Lattice Energy LLC

Clive Irving explains MH-370 mystery in The Daily Beast

Lithium battery cargo fire could have compromised 777's avionics bay

Quoting from Irving's story: "… likely effects of a fire initiated in the two pallets of lithium-ion batteries placed in the forward cargo hold --- and the proximity of the cargo hold to the 777's electronics nerve center --- could have caused the loss of the communications and navigation systems by destroying the power supply line to them, but not the loss of flight controls."

Credit: AFP / Getty images

Lewis G. Larsen
President and CEO
Lattice Energy LLC
October 15, 2015

Credit: Getty images

By July 2010 Lattice had determined that ultralow energy neutron reactions (LENRs) could be triggering a subset of dangerous spontaneous thermal runaways and explosions in Lithium-based batteries carried in aircraft cargo and began issuing public warnings.

Our early technical reports on Li-ion battery safety were met with deafening silence.

Contact: 1-312-861-0115 Chicago, Illinois USA lewisglarsen@gmail.com

http://www.slideshare.net/lewisglarsen/presentations

Clive Irving explains MH-370 mystery in The Daily Beast

Lithium battery cargo fire could have compromised 777's avionics bay

THE DAILY BEAST

EXPLOSIVE 10.15.15 1:13 AM ET

The Deadly Cargo Inside MH370: Exploding Batteries Explain the Mystery

Exclusive insight from inside Boeing and urgent new warnings from the FAA make a compelling case–based on fact, not conspiracy–about what happened.

http://www.thedailybeast.com/articles/2015/10/15/the-deadly-cargo-inside-mh370-how-exploding-batteries-explain-the-mystery.html

Clive Irving is senior consulting editor at ***Condé Nast Traveler***, specializing in aviation; and the author of ***Wide-Body: The Triumph of the 747*** (Morrow).

Clive Irving explains MH-370 mystery in The Daily Beast

Lithium battery cargo fire could have compromised 777's avionics bay

- ✓ Clive Irving's October 15, 2015 *Daily Beast* article is a truly excellent piece of investigative journalism and must-read for anyone interested in understanding the likely fate of the Boeing 777 aircraft in Malaysian Airline's ill-fated flight MH-370
- ✓ Theory of the mysterious MH-370 event propounded in his article --- that (1) a fiery conflagration triggered by a Lithium-ion thermal runaway battery fire in Motorola cargo positioned in close proximity to the Boeing 777's forward avionics bay; and (2) breached a nearby bulkhead which compromised the integrity of key aircraft equipment located in that bay; and that (3) toxic fumes and smoke from the fire subsequently incapacitated or killed the flight crew and passengers --- is fully consistent with the presently known collection of facts about this tragic incident
- ✓ Irving and his technical experts theorize that --- a very hot Lithium-ion battery fire and perhaps explosion (1) could occur *spontaneously* and (2) release enough thermal energy to fuel a catastrophic cargo fire capable of (3) damaging the plane's avionics bay and (4) ultimately incapacitating most if not all of the people on board MH-370 --- is fully consistent with Lattice's predictions about the likely probabilities and dangerous heating behavior of spontaneous thermal runaways, especially those called "field-failures" that can occur in Lithium-based batteries
- ✓ **Conclusion:** Lithium-based batteries in air cargo can pose very serious safety risks

http://www.thedailybeast.com/articles/2015/10/15/the-deadly-cargo-inside-mh370-how-exploding-batteries-explain-the-mystery.html

Increasing awareness of risks with Lithium-ion batteries

U.S. FAA recently made an excellent presentation at meeting in Europe

Boeing very recently warned airlines re risks with Li-ion batteries shipped in cargo

International Aircraft Systems Fire Protection Working Group Meeting
Dresden, Germany, May 12-13, 2015

Fire Hazards of Lithium Ion Batteries

Richard E. Lyon, Richard N. Walters, Sean Crowley,
and *James G. Quintiere

24 PowerPoint slides - for pdf copy go to:

http://www.fire.tc.faa.gov/pdf/systems/may15meeting/lyon-0515-batteryheatrelease.pdf

Exactly 5 years ago, Lattice begin to publicize risks with Li-ion batteries carried inside commercial aircraft because LENRs can potentially trigger catastrophic field-failures; back then, some labeled us as "fear mongers"

Increasing awareness of risks with Lithium-ion batteries

U.S. FAA recently made an excellent presentation at meeting in Europe

FAA Li-ion cargo fire experiment #1

Image: AP photo of FAA video

FAA Li-ion cargo fire experiment #2

Image: FAA report

Battery thermal runaways can pose serious safety issues

Portable electronics

Apple iPod Nano
exploding in Japan (2010)

Battery packs

Severely fire-damaged GS-Yuasa
Li-ion battery pack involved in
Logan Airport 787 incident (NTSB)

Thermal runaway

Aircraft

Boeing 787 Dreamliner
Logan Li-ion battery fire (2013)

THE LEGAL EXAMINER

Woman Burned By Exploding E-Cigarette, Awarded 1.9M

Posted by Claude Wyle

October 10, 2015 9:18 AM

http://sanfrancisco.legalexaminer.com/defective-dangerous-products/woman-burned-by-exploding-e-cigarette-awarded-1-9m/

Lattice's technical reports on Lithium battery safety issues

"Technical discussion - October 1 Tesla Motors Model S battery thermal runaway"
October 16, 2013 [82 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-technical-discussionoct-1-tesla-motors-model-s-battery-thermal-runawayoctober-16-2013

"On Oct 1 Tesla Model S caught fire on highway - has company's luck run out"
October 3, 2013 [23 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llcon-oct-1-tesla-model-s-caught-fire-on-highwayhas-companys-luck-run-outoct-3-2013

"Electronic cigarette explodes, burns child sitting in car seat - LENRs in batteries"
September 25, 2013 [58 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-electronic-cigarette-explodes-burns-child-sitting-in-car-seatlenrs-in-batteriessep-25-2013

"Large increases in battery energy densities drive convergence between energetic materials, LENRs and batteries"
September 6, 2013 [108 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-increased-energy-densities-drive-convergence-of-batteries-and-lenrssept-6-2013

Lattice's technical reports on Lithium battery safety issues

"$LiFePO_4$ immune to runaways: another fool's paradise?"
August 21, 2013 [35 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llclithium-iron-phosphate-batteries-are-not-immune-to-thermal-runawaysaug-21-2013

"Containing battery thermal runaways: a fool's paradise?"
August 6, 2013 [93 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-containment-of-lithiumbased-battery-firesa-fools-paradiseaug-6-2013

"Technical discussion: NTSB reports indicate very high temperatures"
May 7, 2013 [51 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-technical-discussionntsb-logan-dreamliner-runaway-data-suggest-high-local-tempsmay-7-2013

"Steel microspheres in NTSB Dreamliner battery SEM images suggest high local temps"
April 30, 2013 [33 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-steel-microsopheres-in-ntsb-dreamliner-battery-sem-images-suggest-high-local-tempsapril-30-2013

Lattice's technical reports on Lithium battery safety issues

Lattice makes comments on, "Microscopic Dendrites Focus in Boeing Dreamliner Probe" - *Wall Street Journal* article published on Feb. 11, 2013
February 11, 2013 [4-pages in MS-Word format]

http://www.slideshare.net/lewisglarsen/microscopic-dendrites-focus-in-boeing-dreamliner-probe-wall-street-journalfeb-11-2013

"LENRs potentially another mechanism for producing so-called field failures that can trigger catastrophic thermal runaway fires in Lithium-based batteries"
January 23, 2013 [28-pages in MS-Word format]

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-field-failures-and-lenrs-in-lithiumbased-batteriesjan-23-2013

"Could LENRs be involved in some Li-ion battery fires? LENRs in advanced batteries"
July 16, 2010 [68 slides]

http://www.slideshare.net/lewisglarsen/cfakepathlattice-energy-llc-len-rs-in-liion-battery-firesjuly-16-2010

Lattice Energy LLC

Commercializing a next-generation source of safe CO_2-free nuclear energy

Following section is for those who wish to learn more about the technical details of LENRs in Lithium-based batteries

Battery industry is likely already encountering LENRs

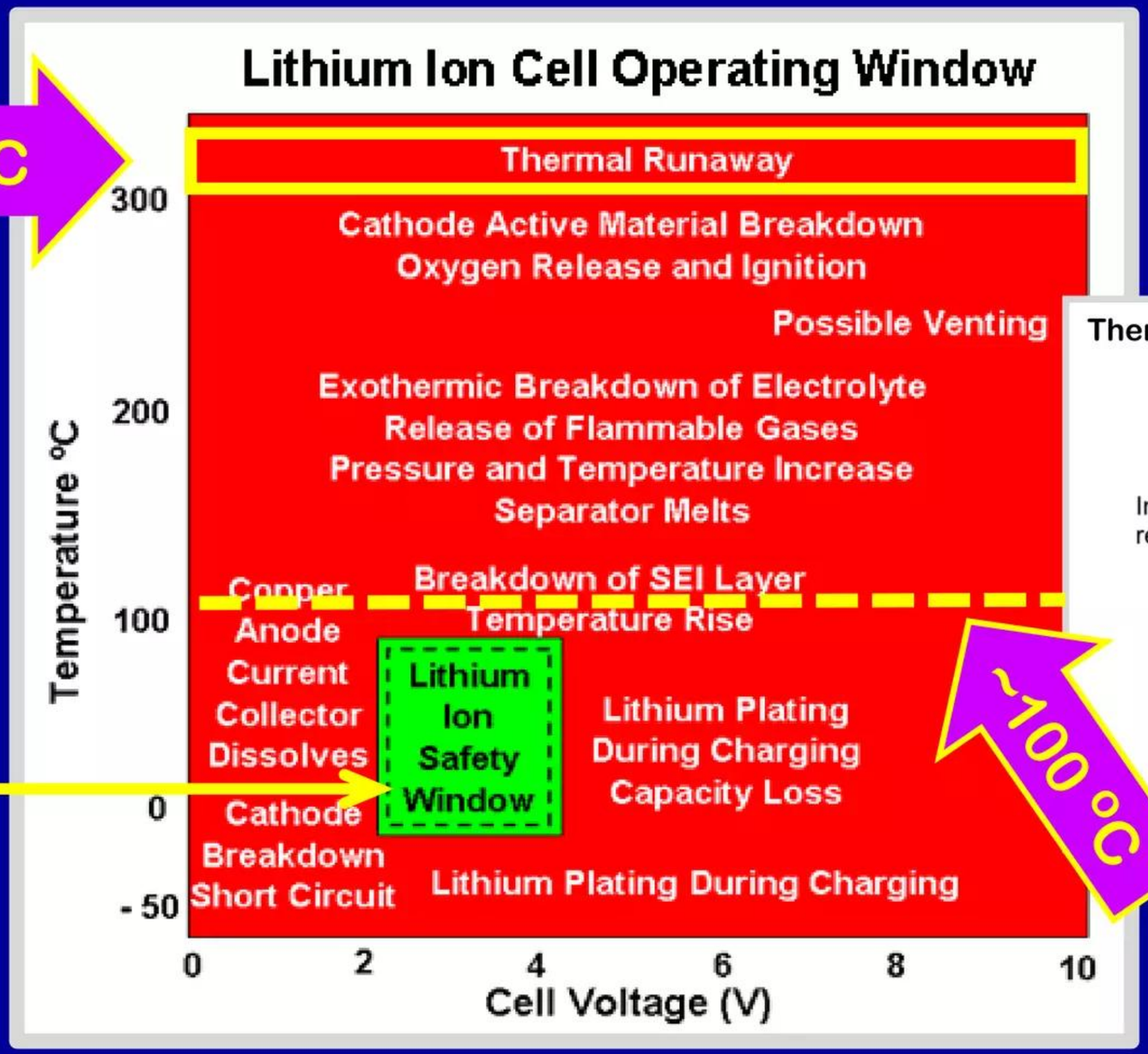
Lithium-ion battery cells have relatively small safe operating window

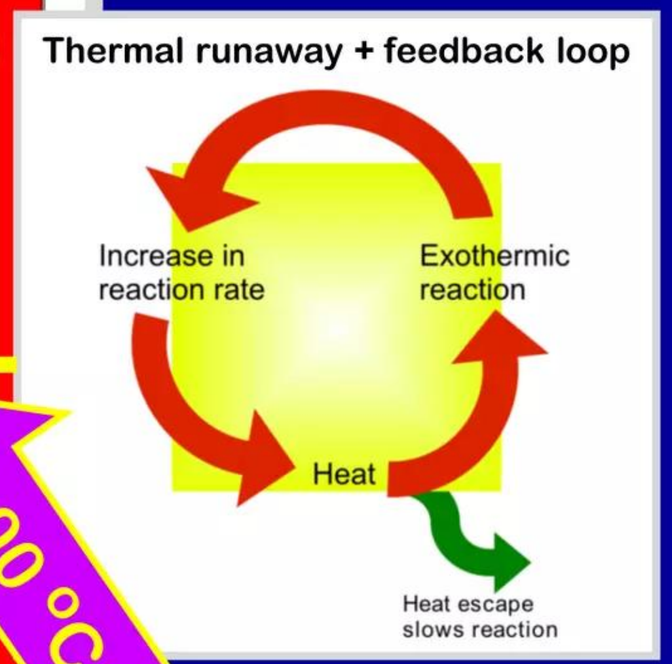
Catastrophic thermal runaways can be created by temperatures as low as 325 ºC

~325 ºC

Damage zone starts at ~ 100º C

Voltage/temp safe operating window only occupies small portion of entire battery parameter space





Three different technologies now converging on nanoscale

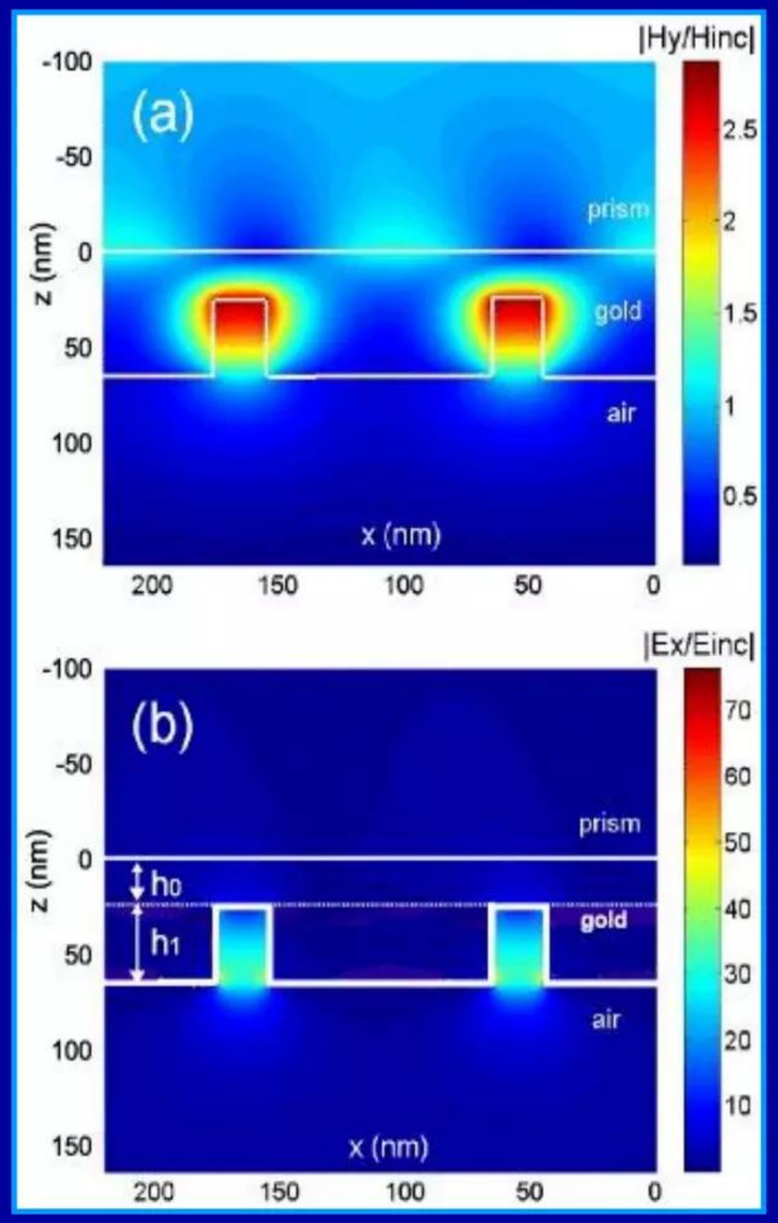
Each domain is being driven by a quest for higher energy densities

- ✓ **Chemical batteries:** devices used for reversibly storing electrical input energy (charging) in chemical bonds and controllably releasing clean electricity (discharging) on demand. Rise of portable electronic consumer products has driven vast, meteoric growth in both primary and secondary battery markets for more than 40 years

- ✓ **Energetic materials:** chemical compounds that can be triggered to irreversibly release very large amounts of chemical bonding energy via extremely fast reactions; are typically quite uncontrollable after being triggered

- ✓ **Ultralow energy neutron reactions (LENRs):** unlike more familiar fission or fusion processes mainly driven by the strong interaction, these are truly eco-green nuclear processes wherein key steps depend instead on weak interactions; importantly, while LENRs can be designed to controllably release extremely large amounts of CO_2-free thermal energy, they do not emit any dangerous fluxes of deadly energetic neutron or gamma radiation

Coherent cavity mode
high-E-field hot spots

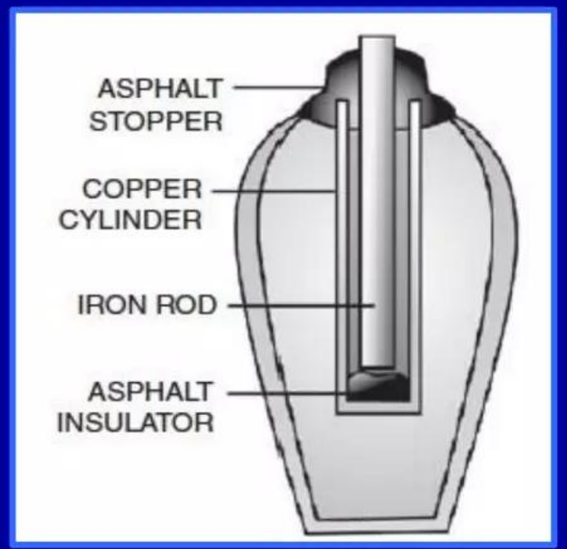


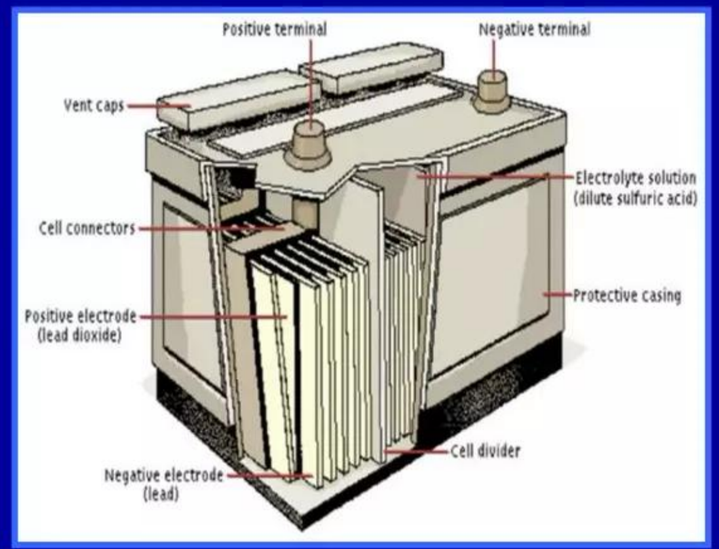
Credit: J. Le Perchec, *Europhysics Letters* (2010)

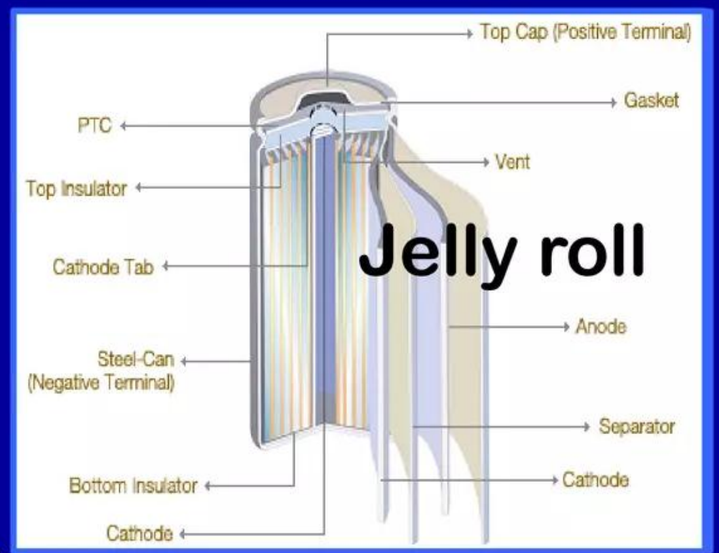
Mutual technology convergence is length-scale related

Huge decrease in distances separating battery anodes from cathodes

centimeter (1.0 cm) millimeter-scale (.01 cm) micron-scale (.001mm)







Baghdad battery ~ 250 BCE? → 20th century lead-acid starter battery → Contemporary lithium-ion battery

Impervious to μ–scale LENRs

Jelly roll architecture maximizes internal surface area

Separators between anode and cathode can be very thin

Mutual technology convergence is length-scale related

All paths lead toward using micron- to nm-scale objects and processes

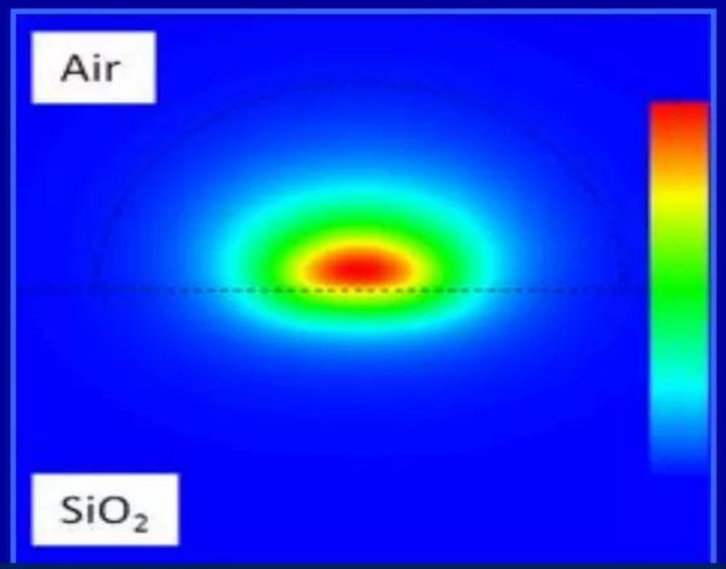
- ✓ Battery performance is diffusion-rate-limited through intervening materials and across interfaces; to improve this parameter and increase overall energy density of battery cells, manufacturers invented the "jelly roll" architecture and shrank thicknesses of dielectric plastic separators between anode and cathode from centimeters to microns (thousand-fold decrease); to further increase performance and energy density parameters, they are increasingly utilizing nanotechnology and developing new types advanced battery chemistries, e.g., Lithium-Oxygen technology

- ✓ Independently, technologists working to improve energy density and performance metrics of energetic chemical materials used in thermal igniters, propellants, and certain types of explosives are increasingly utilizing much of the same nanotechnology --- this relatively new area of R&D is called "nano-energetic materials"

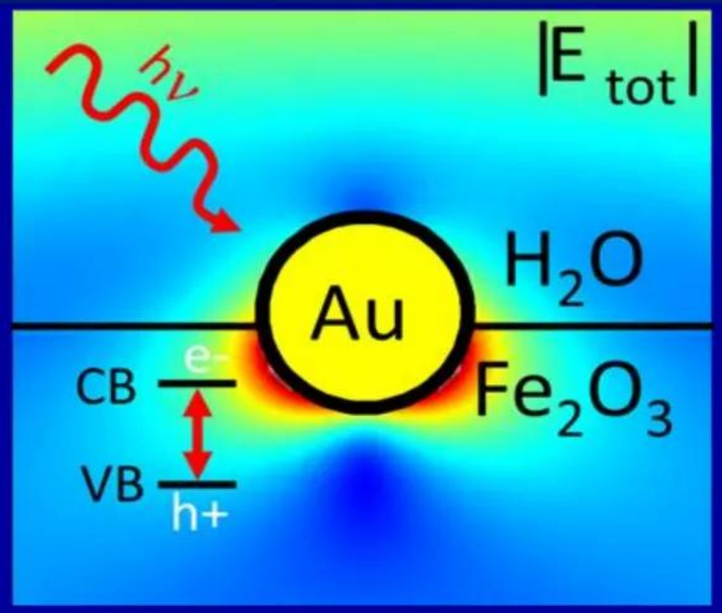
- ✓ Paradigm-shifting Widom-Larsen theory explains the key role of nanoplasmonics in LENRs, why they are intrinsically μm- to nm-scale surface and interfacial phenomena, and illuminates an R&D pathway that incorporates existing nanotechnology to design and fabricate commercial versions of LENR heat sources at low cost

- ✓ Conclusion: energetic materials, battery and LENR technologies are converging by utilizing μm-to nm-scale objects and processes

High E-field nm-scale hot spots near interfaces



Credit: *Scientific Reports* 3 paper #2335 (Aug. 2013)



Credit: the Thomann Group at Rice University

Technology domains converging at nanometer length-scales

Being driven to nm length-scales in a quest for higher energy density

Technology domain	Main purpose	Source of energy	Energy-scale	Typical rates of reactions	Temps in Centigrade	Representative examples
Electro-chemical batteries	Store electrical energy reversibly in chemical bonds	Chemical bonds	Electron Volts (eV)	Slow to moderate; typically diffusion rate-limited at various types of interfaces found inside batteries	Li batteries can generally be operated safely only at temperatures < 100° C	Large variety of different chemistries: lead-acid, alkaline, NiMH, Nickel-cadmium, Lithium-ion, $LiFePO_4$, Lithium-oxygen, etc.
Energetic materials	Thermal igniters, explosives, propellants	Chemical bonds	eVs	Fast combustion processes w. O_2, e.g., deflagration and detonation	Macroscopic peak temps max-out at ~5,000° C	Thermite reactions (burning of metals), dinitro-chloro-azido benzene, RDX, etc.
Ultralow energy neutron reactions (LENRs)	Produce large amounts of CO_2-free thermal energy from decay particles' kinetic energies and gamma conversion to infrared	Nuclear binding energy stored inside atomic nuclei	Mega-electron Volts (MeVs) one MeV is equal to a million eVs	Nuclear reactions themselves are super-fast, i.e., picosecond and faster; decays of any resulting unstable isotopes can range from very slow on order of millions of years to fast, i.e., nanoseconds	Peak temperatures in micron-scale, short-lived LENR hotspot regions on surfaces and at interfaces typically reach ~4,000° to 6,000° C	Neutron captures on various elements and isotopes; for example, LENR neutron capture processes starting with Lithium as base fuel target can release ~27 MeV in short sequence of nuclear reactions that do not release any energetic neutron or gamma radiation

LENRs are a paradigm-shifting nuclear energy technology

No deadly gamma radiation

No dangerous energetic neutron fluxes

Insignificant production of hazardous radwastes

Revolutionary, disruptive, and environmentally safe

Occurs out in Nature as well as in man's laboratories

Image credit: co-author Domenico Pacifici
From: "Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing"
J. Feng *et al.*, *Nano Letters* pp. 602 - 609 (2012)

Laura 13

Electroweak reaction in Widom-Larsen theory is simple

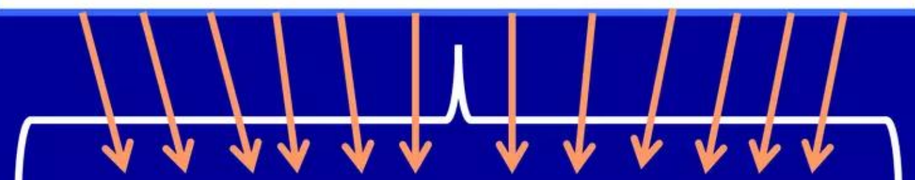
Protons or deuterons react directly with electrons to make neutrons

W-L explains how $e + p$ reactions occur at substantial rates in condensed matter

Draw energy from electric fields > 2.5 x10^{11} V/m Heavy-mass e^{-}* electrons react directly with protons

Collective many-body quantum effects: many electrons each transfer little bits of energy to a much smaller number of electrons also bathed in the very same extremely high local electric field

Quantum electrodynamics (QED): smaller number of electrons that absorb energy directly from local electric field will increase their effective masses ($m = E/c^2$) above key thresholds β_0 where they can react directly with a proton (or deuteron) ⟶ neutron and neutrino



$$\text{Energy}_{\text{E-field}} + e^-_{sp} \rightarrow e^{-*}_{sp} + p^+ \rightarrow n^0 + \nu_e$$

ν_e neutrinos: ghostly unreactive photons that fly-off into space; n^0 neutrons capture on nearby atoms

LENR ULE neutrons induce radiation-free nuclear transmutations and generate infrared heat

Neutrons + atomic nuclei ⟶ heavier elements + decay products

Widom-Larsen theory says LENRs are multi-step process

Summary of key steps that must occur in LENR transmutation process

Five-step green radiation-free process occurs in 200 - 400 nanoseconds or less

1. Collectively oscillating, quantum mechanically entangled, many-body patches of hydrogen (either protons or deuterons) form spontaneously on surfaces
2. Born-Oppenheimer approximation spontaneously breaks down, allowing E-M coupling between local surface plasmon electrons and patch protons; enables application of input energy to create nuclear-strength local electric fields >> 10^{11} V/m - increases effective masses of surface plasmon electrons in patches
3. Heavy-mass surface plasmon electrons formed in many-body patches can react directly with electromagnetically interacting protons; process creates neutrons and benign neutrinos via a collective electroweak $e + p$ reaction
4. Neutrons collectively created in patch have ultra-low kinetic energies; almost all absorbed by nearby atoms - few neutrons escape into environment; locally produced or ambient gammas converted directly into infrared photons by unreacted heavy electrons (US# 7,893,414 B2) - no deadly gamma emissions
5. Neutrons captured, elements transmuted → 'crater' formation at active sites

Parallels between LENRs and Lithium-based batteries

Neutron captures on Li releases 27 million x more energy vs. chemical

Widom-Larsen theory posits the following Lithium-target LENR network fuel cycle

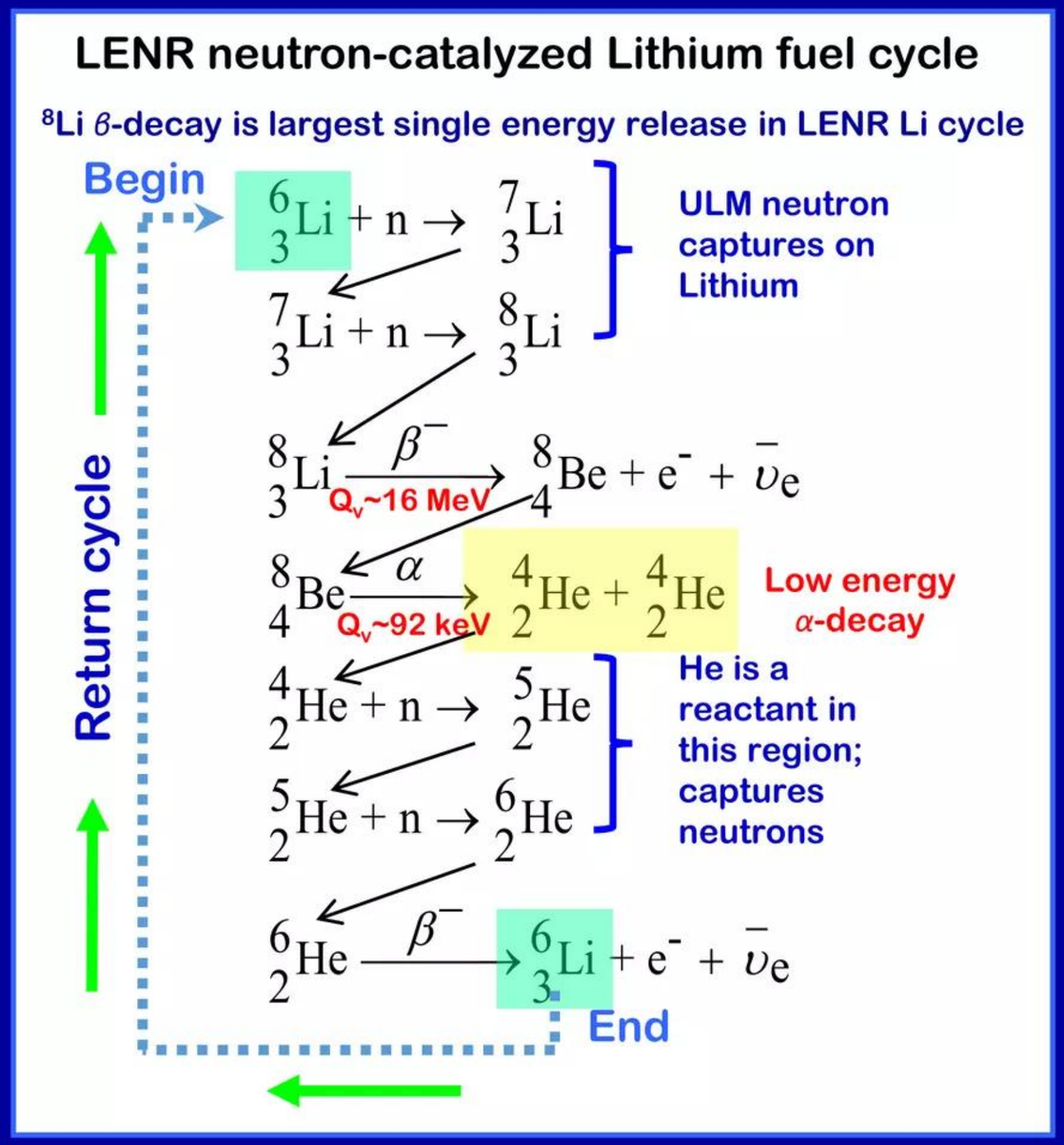
Lithium-6 + 2 ULE neutrons → 2 Helium-4 + beta particle + 2 neutrinos + Q-value of ~26.9 MeV

This particular cyclical LENR pathway can release about the same amount of energy as the D-T fusion reaction without creating any MeV-energy energetic neutrons, hard gamma radiation, or radioactive isotopes. Although portion of 26.9 MeV in excess nuclear binding energy released is lost ("haircut") with emitted neutrinos, much still remains in kinetic energy of two helium atoms (which are low-energy alpha particles), and very energetic beta particle

In this case, local solid matter is heated-up by scattering of low-energy alpha and much-higher-energy beta particles; **heavy-mass electrons also present in LENR-active sites will convert any locally produced hard gammas or X-rays (coming from whatever process) directly into infrared heat**

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces" A. Widom and L. Larsen *European Physical Journal C – Particles and Fields* 46 pp. 107-111 (2006)
ULMN-catalyzed LENR Lithium network cycle – from Eqs. 30 - 32

http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006



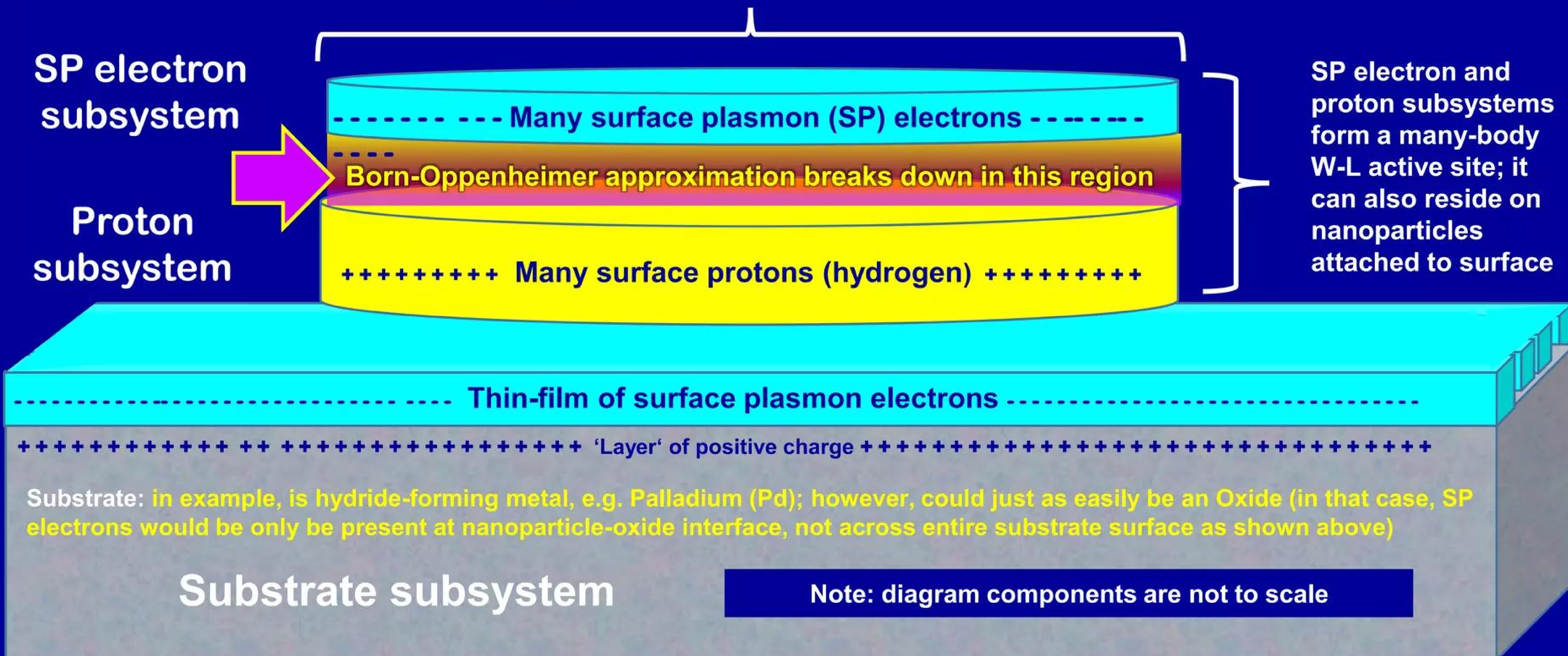
Conceptual overview of LENR-active site on surface

Comprised of many-body patches of protons/electrons on surface

SP electrons and protons oscillate collectively and are mutually Q-M entangled

Diameters of many-body active sites randomly range from several *nm* up to ~ 100⁺ microns

Microscopic details of an LENR active site

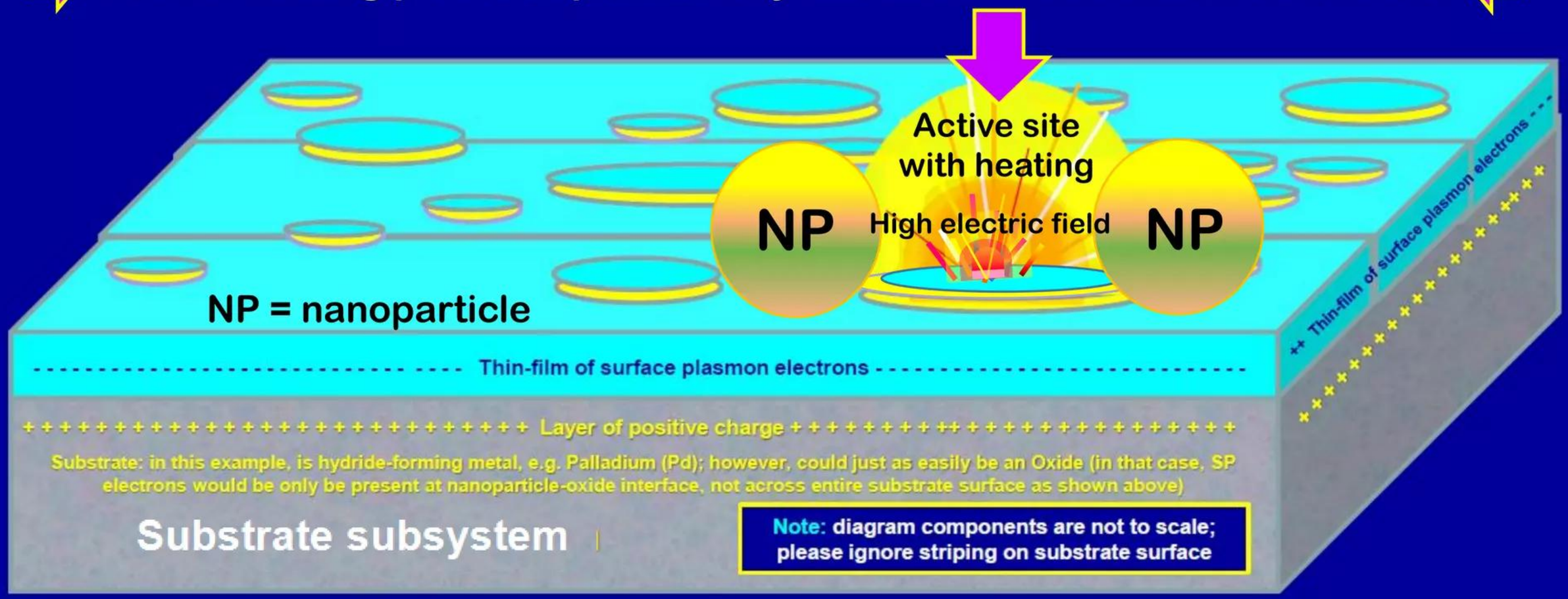


Conceptual overview of LENR-active site on surface

One such site at vulnerable location in battery can trigger a runaway

Site triggered and 'dies' within 200 - 400 nanoseconds; peak temp up to 6,000º C

Nuclear heating process operates very fast and will create blow-out craters



On metallic substrates LENR active sites often create distinctive surface craters ~100⁺ microns in diameter

Such craters can be observed on LENR-active metallic substrates post-experiment with scanning electron microscopes (SEM); LENR transmutation products have been observed in exactly the same areas with SIMS

Microscopic LENR-active sites can trigger thermal runaways

Short-lived nuclear heating processes can flash-boil refractory metals

Boiling creates metallic phase explosions: vapor expands 40,000 - 70.000x

Intense heating by nuclear processes during short lifetimes of micron-scale LENR-active sites on surfaces can result in local flash-boiling of metals in what is also known as a phase explosion. In such events, local region of metal is vaporized; depending on metal, heated material can expand by 40,000 to 70,000 times its previous volume as a solid. Vapor cloud then cools and condenses into tiny droplets; this creates tiny microspheres seen in SEM images. Similar effects are created by laser ablation of surfaces; e.g. see:

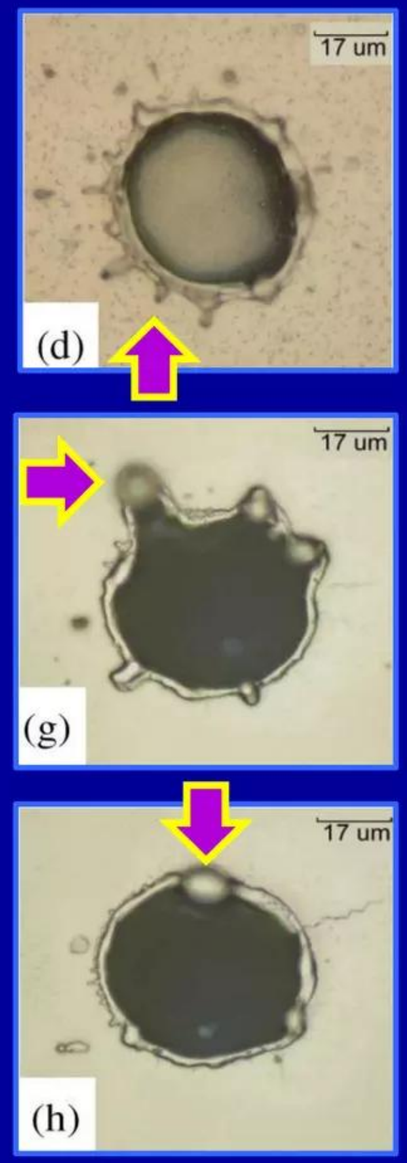
"Phase explosion and Marangoni flow effects during laser micromachining of thin metal films"

Their most recently published work alone this line of inquiry is:

"Nanosecond time-resolved measurements of transient hole opening during laser micromachining of an Aluminum film"
M. Hendijanifard and D. Willis
Journal of Heat Transfer 35 article #091201 (2013)

http://lyle.smu.edu/~mhendija/index_files/Hendijanifard%20SPIE2008.pdf

Hendijanifard & Willis

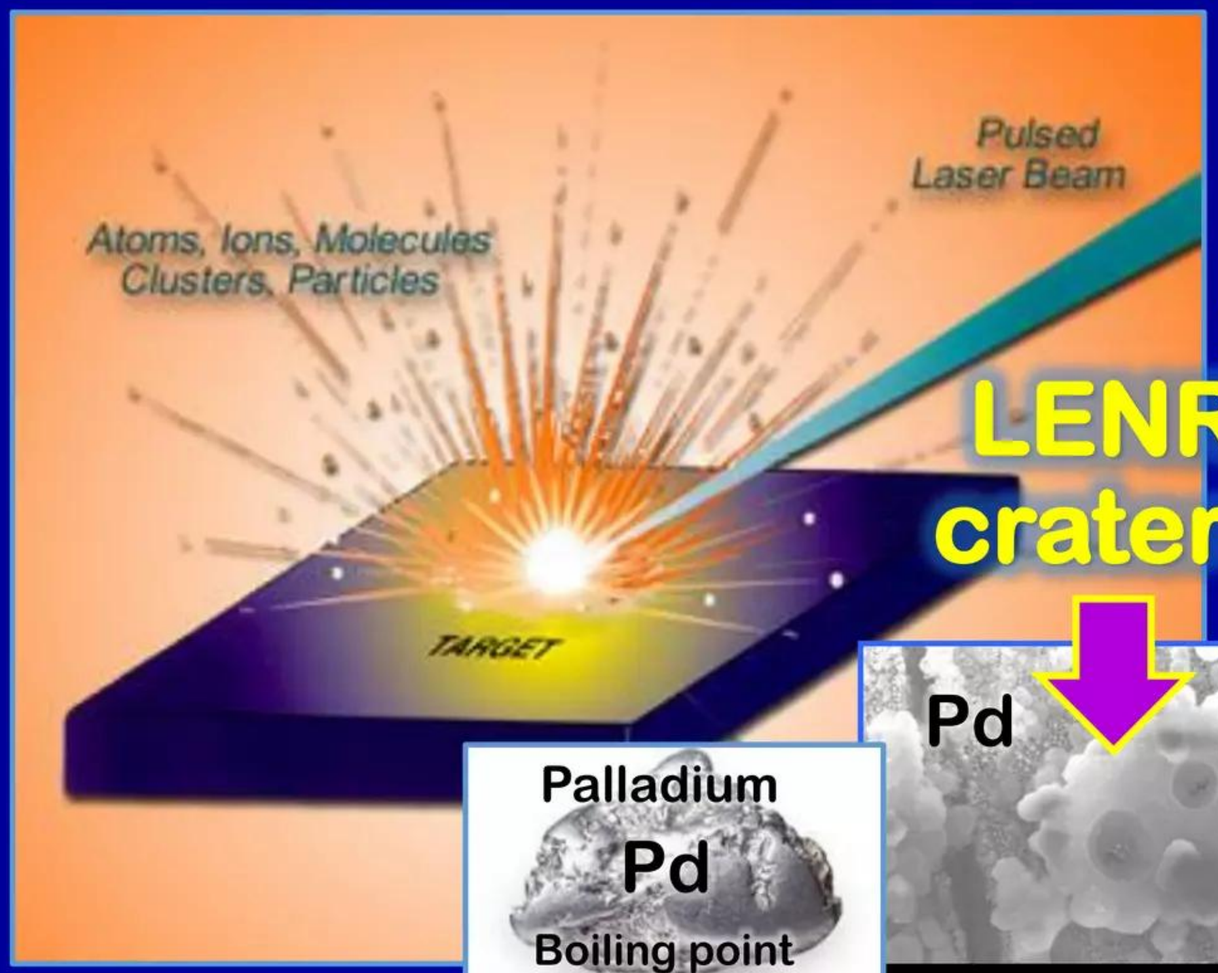


Craters produced by lasers and LENRs are very similar

Similarity in crater sizes/morphology suggest comparable heat transfer

Rather steep walls of LENR craters indicate extremely rapid local energy release

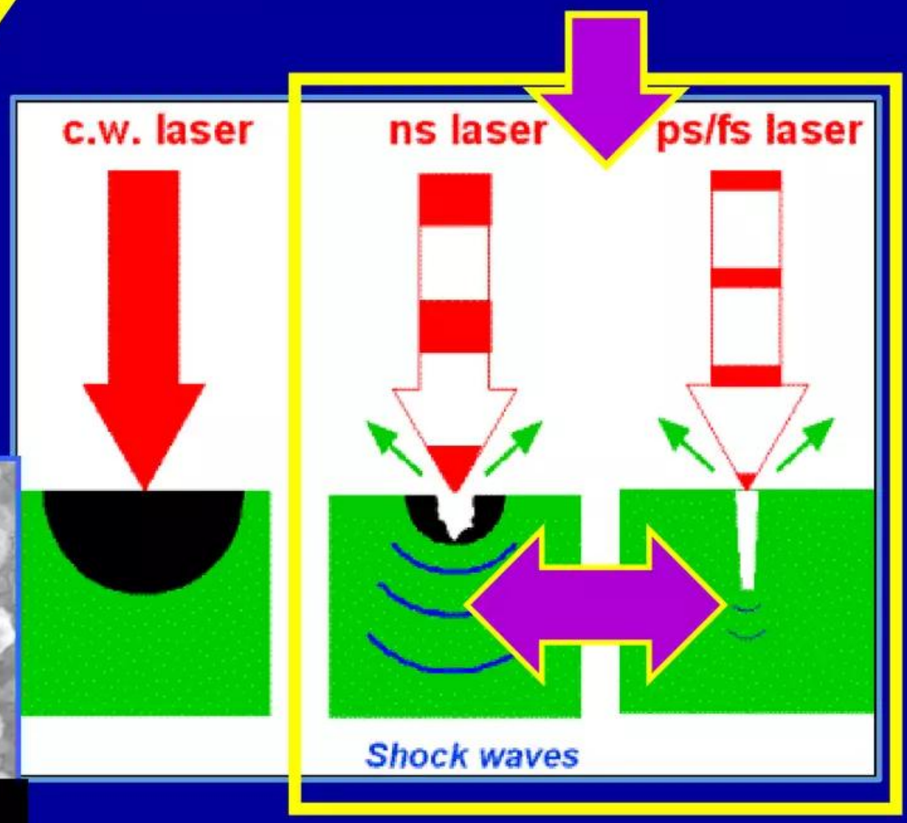
Direct conversion of gammas into infrared in LENR-active sites creates huge heating



LENR craters

P. Boss, U.S. Navy

Shorter-duration laser pulses produce craters with steeper, crisply defined vertical walls



Craters produced by lasers and LENRs are very similar

Microspheres are also produced in jets from explosively boiling liquids

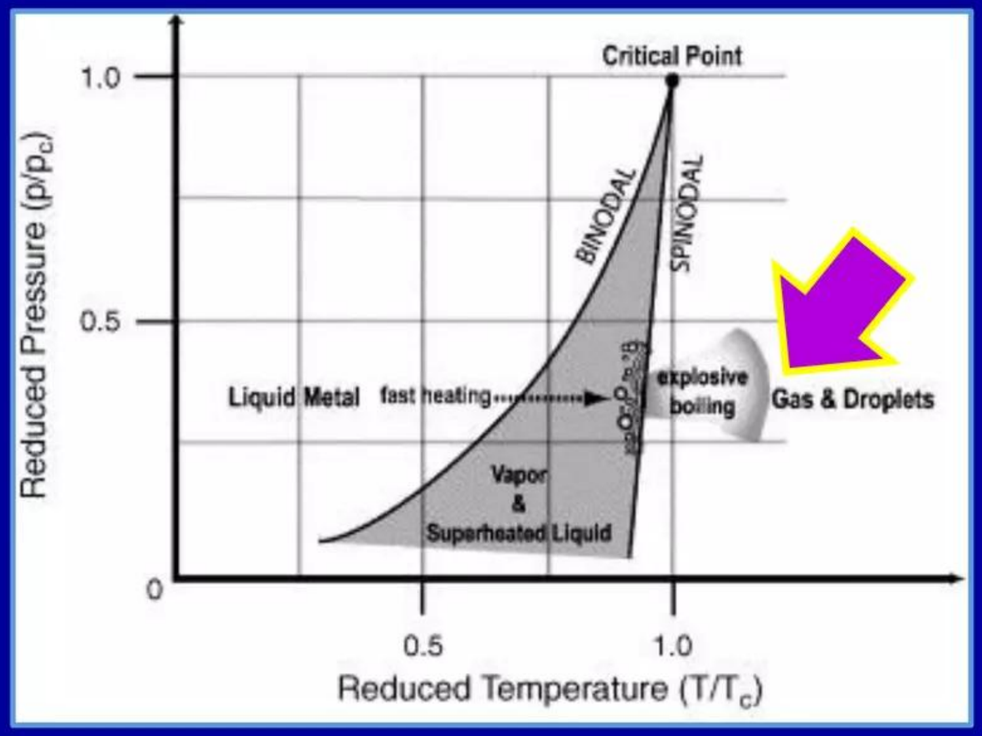


Fig. 1. Phase stability diagram of a liquid metal near the critical point. For fast heating, as obtained during *ns* laser ablation, the melt can be pushed close to critical conditions (superheating), which favors the realization of explosive boiling

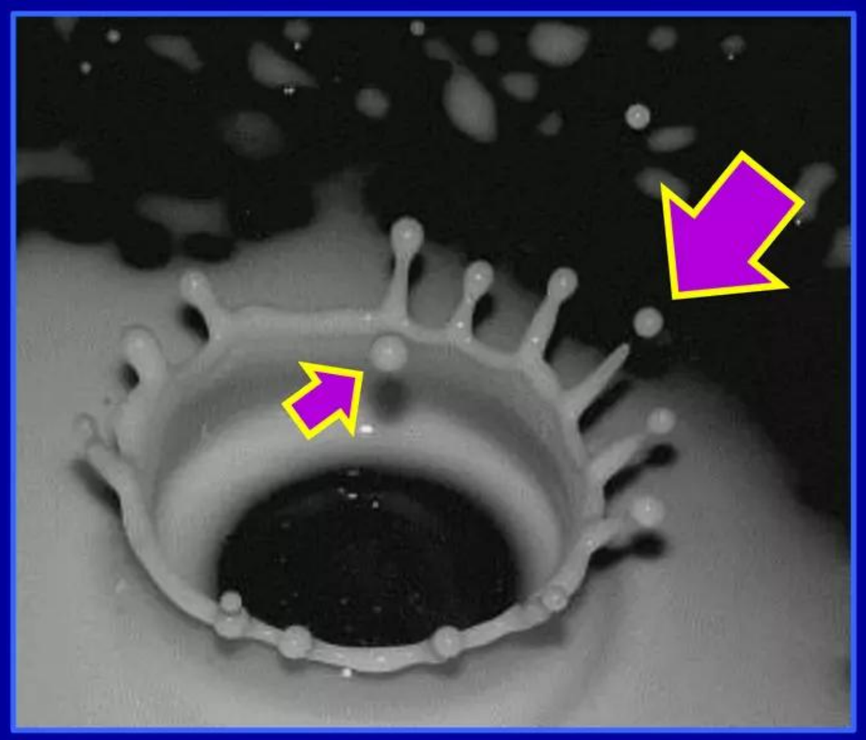


Fig. 2. Schematic visualization of the hydrodynamic evolution of a fluid system under and impulse stress (here milk). Note the non-deterministic formation of jets at the sides and their break-up into droplets. From Ref. [58]

Excerpted and quoted directly from:

"Multiplicity and contiguity of ablation mechanisms in laser-assisted analytical micro-sampling"

D. Bleiner and A. Bogaerts, *Spectrochimica Acta Part B: Atomic Spectroscopy* 61 pp. 421 - 432 (2006)

http://www.sciencedirect.com/science/article/pii/S0584854706000437

NTSB's SEM images of perfect steel microspheres (2013)

Created during thermal runaway in Dreamliner battery at Logan Airport

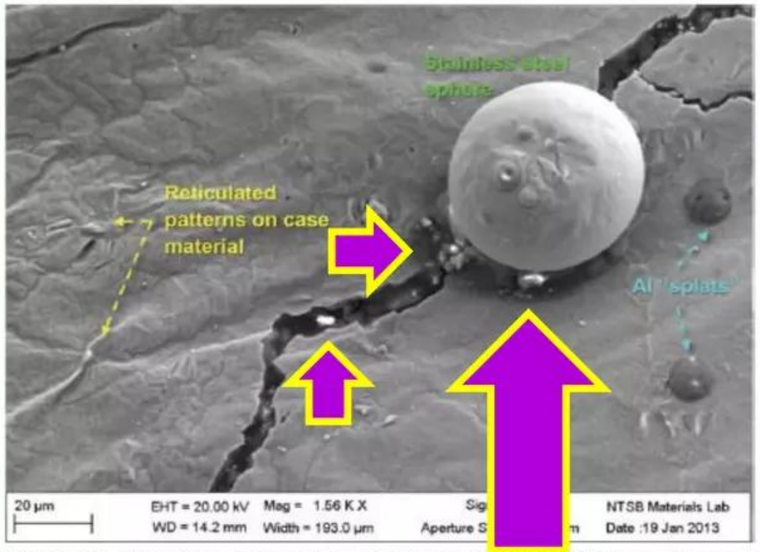


Figure 69. SEM micrograph of a spherical particle of stainless steel found near the exterior side of hole 3.

Figure 70. SEM micrograph of lamellar structure consistent with incipient melting near the exterior of hole 4.

Purple arrows added by Lattice

Microspheres in ruined battery debris can only be created via condensation from vapor of steel that has been locally flash-heated to boil at temperatures > 3,000º C

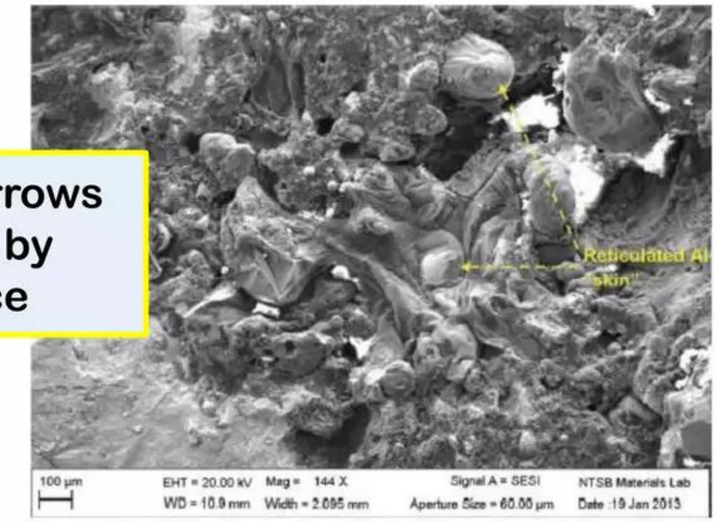


Figure 65. SEM micrograph of hole 1 from the exterior of the C5 cell case. This region exhibited rounded protrusions consistent with resolidified steel encompassed by an external layer of aluminum alloy.

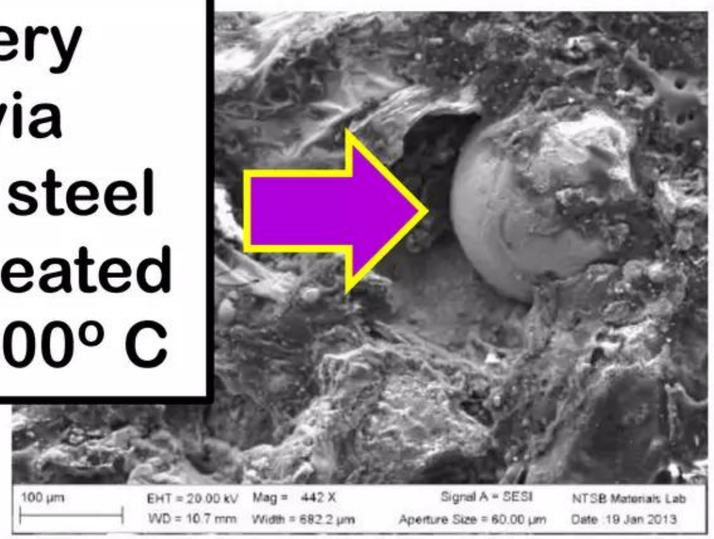


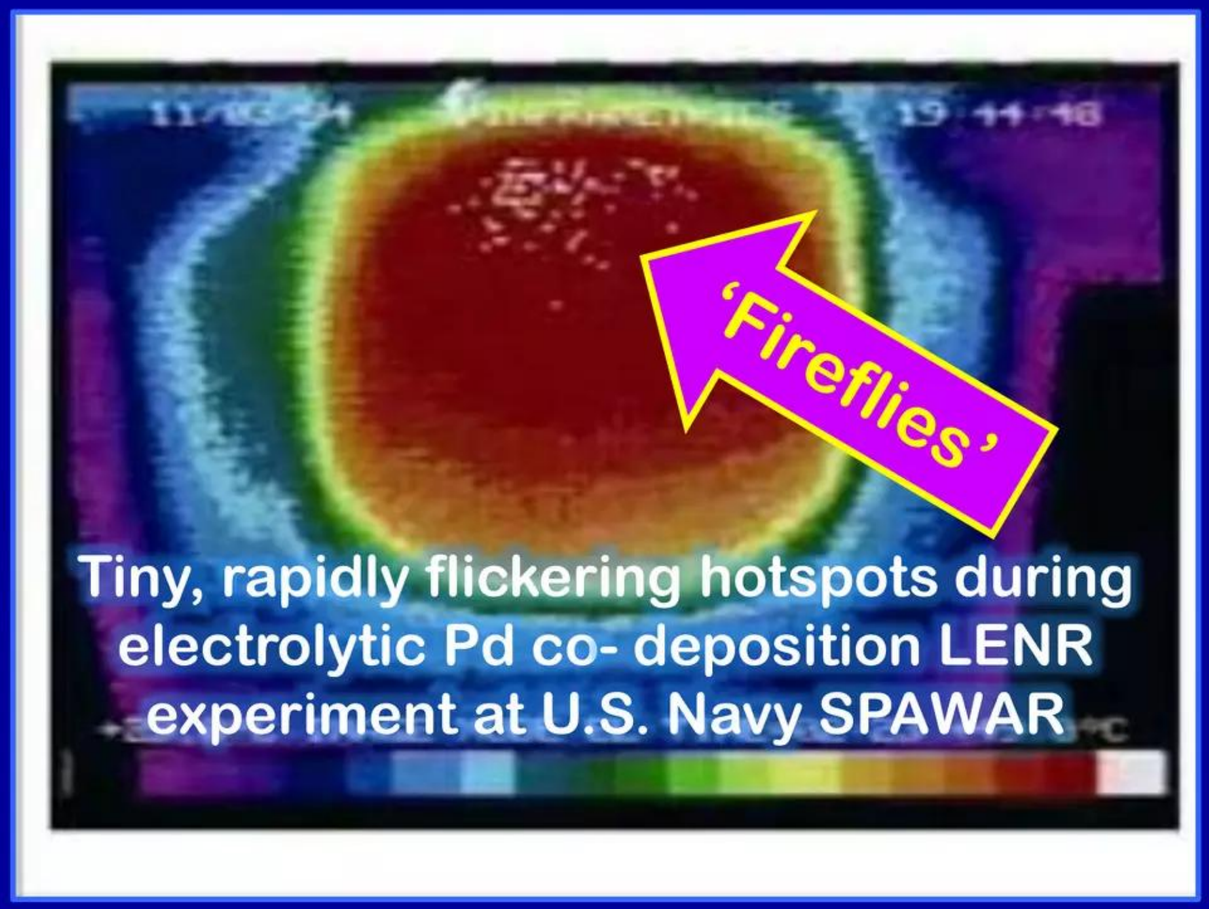
Figure 66. SEM micrograph of steel sphere embedded in combustion products in the interior of hole 1 on the C5 cell case.

LENR-active sites create short-lived high temp hot spots

Dynamic infrared (IR) imaging of LENR hotspots by U.S. Navy SPAWAR

2005 - U.S. Navy SPAWAR San Diego LENR research lab: infrared measurements
Jan 13, 2009 - 2 min - Uploaded by Steven Krivit of New Energy Times

You are urged to view USN SPAWAR's (P. Boss *et al.*) fascinating short video clip: it is very reminiscent of high-speed flickering of thousands of tiny fireflies in a dark field at night



https://www.youtube.com/watch?v=OUVmOQXBS68

LENRs can trigger violent nano-explosions on surfaces

Piezoelectric detection of such explosions on LENR electrode surface

Quoting directly: "The flashes observed in the IR experiments suggest 'mini-explosions' so we designed an experimental set-up to see if we could record these events using a piezoelectric sensor. Again, the co-deposition approach made this possible. A piezoelectric transducer was coated with epoxy as an insulation layer except for approximately 1 sq. cm on the front on which an electrically conducting material (Ag) was deposited. This became the cathode onto which Pd was co-deposited from the PdCl in a deuterated water solution. The experimental setup and instrumentation is shown."

Polarized $D^+/Pd–D_2O$ system: Hot spots and mini–explosions

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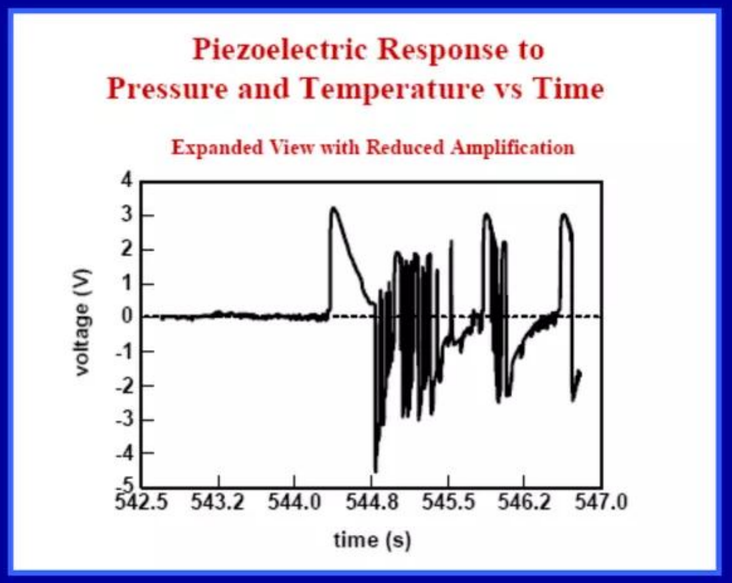
Abstract

Two types of activities occurring within the polarized $D^+/Pd–D_2O$ system, viz. the presence of localized heat sources (hot spots) and associated with them mini–explosions, are described. The "birth and death" of hot spots is monitored by IR imaging while the mini–explosions are displayed by the voltage spikes exhibited by a piezoelectric substrate onto which a Pd/D film was co–deposited. Processes leading to the formation of unstable domains as a precursor to the observed behavior is examined.

Lattice comment: U.S. Navy SPAWAR researchers observed acoustic events in parallel with thermal imaging of transient LENR hot spots on electrodes



Copy of PowerPoint slides presented at ICCF-10 held in Cambridge, MA (2003); this document may differ from the accompanying paper that was published by World Scientific, Inc. in official conference *Proceedings* (2003)

http://lenr-canr.org/acrobat/SzpakSpolarizedda.pdf

Detailed description of LENR processes in batteries

LENR-active site near separator can vaporize it and create internal short

- ✓ Please note that as little as a single blazing hot LENR-active site measuring only 30 microns in diameter --- if it happens to occur in vulnerable physical location deep inside a battery cell and adjacent to the surface of a plastic separator only 25 microns thick --- can effectively vaporize a tiny local region of the separator, almost instantly turning it into a dense, micron-sized ball of highly conductive plasma. This would in turn create an electrical short between anode and cathode at that location, triggering a large inrush of electrical arc current through the breach in the separator dam. Intense local Joule heating would ensue from the arc current, further enlarging the breach and spatially expanding the superheated region inside a given battery cell. Depending on many complex, event-specific details, such a conflagration may or may not grow to engulf an entire cell; thus rare LENR events do not inevitably cause catastrophic heat runaways

- ✓ Under just the right conditions, a single microscopic LENR site can trigger a chain of energetic electrical (Joule heating) and chemical (exothermic reactions) processes that together create spatially autocatalytic, very macroscopic thermal runaway events that destroy battery cells billions of times larger than volumes of LENR site(s). In course of such runaways, 99.9^{+}% of total energy released is non-nuclear; hot spark LENRs are just an effective triggering mechanism. Also note that internal electrical shorts - whatever their cause - can also trigger runaways

Detailed description of LENR processes in batteries

LENR-active sites create witches' brew of high temp chemical reactions

- ✓ Within as little as milliseconds after the creation of an electric arc or LENR-active site, nm- to cm-scale local regions of a battery cell at or near such locations can become a super-hot, fiendishly complicated chemical witches' brew consisting of many different types of old and newly created compounds, expected thermal decomposition products, various ionized species, and a vast number of mutually competing and interacting chemical reaction pathways
- ✓ Positive thermal (heat) feedback loop: the hotter a given region gets, the faster local chemical reactions accelerate therein and the more widely the conflagration spreads into previously unaffected regions of a given battery cell --- this is causative root of thermal runaway effect and so-called "thermal fratricide" that can propagate superheating to many cells
- ✓ Evolution of such hybrid chemical-nuclear systems is very rapid and incompletely understood - quite unpredictable with respect to final results. Outcomes can range from minor thermal damage to single cell; to combustion of flammable electrolytes and charring of materials inside case and outside via venting; and at worst, to complete combustion of all materials located inside of and including cell casings --- even all contents of surrounding multi-cell enclosures; worst-case Armageddon scenarios involve thermite-like, violent super-fast-reacting pyrotechnic processes