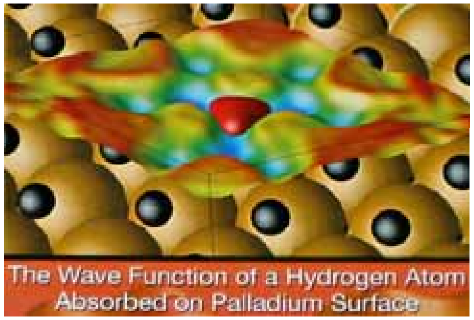
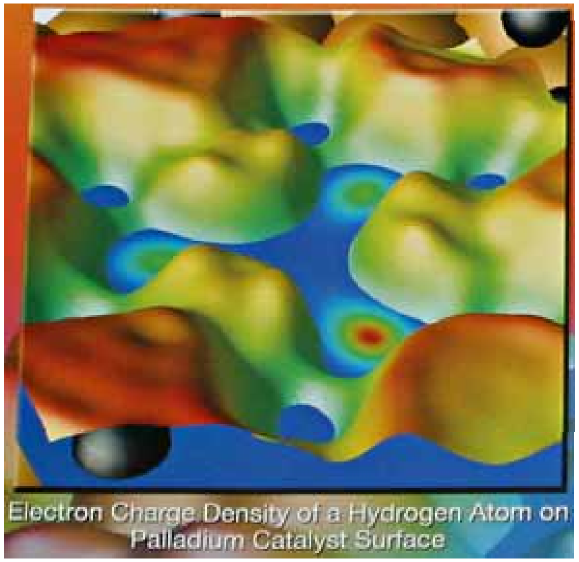
Next Level Questions

- Why does the hydrogen loading have to exceed an apparent minimum value?
  - How do vacancies alter the collective effects
- Do the high fields result from an inability to maintain a pseudo-solid body (quasi-crystalline) motion?

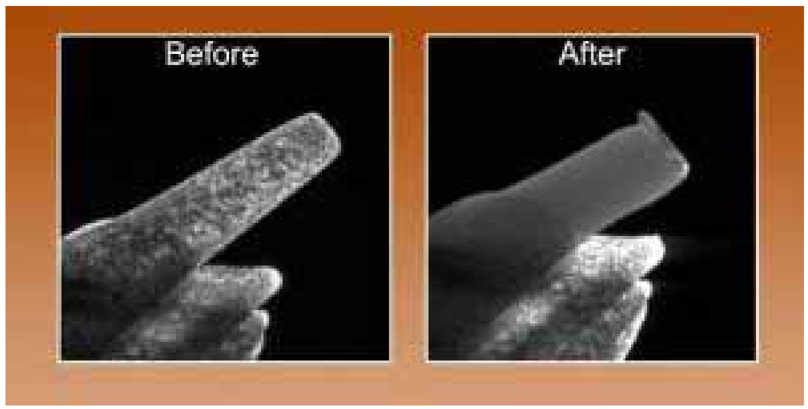






Next Level Questions

- Why is sample preparation so critical?
  - Surface layer contaminants?
  - Are cracks and other lattice defects vital?



- How can we model the generation of high fields?
  - How to take this from the parlor and into the factory?

System Components

SPP sources

- Electron beam
- Ion flux
- Photons
- Plasmonics
- Phonons

Reactor Types

- I: One-shot
- II: Steady state
  - A: Closed
  - B: Open
- III: Flow-through

Control Systems

- Sensors
- Thermal
- Fuel flow
- “Throttle”

Materials

- Lattice
- Fuel/isotope
- Catalyst
- Products

Reactor Geometry

- 2-D Islands
- 3-D Pits
- Tubular flow
- Sheet flow

System Integration

- Heat extraction
- Heat conversion
- Fuel system
- Maintenance