Lithium-based batteries in e-cigarettes can explode

Battery field-failures occur in electronic cigarettes

Frequency roughly agrees with what Japanese Li-battery data predict

Utah, USA - Sept. 20, 2013: e-cigarette being charged in car explodes and burns child

Georgia 9/3/2013 - device explodes in USB port; Florida 2/13/2012 - one explodes in man's mouth

Small form-factor Li-based batteries

LENRs ⇨ nano energetic materials

Even small batteries can be risky

Lewis Larsen

President and CEO
Lattice Energy LLC
September 25, 2013

"I have learned to use the word 'impossible' with the greatest caution."

Wernher von Braun

Contact: 1-312-861-0115
lewisglarsen@gmail.com
http://www.slideshare.net/lewisglarsen

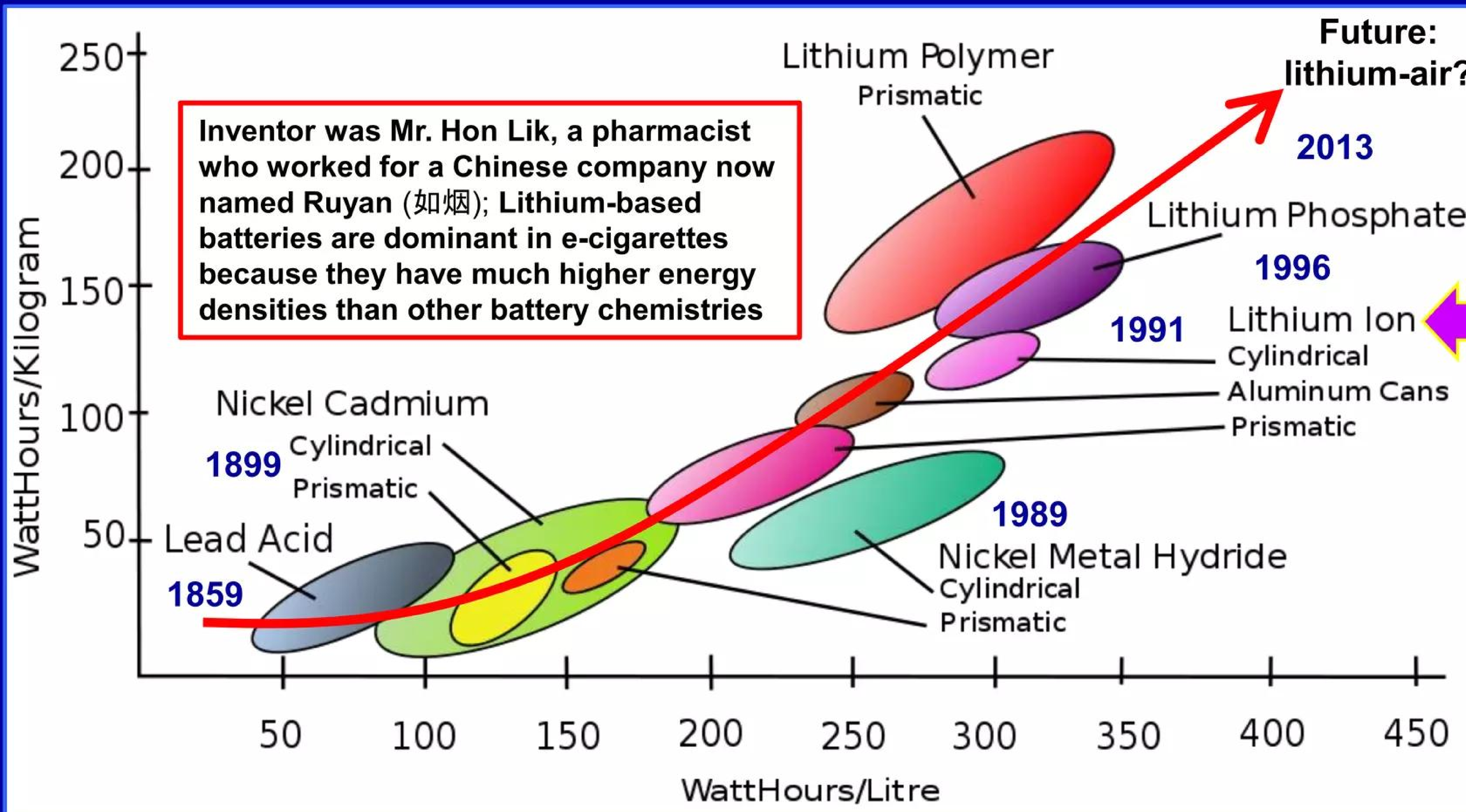
Recent Georgia, USA incident (2013)

http://www.szseego.com/eHit/eHit.html

Lithium-based batteries in e-cigarettes can explode

Battery-driven electronic cigarettes invented in China (2003)

Energy densities too low prior to Lithium-based batteries (1991)

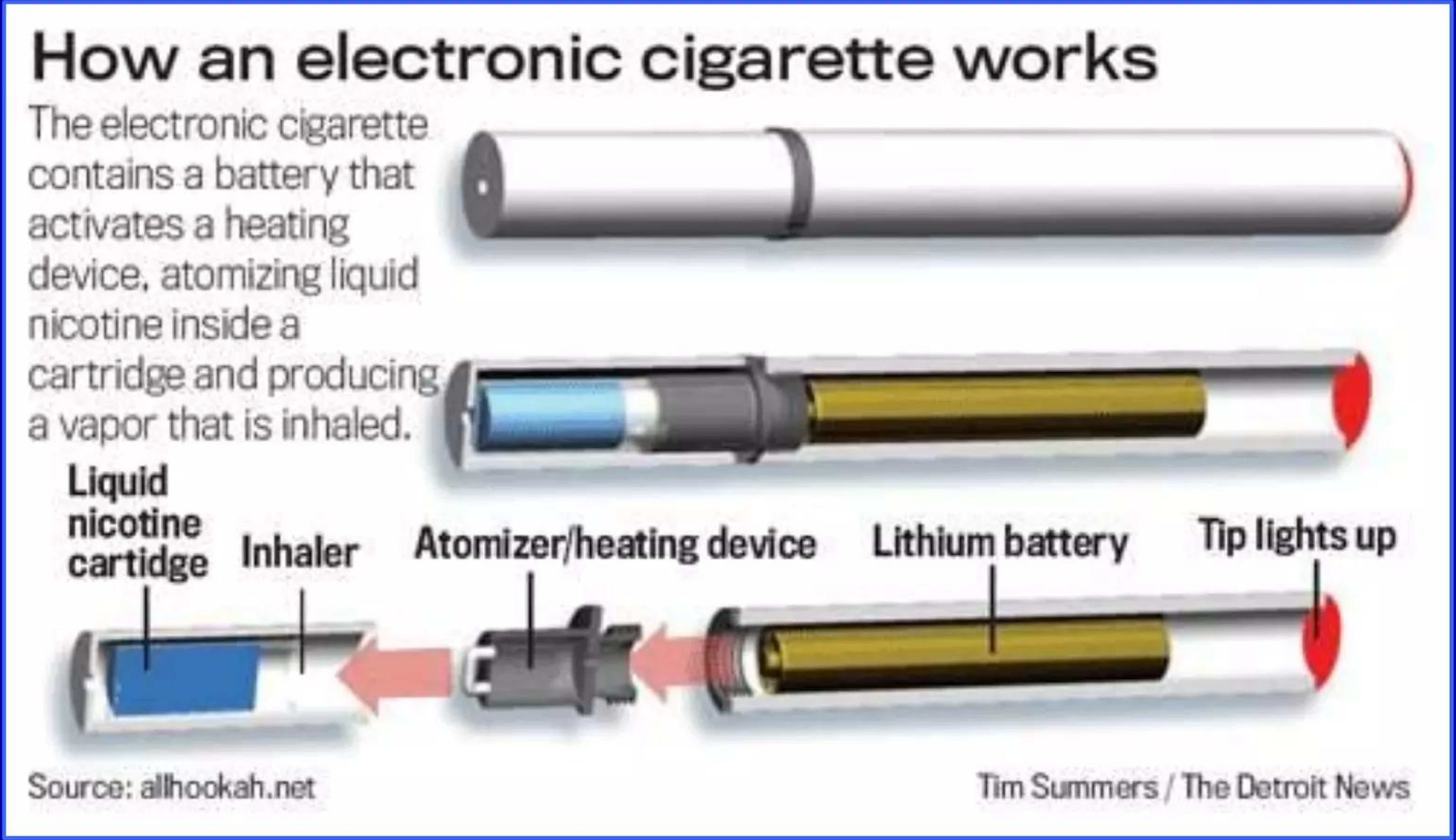


Adapted from source: http://liteplusbattery.com/lifepo4-energy-density/

Lithium-based batteries in e-cigarettes can explode

Battery energizes heater to vaporize liquid with nicotine

High energy density of Lithium-based batteries enables compact devices



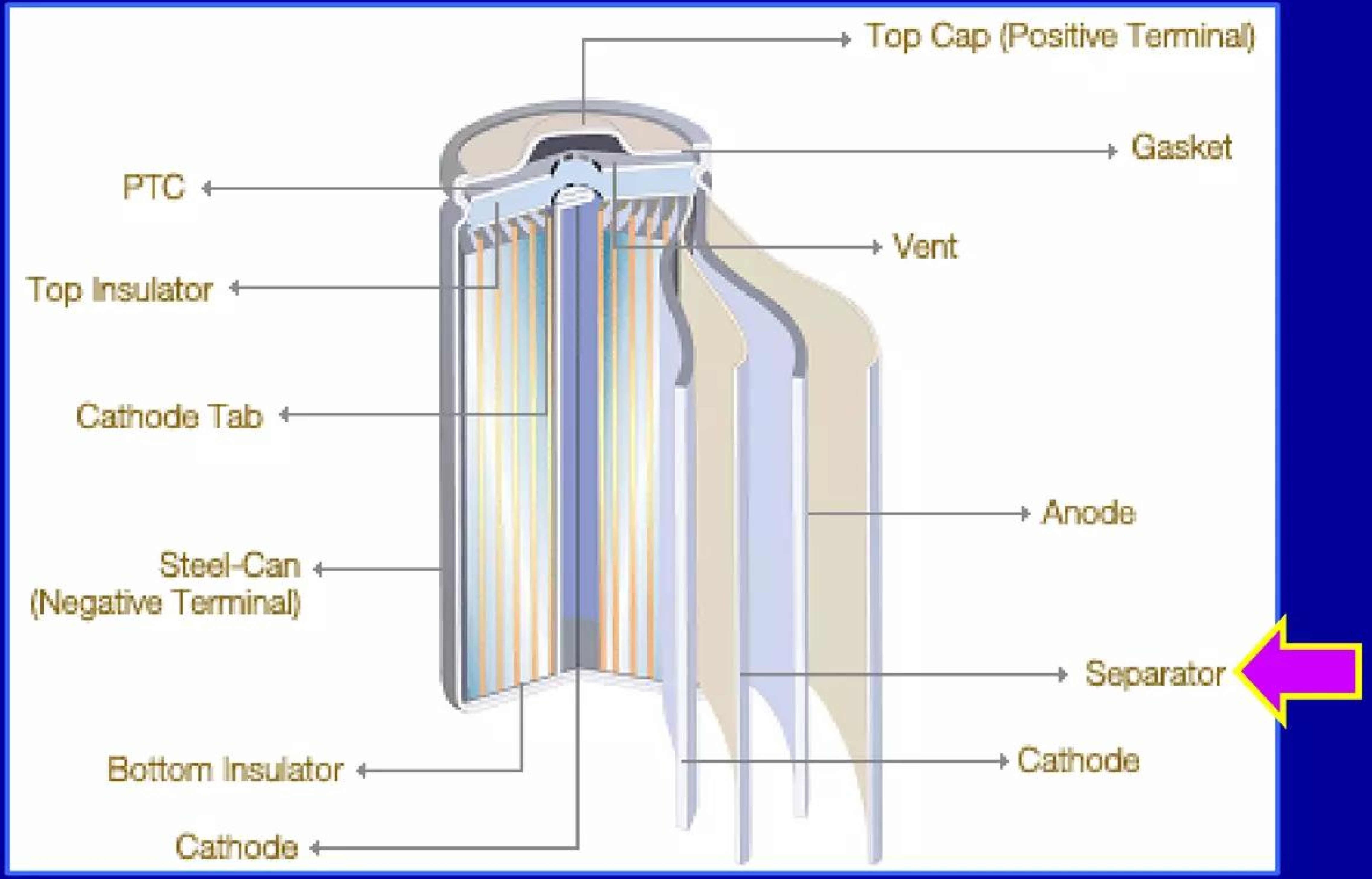
Source: http://e-cigsforbeginners.weebly.com/

Lithium-based batteries in e-cigarettes can explode

Anatomy of cylindrical Lithium e-cigarette batteries

So-called "jelly roll" architecture helps increase energy storage density

Separators are very thin plastic membranes only 20 - 30 microns thick that maintain a safe distance between anode and cathode layers; if separators are damaged it can result in simple battery failure or explosive thermal runaways



Source: http://www.mpoweruk.com/cell_construction.htm

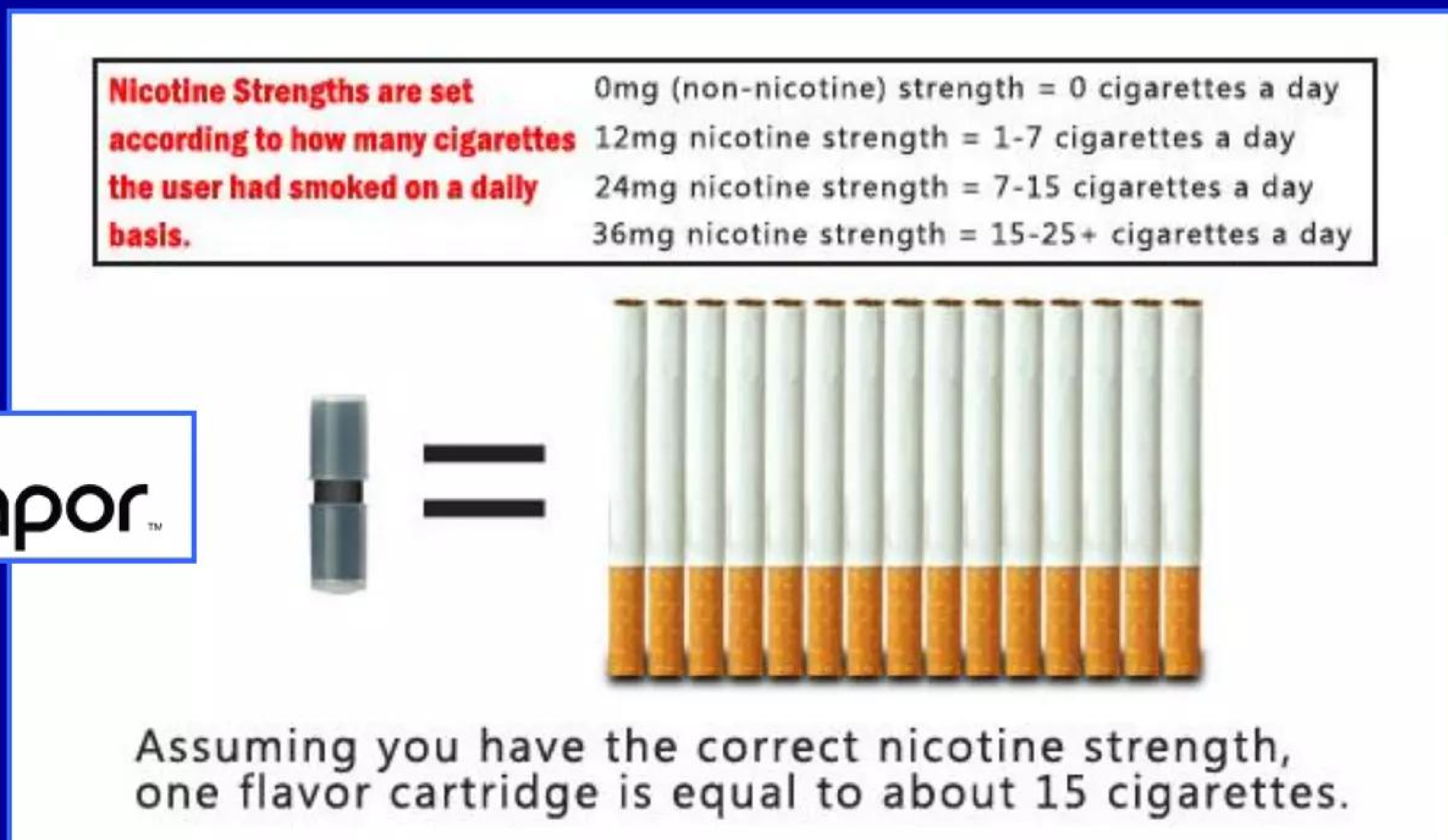
Lithium-based batteries in e-cigarettes can explode

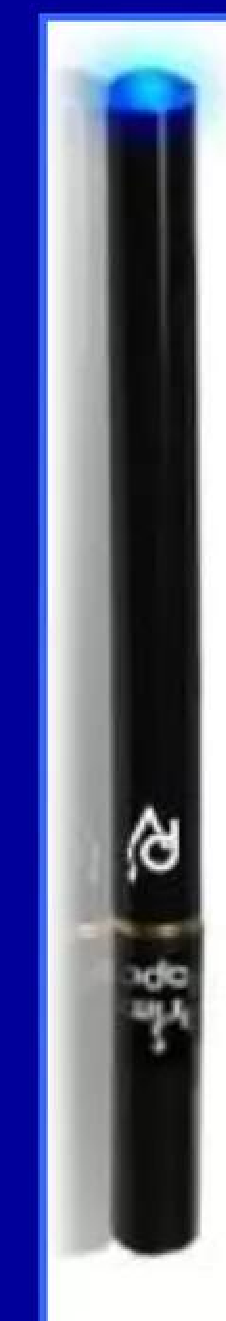
Devices deliver nicotine doses without smoke carcinogens

Displacing traditional cigarettes in early-adopter niche amongst smokers

Quoting from PrimeVapor's website: "First we must make clear that 'your mileage may vary'. There are many factors that contribute to the longevity of a flavor cartridge. How often you inhale, how deep you inhale and so on … After it is all said and done, PrimeVapor believes that each of our exclusive PrimeVapor Flavor Cartridges are approximately equal to 3/4 of a pack of cigarettes."

PrimeVapor™





Source: http://www.primevapor.com/pages/e-cigarette-faq-how-long-does-one-e-cigarette-cartridge-last-15.html

Lithium-based batteries in e-cigarettes can explode

Examples of wide variety of electronic cigarettes

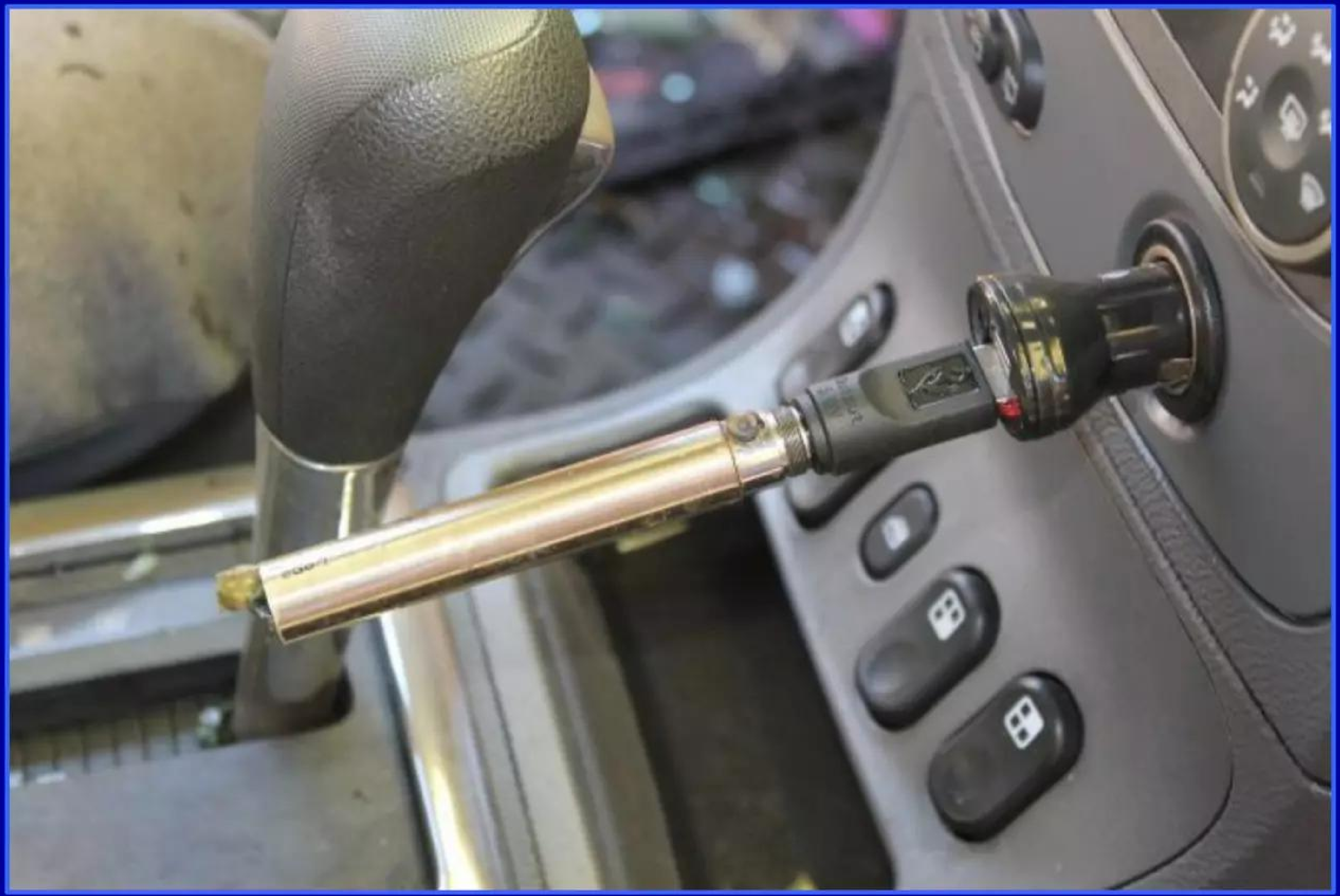
Many different device styles; all have similar internal engineering

Batteries are commonly rechargeable; some are disposable

Lithium-based batteries in e-cigarettes can explode

Many e-cigarette incidents occur during charging

Device being charged inside vehicle via a USB adapter connection



Source: http://kpho.images.worldnow.com/images/22071692_BG2.JPG

Five examples of incidents with electronic cigarettes

Lithium-based batteries in e-cigarettes can explode

Battery exploded while device being charged in a vehicle

White-hot metal shrapnel ejected which ignited nearby combustibles

Source: http://fox13now.com/2013/09/21/child-burned-after-e-cigarette-explodes-in-car-charger/ video clip of news story embedded in article

"Electronic cigarette explosions: Child burned after e-cigarette explodes in car charger"

Posted on: 9:25 pm, September 21, 2013, by Meredith Forrest Kulwicki and Adam Rodriquez; updated on 10:32pm, September 21, 2013

Quoting: "Seeing your child on fire and hearing them scream 'Help me!' is pretty terrifying," Kinzie Barlow said. Barlow said she was driving in Provo with her son, Khonor, Friday when she noticed a strange smell. "Then there was a big bang, and kind of a flash, and there's smoke everywhere," Barlow said.

Barlow said her e-cigarette had exploded in its charger, shooting out a white-hot copper coil that bounced off the ceiling and landed in her son's car seat. She says the coil had burned through the fabric cover and melted the hard plastic, sending flames shooting up the little boy's body. "He was screaming and saying, 'Mom, get me! Get me!"

Quote continued: Barlow said she tried smothering the fire with her shirt sleeve, which also caught fire. So she grabbed an iced coffee from the front seat and poured it on Khonor, dousing the flames …

Provo Fire Marshal Lynn Schofield said he has no doubt Barlow's White Rhino e-cigarette exploded, just like she claimed. "(The charging e-cigarette) was attended. It was a catastrophic failure of the device," Schofield said. "And fortunately only minor burns, but painful burns."

But it's not the first time Schofield said he has investigated a fire caused by an exploding e-cigarette.

"This is the second time it's happened in Provo," Schofield said. "This is the first time we've had an injury."

Lithium-based batteries in e-cigarettes can explode

Battery exploded while device being charged at home

Victim described a powerful, explosive detonation of the device

Mail Online

Source: http://www.dailymail.co.uk/news/article-2410425/E-cigarette-eHit-explodes-sends-4-foot-flames-womans-living-room.html/

"Woman's shock after her e-cigarette EXPLODED when she charged it"

By Snejana Farberov
Published 15:22 EST Sept. 3, 2013
Updated 18:51 EST Sept. 3, 2013

Quoting: A Georgia woman has invested in an e-cigarette hoping to improve her health and lifestyle, but instead she nearly lost her home when the device blew up. Elizabeth Wilkowski, of Atlanta, plugged the Chinese-made eHit electronic cigarette into her computer to charge it up before use. A short time later, the woman said a blast went off, rattling the walls of her Grant Park home.

It wasn't a boom, it wasn't a pop... it was a Kaboom!' the shaken Wilkowski recalled to the station WSB-TV. 'I screamed… it was a real freak-out moment.'

Quote continued: The Atlanta resident compared the explosion to a bomb detonation, which shot 4-foot flames across her living room, scorching her couch and rug. After overcoming her initial shock, the woman grabbed a wet wash rag to protect her hand and yanked the smoldering e-cigarette out of a USB port. 'If I hadn't had been home, I would have lost my dogs, I would have lost my cats, I would have lost my house,' Wilkowski said. Leonard Rodda, who sold Wilkowski the e-cigarette at his store, has offered to replace it for free with a different model. 'I've only recently heard about that with the battery, and it's a low voltage so I'm surprised that anything like that would happen,' Rodda told the station.

Vapor cigarettes sold under the eHit brand are manufactured by Shenzhen Seego Technology Co. LTD, based out of Shenzhen, China. The company unveiled the eHit model earlier this year, boasting on its website that the device is 'using the best raw materials and craft for whole product, which is more and more popular in the market.' The unit features 'hollow special design for atomizer and battery,' according to its description.

According to the Tobacco Vapor Electronic Cigarette Association (TVECA), there are currently more than 3.5 million Americans puffing on the devices.

Lithium-based batteries in e-cigarettes can explode

Battery exploded while device being smoked by a person

Victim received serious medical injuries to his front teeth and tongue

CBS

Source: http://www.cbsnews.com/8301-504763_162-57379260-10391704/electronic-cigarette-explodes-in-mans-mouth-causes-serious-injuries/

"Electronic cigarette explodes in man's mouth, causes serious injuries"

By CBS News Staff
CBS News/ February 16, 2012, 10:57 AM

Quoting: (CBS/AP) So much for being safer. An electronic cigarette blew up in a Florida man's face, leaving him in a hospital with severe burns, missing his front teeth and a chunk of his tongue. Fire officials said Wednesday that the man had switched to electronic cigarettes to try and quit smoking, and that the scary situation was caused by a faulty battery.

"The best analogy is like it was trying to hold a bottle rocket in your mouth when it went off," said Joseph Parker, division chief for the North Bay Fire Department. "The battery flew out of the tube and set the closet on fire." Fire Chief Joseph Miller said the victim contacted the department on Wednesday to thank firefighters and told them he was recovering at a hospital in Mobile, Ala., and anticipated being released later in the day. Officials have not publicly identified him, citing department policy.

Quote continued: But a Facebook page under the name of 57-year-old Tom Holloway of Niceville was filled with well-wishers commenting on the injury and database searches matched his address on the fire report with his name. Holloway was at his home office when the device exploded, leaving behind burned carpet, chair cushions, pictures and office equipment. A scorched battery case found on a piece of melted carpet appears to be one for a cigar-sized device, the report said. Those in the house with him rushed to his aid in the smoke-filled room and tried to put the fire out with salt, the report said.

Holloway and his family members didn't answer The Associated Press' requests for interviews. Investigators do not know the brand of cigarette, type of battery or age of the device, Parker said. It appears the battery was rechargeable lithium because a recharging station and other batteries were in the room, he said. Parker has forwarded information about the blaze to the fire marshal's office to include in any databases on the devices. But Parker said he has yet to hear of any similar instances

Lithium-based batteries in e-cigarettes can explode

Battery exploded while device being charged in a vehicle

Victim's clothing caught fire causing second-degree burns on body

CBS

Source: http://losangeles.cbslocal.com/2013/07/11/corona-couple-sues-after-e-cigarette-battery-explodes-in-car/

"Corona couple sues after E-cigarette battery explodes In car"

July 11, 2013 11:52 PM

Quoting: CLAREMONT (CBSLA.com) - A Corona husband and wife have sued an e-cigarette manufacturer after its rechargeable battery exploded in their vehicle, leaving the woman with second-degree burns.

Jennifer Ries and her husband, Xavier, were on their way to the Los Angeles International Airport for a volunteer trip to South America back in March. Ries said she was charging a VapCigs e-cigarette when an aroma filled the car.

"My husband asked if I had nail polish in the car. I looked around and I saw the battery to the (e-cigarette) dripping. I went to unscrew it and the battery started shooting fire toward me and then exploded and shot the metal pieces onto my lap," she said.

Quote continued: Ries told CBS2's Serene Branson that her cotton dress caught fire.

"A blowtorch type of fire and then an explosion," she said.

Xavier said he immediately got the car into the emergency lane.

"I let go of (Jennifer) so she could get out, grabbed the coffee that was sitting between us, and threw it on the seat to put (the fire) out," he said.

"I got severe second-degree burns on both the back of my upper thighs and and my lower buttocks," said Ries.

Ries said she's still visiting doctors at UC Irvine Health Regional Burn Center.

Lithium-based batteries in e-cigarettes can explode

Battery exploded while device being charged in a vehicle

Incident caused fire damage to back seat of unattended vehicle

Source: http://www.kpho.com/story/22071692/lighting-up-e-cigarette-charger-sparks-car-fire-in-az

"Lighting up: E-cigarette charger sparks car fire in AZ"

By Lindsey Reiser Peoria, AZ (CBS5)
Posted: Apr 24, 2013 10:40 PM CDT
Updated: May 09, 2013 8:06 AM CDT

Quoting: Plenty of people charge cell phones at night when they're sleeping or leave a charger plugged in when they're not there. But that inattention proved devastating for a Peoria couple when an e-cigarette left in a car charger sparked a fire. … Still, this couple thought nothing of it when they left it in their car to charge. "I put it into the cigarette lighter and this red light comes on to let you know it's charging," said Jennie Burton.

She and her husband, Lee, headed to the hospital for an appointment and left their electronic cigarette to charge while they were inside. The appointment lasted a couple of hours, longer than expected.

"We get a call over the loud speaker of the hospital: 'Lee Burton, go to your car,'" Jennie Burton said.

Quote continued Jennie Burton went outside and realized that the electronic cigarette was not as harmless as she thought. "All of a sudden, I see the hood of the car that's raised, it's orange, you can't miss it, and two or three fire trucks and about 20 guys," Jennie Burton said.
The car had caught fire, and though it was out by the time Jennie Burton got outside, the damage was already done. "This just shot out into the back seat and created the fire," Jennie Burton said, pointing to the tip of the electronic cigarette. "It started smoldering like a hot cigarette and created the fire."

The fire was caused by "a small lithium battery that is commonly found in cameras, camcorders, things of that nature," said Michael Young with the Glendale Fire Department. He said they believe the lithium battery inside the electronic cigarette exploded. He said this is the first case he's seen, but as more people start to use electronic cigarettes - and as the weather heats up - he said you should never leave them unattended.

"The fact that this was contained to just the back seat, she's extremely lucky," Young said.

Lithium-based batteries in e-cigarettes can explode

Incidents with Lithium-based batteries are increasing

Besides e-cigarettes, other applications have had runaways/explosions

Fires and other dramatic incidents have received much attention in media

Within the past several years, there have been battery-caused:

- ✓ **Incinerations of hybrid and all-electric consumer vehicles**
- ✓ **Houses burned to the ground (EVs, laptop computers)**
- ✓ **Cargo aircraft destroyed in flight with multiple crew fatalities**
- ✓ **Thermal runaways on new passenger aircraft (Boeing 787)**
- ✓ **Bizarre explosion of a lithium-ion battery recycling plant**
- ✓ **Unexplained destruction of U.S. Navy's all-electric ASDS minisub**
- ✓ **And a myriad of other battery-related mishaps involving virtually every type of Lithium chemistry have also been publicly reported**

Low energy nuclear reactions (LENRs) could be super-hot triggers for some incidents

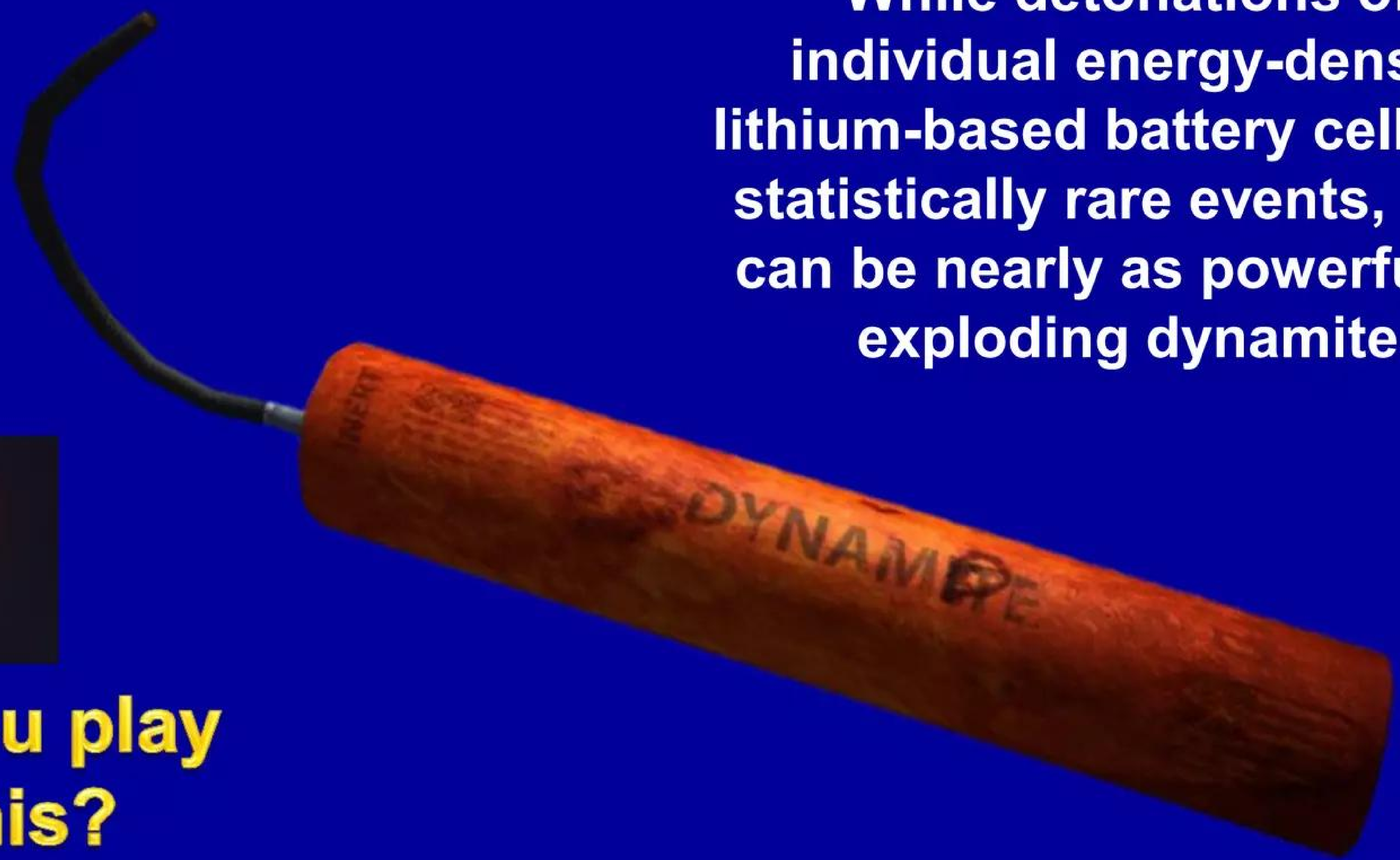
Lithium-based batteries in e-cigarettes can explode

Key

take-aways

Key take-aways

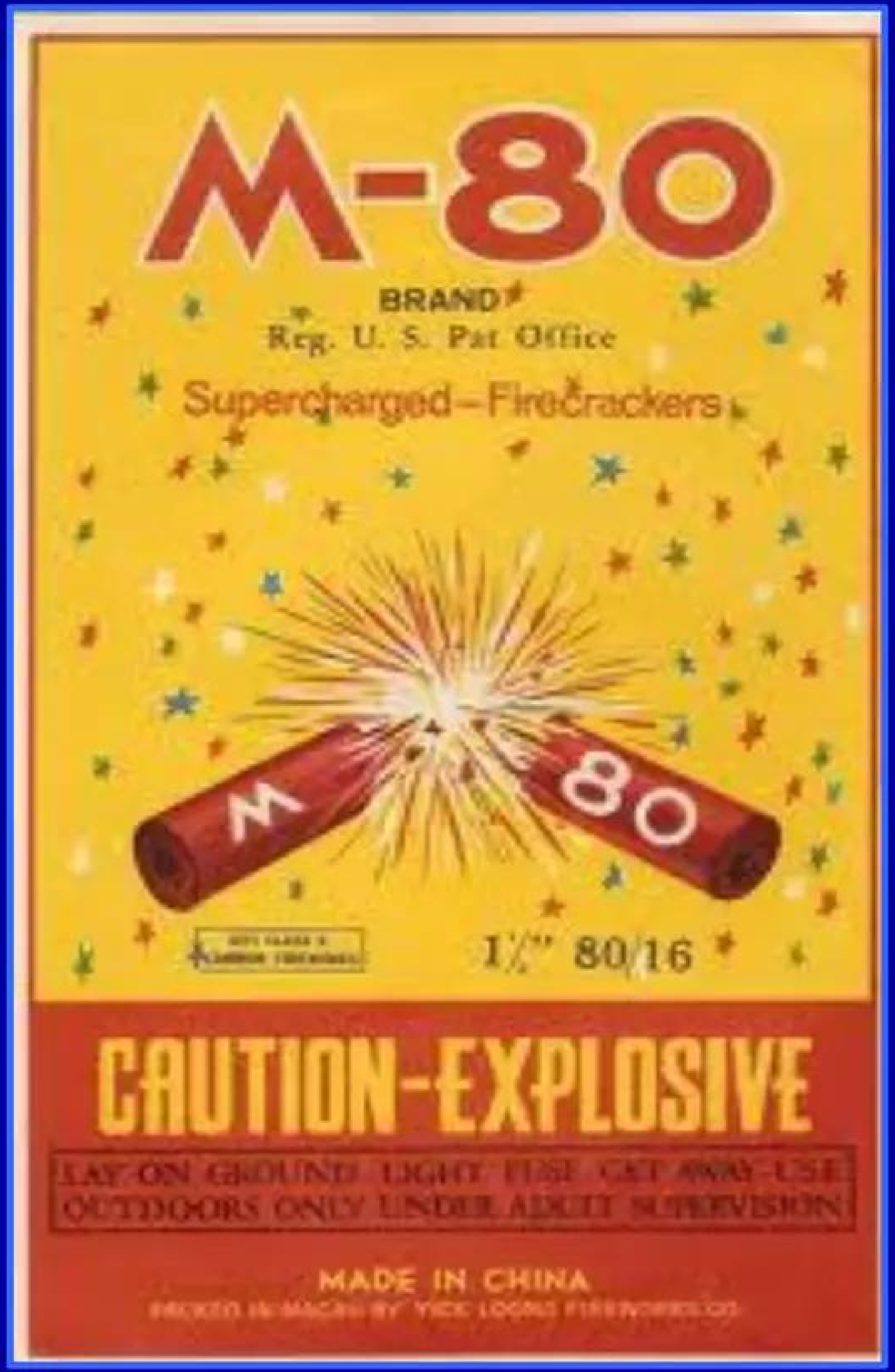
While detonations of individual energy-dense, lithium-based battery cells are statistically rare events, they can be nearly as powerful as exploding dynamite



Would you play with this?

Key take-aways

Or would you put one of these in your mouth and light a match?

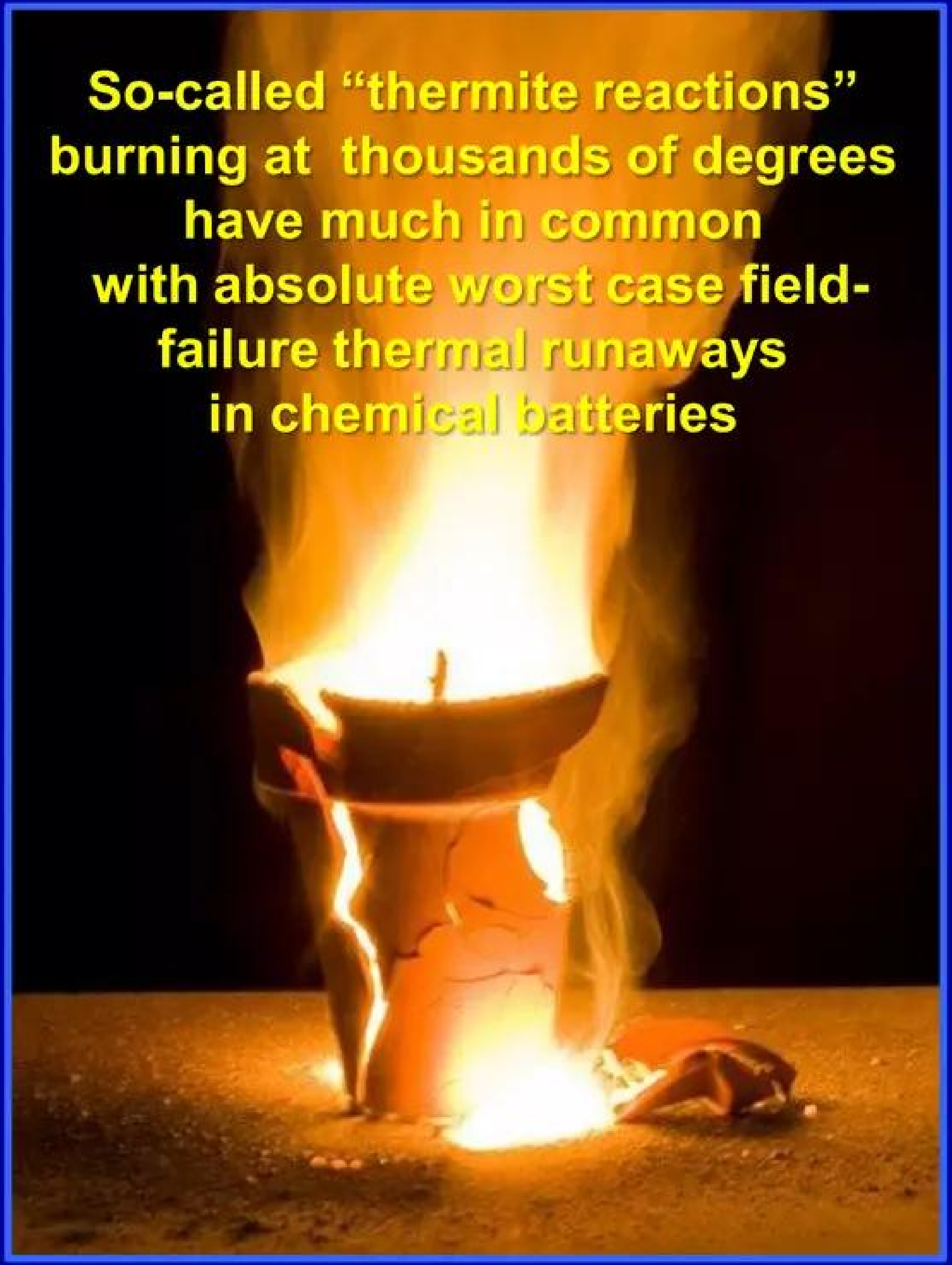


Lithium-based batteries in e-cigarettes can explode

Key take-aways

- ✓ Seeing increasing numbers of statistically rare but serious incidents occurring with electronic cigarettes in which their Lithium-based batteries have had thermal runaways and even violent explosions; some have caused human injuries
- ✓ Incidents occurred inside buildings and in motor vehicles
- ✓ An unknown percentage of such events may have been caused by low energy nuclear reactions (LENRs) that are potent triggers for catastrophic types of battery failures
- ✓ If you doubt either the frequency or seriousness of such incidents, then query Google using the search terms e-cigarette fire explosion and see many different stories
- ✓ Anyone who smokes e-cigarettes should treat them with the proper caution and great care accorded to any type of device that stores a great deal of chemical energy in a small compact package, such as M-80 mega-firecrackers

Certain chemical reactions release enough heat to actually melt metals



Source: http://www.popsci.com/node/30347

Lithium-based batteries in e-cigarettes can explode

Key take-aways

- ✓ **According to the *New York Times* story cited to right, annual sales of e-cigarettes and refills are expected to approach US$ 1.7 billion in CY 2013**
- ✓ **Industry participants estimate e-cigarettes will account for ~1% of total US cigarette sales in CY 2013; sales of these devices are growing very fast**
- ✓ **Under current U.S. legislation, e-cigarettes more-or-less unregulated by states and federal government**
- ✓ **Devices are manufactured mainly by smaller-sized companies located in U.S. or offshore; large est. tobacco companies just starting to get in the game**
- ✓ **Many catastrophic e-cigarette failure incidents are associated with charging of their Lithium-based batteries; battery charging process very much akin to LENR experiments with electrolytic chemical cells**
- ✓ **Significant safety risks associated with such devices are not well-understood or widely appreciated by majority of customers and e-cigarette manufacturers**

The New York Times

ADVERTISING
"E-Cigarette Makers' Ads Echo Tobacco's Heyday"
By Stuart Elliott
Published: August 29, 2013

Source:
http://www.nytimes.com/2013/08/30/business/media/e-cigarette-makers-ads-echo-tobaccos-heyday.html?_r=0

Quoting directly:

"Electronic cigarettes may be a creation of the early 21st century, but critics of the devices say manufacturers are increasingly borrowing marketing tactics that are more reminiscent of the heady days of tobacco in the mid-1900s. With American smokers buying e-cigarettes at a record pace — annual sales are expected to reach $1.7 billion by year's end — e-cigarette makers are opening their wallets wide, spending growing sums on television commercials with celebrities, catchy slogans and sports sponsorships. Those tactics can no longer be used to sell tobacco cigarettes, but are readily available to the industry because it is not covered by the laws or regulations that affect the tobacco cigarette industry."

Lithium-based batteries in e-cigarettes can explode

Thermal runaways:

batteries behaving badly

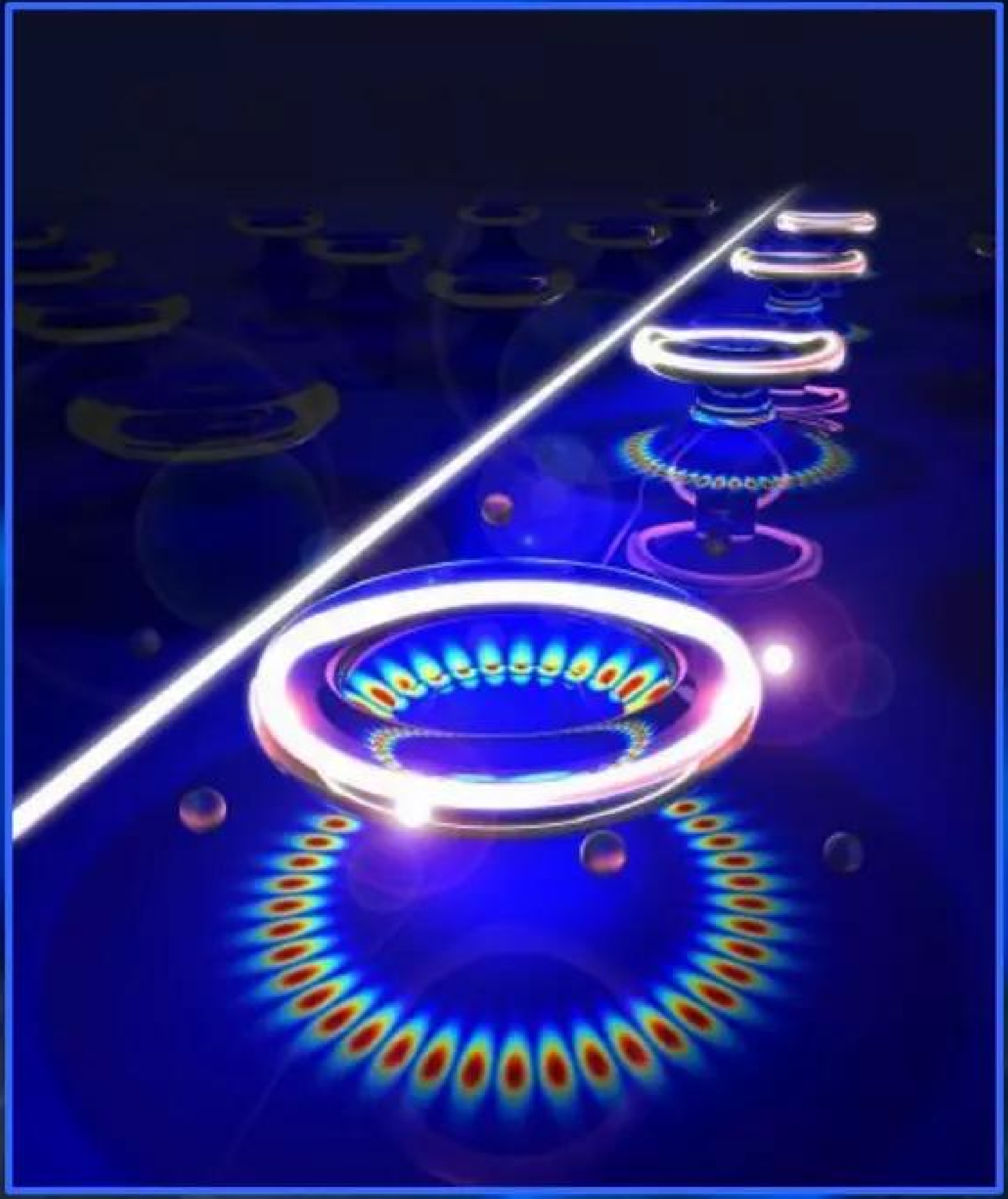
Lithium-based batteries in e-cigarettes can explode

Thermal runaways: batteries behaving badly

No lithium-based battery chemistry is 100% immune to runaway risks

- ✓ Market success of lithium-based batteries since 1991 and substantial increases in cell energy densities have encouraged battery technologists to proliferate them into a myriad of new and different market applications
- ✓ One such new application is electronic cigarettes (2003)
- ✓ MYTH: Lithium iron phosphate ($LiFePO_4$) battery chemistry is effectively immune to any risk of thermal runaways and/or catastrophic field-failures; this statement made by many companies is patently false
- ✓ There is really no such thing as a real-world Lithium battery chemistry that is 100% immune to danger of thermal runaways and/or catastrophic field-failures. From risk management perspective, various lithium chemistries only differ in their relative probabilities; some are more or less problem-prone than others

High-Q microresonators on a silicon wafer - class of devices called whispering-gallery-mode resonators



Credit: Image by Jiangang Zhu and Jingyang Gan/WUSTL

Lithium-based batteries in e-cigarettes can explode

Thermal runaways: batteries behaving badly

Lithium-based batteries in e-cigarettes can explode

Thermal runaways: batteries behaving badly

- ✓ Typically well-controlled electrochemical reactions in batteries ordinarily generate a certain amount of unavoidable process heat which is then dissipated harmlessly simply by emitting invisible infra-red radiation from the battery case out into the local environment; during normal operation, contents of battery cells still remain well-within proscribed boundaries of designed range of optimal thermochemical operating temperatures
- ✓ On rare occasions, for a variety of different reasons, a battery cell's electrochemical reactions can suddenly start running at greatly elevated rates that create more process heat than a battery's normal thermal dissipative mechanisms can easily handle, which then starts raising the temperature of battery cell contents out beyond their ideal safe operating range; threshold for out-of-control danger has not yet been crossed

At key point --- call it the Rubicon River for a failing battery cell --- a very dangerous positive (+) feedback loop is created: whereby, increasing cell temperatures further accelerate electrochemical reactions in cells which produces even more heat, boosting local cell temperatures even higher, etc.

Thermal runaways are thus born: only question is how bad they get before destroying enough of a battery to stop + feedback-accelerated reactions

Lithium-based batteries in e-cigarettes can explode

Thermal runaways: batteries behaving badly

Good news: thermal runaway events are statistically rare

Bad news: when they do happen they can cause catastrophic effects

By any reasonable standard, lithium-based batteries are a pretty safe technology: garden variety thermal runaways only occur at frequencies of one such event per several millions of battery cells

The very worst, least understood type of thermal runaway, which goes under innocuous-sounding sobriquet of "field-failure," occurs at a rate of one such event per ~ 4 - 5 million lithium-based battery cells right off the production line and regardless of their chemistry or primary vs. secondary, according to statistics collected by a major Japanese manufacturer of lithium-ion consumer batteries

There's one more issue: although it's hard to quantitatively specify, probability of thermal runaways seems to increase significantly as batteries age and go thru a great many charge-discharge cycles

Lithium-based batteries in e-cigarettes can explode

Thermal runaways: batteries behaving badly

"Garden variety" thermal runaways:

- Reasonably well understood
- Triggered by substantial over-charging or excessively deep discharges
- Triggered by external mechanical damage to battery cells, e.g., crushing, punctures; internal dendrites can penetrate separators

Field-failure thermal runaways:

- Much rarer and comparatively poorly understood
- Many believe triggered by electrical arc discharges (internal shorts); but what causes initial micro-arcs?
- Much higher peak temps vs. garden variety events
- Lattice suggests: low energy nuclear reactions (LENRs) could well be triggers for some % of them

Lithium-based batteries in e-cigarettes can explode

Thermal runaways: batteries behaving badly

Thermal runaways can have greatly varying degrees of severity

Garden variety single-cell thermal runaways can be as little as a battery that just heats-up a bit and simply stops functioning … or a battery's case can bulge significantly from internally generated heat without designed venting and releasing of contents from the inside before it stops functioning and then starts cooling down on its own

A slightly worse variant of a garden variety thermal runaway results in just a single cell venting or rupturing, but (in cases of flammable electrolytes) there are no hot, flaming battery contents spewed-out that could potentially ignite local combustibles and adjacent cells

In worst-case garden variety runaway, hot flaming electrolyte erupts from a ruptured battery cell, which may ignite nearby materials and cells; in this event variant (that is still not the worst-of-the-worst), internal peak temperatures usually not yet hot-enough to melt metals

Lithium-based batteries in e-cigarettes can explode

Thermal runaways: batteries behaving badly

Field-failures are truly catastrophic events in chemical batteries

Battery industry definition of a field-failure thermal runaway event:

Safety concerns have been heightened by highly publicized safety incidents and ensuing widespread recalls of lithium-ion batteries used in laptop computers and cell phones [14, 15]. When these rare safety incidents occur, lithium-ion batteries operating under otherwise normal conditions undergo what appear to be spontaneous thermal runaway events, often with violent flaming and extremely high temperatures. Moreover, these failures usually involve cells and cell designs that have passed extensive abuse testing, including the standardized abuse safety tests. *Most such Li-ion safety incidents in the field are not preceded by any obvious external abuse*. We refer to these spontaneous safety incidents as "field-failures".

Source: **"Batteries for Sustainability – Selected Entries from the Encyclopedia of Sustainability in Science and Technology," Ralph J. Brodd, Ed., Chapter 9 by B. Barnett et al., "Lithium-ion Batteries, Safety" Springer ISBN 978-1-4614-5791-6 (2012)**

Lithium-based batteries in e-cigarettes can explode

Thermal runaways: batteries behaving badly

Absolute worst-case Armageddon runaways involve burning metals

Field-failure category of thermal runaways can reach extremely high peak temperatures of thousands of degrees Centigrade along with big electric arcs

Such temperatures are hot-enough to melt metallic structures inside batteries and combust almost anything and everything located within a battery case

If initiating spark is hot-enough, battery materials containing chemically bound oxygen will release it as O_2; by creating its own oxygen supply, combustion process becomes self-sustaining, self-propagating flame front that consumes all burnable battery materials. Progressive thermal fratricide between cells can reduce batteries to unrecognizable debris; such fires could burn in a vacuum

In absolutely worst-case events, even METALS can start burning in very fast, thermite-like reactions that can boost temps up to ~ 4,000° C; this is nightmare scenario wherein even deadly explosions with shrapnel can potentially occur

Lithium-based batteries in e-cigarettes can explode

E-cigarette failures roughly consistent with Japanese data

Given small form-factors, the severity of certain incidents is anomalous

- ✓ Reiterating: a major Japanese manufacturer of high-volume consumer Lithium-based batteries has compiled long term statistics indicating that catastrophic field-failures occur at a rate of one such event per ~ 4 - 5 million battery cells right off the production line and regardless of their chemistry or whether batteries are primary vs. secondary (rechargeable)
- ✓ Using that statistic, and assuming that there is just one cell per small form-factor e-cigarette Lithium battery, we can calculate a conservative worst-case upper bound estimate for the total expected number of catastrophic battery field-failures of e-cigarettes per year in the U.S.
- ✓ Use a total CY 2013 U.S. sales figure of US$ 1.7 billion; assume an average purchase price of $25 per device (this pointedly ignores refill sales, so total number of cigarette units sold will be substantially over-estimated). So $1.7 billion/$25 = 68 million units annually (this is obviously high since there are only an estimated ~4 million e-smokers in U.S.). Then divide 68 million units by 5 million (est. frequency of field failures) and we obtain an estimated ~14 catastrophic battery field failures per year in U.S.; although we don't have comprehensive incident statistics, what is observed qualitatively with many Google searches seems to roughly agree with this prediction in the sense that we're certainly not seeing reports of hundreds of such incidents per year
- ✓ It should be noted that as of today there is no conclusive mass spectroscopy proof for the involvement of LENRs in the rash of e-cigarette battery field-failure explosions … yet. That said, there are anomalous features of such explosions such as: their severity in the light of small volumes of internal materials and electrolyte; seemingly abnormal frequency of quite violent detonations which are suggestive of super-hot, fast pyrotechnic processes inside batteries, etc.

Lithium-based batteries in e-cigarettes can explode

LENRs

Widom-Larsen theory of LENRs

Revolution in nuclear technology

What are they?

Lithium-based batteries in e-cigarettes can explode

LENRs are neither fission nor fusion but something rather different

Low energy nuclear reactions (LENRs) are a uniquely green nuclear technology: no deadly energetic gamma or neutron radiation and no production of long-lived radioactive wastes

Lithium-based batteries in e-cigarettes can explode

LENRs are a paradigm-shifting nuclear technology

No deadly gamma radiation …

No dangerous energetic neutron fluxes and

Insignificant production of radioisotopes

Truly revolutionary and environmentally safe

Lithium-based batteries in e-cigarettes can explode

LENRs are a very new type of green nuclear technology

Combustion of fossil fuels (strictly chemical processes involving outer valence electrons of nuclei):

Comments: emits copious quantities of CO_2, a greenhouse gas; comprises vast majority of mankind's energy production today

Scale of energy release: eVs (chemical regime)

Alternate natural sources of fuel: primarily oil, coal, and biomass; basic reaction: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ + energy

Controlled release of nuclear binding energy (fission and fusion; mainly involve strong interaction):

Comments: no CO_2 emission; emit dangerous *energetic* radiation (γ, neutron); today <10% of global energy production

Scale of energy release: MeVs (nuclear regime) > 1,000,000x all chemical energy sources

Heavy-element fission (involves shattering heavy nuclei to release stored nuclear binding energy):

Comments: requires massive shielding and containment structures to handle radiation; major rad-waste clean-up

Alternate natural sources of fuel: today, almost entirely Uranium; Thorium-based fuel cycles now under development

Heavy element U-235 (fissile isotope fuel) + neutrons → (complex array of lower-mass fission products; some are very long-lived isotopes) + energetic gamma radiation + energetic neutron radiation + energy

Fusion of light nuclei: (involves 'mashing' light nuclei together to release stored nuclear binding energy):

Comments: present multi-billion $ development efforts (e.g., ITER, NIF, Tokamaks) focusing mainly on D+T fusion reaction; requires massive shielding/containment structures to handle 14 MeV neutron radiation; minor rad-waste clean-up $ vs. fission

Natural sources of fuel: Deuterium and Tritium (two heavy isotopes of hydrogen)

Most likely commercial fusion reaction involves: D + T → He-4 (helium) + neutron + energy (total 17.6 MeV; ~14.1 MeV in neutron)

Low energy neutron reactions (LENRs - key distinguishing feature is neutron production via weak interaction; neutron capture + gamma conversion to IR + decays [α, β] release nuclear binding energy):

Comments: early-stage technology; no emission of energetic neutron or gamma radiation; no long lived rad-waste products; LENR systems do not require massive and expensive radiation shielding and containment structures → much lower $ cost

Natural sources of fuel: any element/isotope that can capture LE neutrons and release >0.78 MeV in nuclear binding energy

Involves complex, branching LENR nucleosynthetic transmutation networks that begin with neutron captures on seed nuclei then proceed from lower to higher values of atomic mass (A); very similar to what happens in stars, only at low temps/pressures

Lithium-based batteries in e-cigarettes can explode

LENRs can occur in chemical cells = batteries

Collective electroweak neutron production, capture, and nuclear decays

Nuclear-strength, micron-scale, local electric fields drive catalytic neutron production

Collective effects + external input energy:

$Energy_{E\text{-}field} \rightarrow e^{-*} + p^{+} \rightarrow n + \nu_e$ [chemical cells]

$Energy_{B\text{-}field} \rightarrow e^{-} + p^{+} \rightarrow lepton + X$ [solar flares]

Collective electroweak production of neutrons in condensed matter and large-scale magnetic regimes

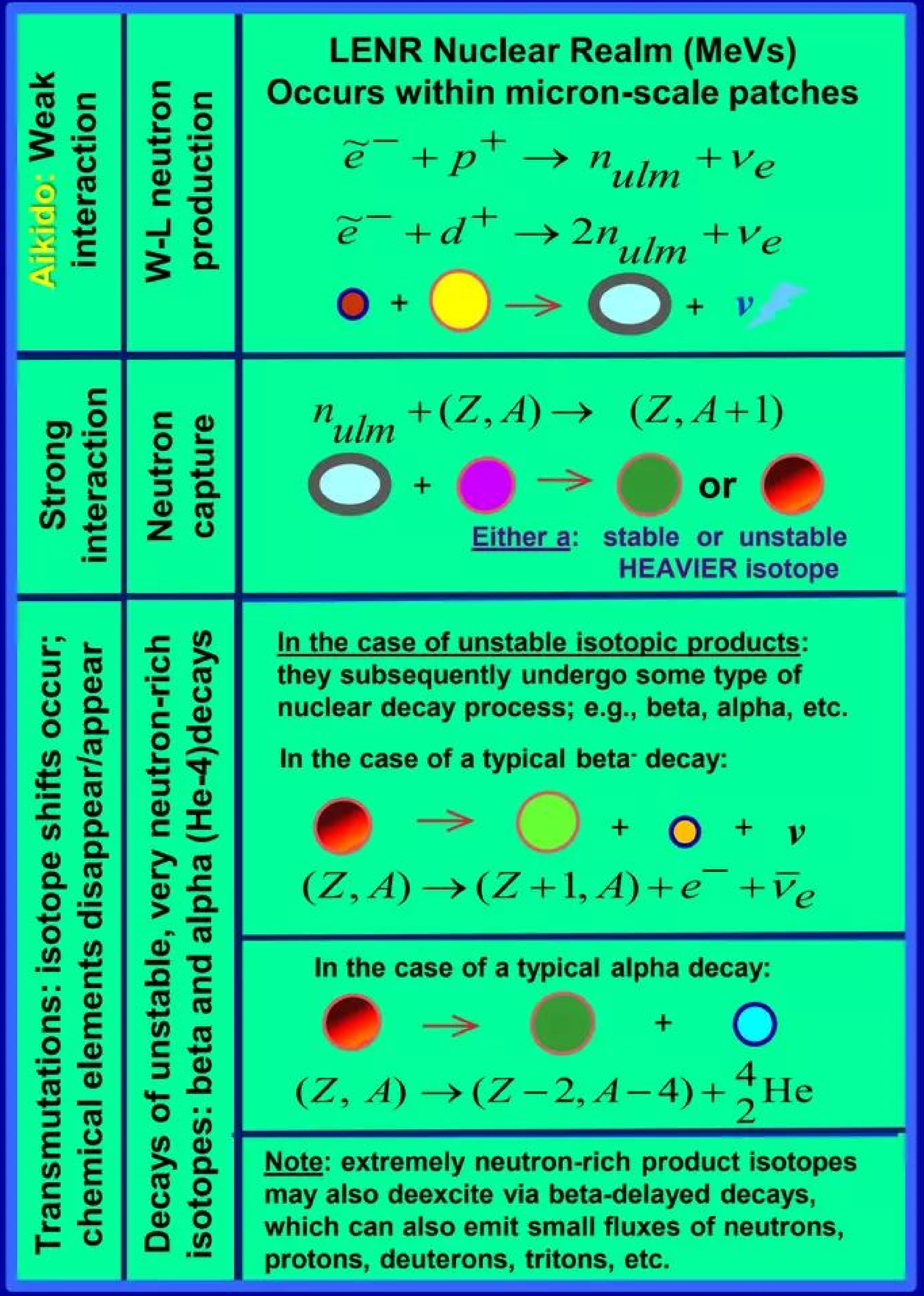
Afterwards the neutrons capture on targets:

$n + (Z, A) \rightarrow (Z, A+1)$ [neutron capture]

$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \nu_e$ [beta^{-} decay]

Mainly β^{-} decays of neutron-rich isotopic products and direct conversion of gamma radiation into infrared heat

This releases nuclear binding energy >1 million x chemical



Lithium-based batteries in e-cigarettes can explode

Batteries, energetic materials, and LENRs are converging

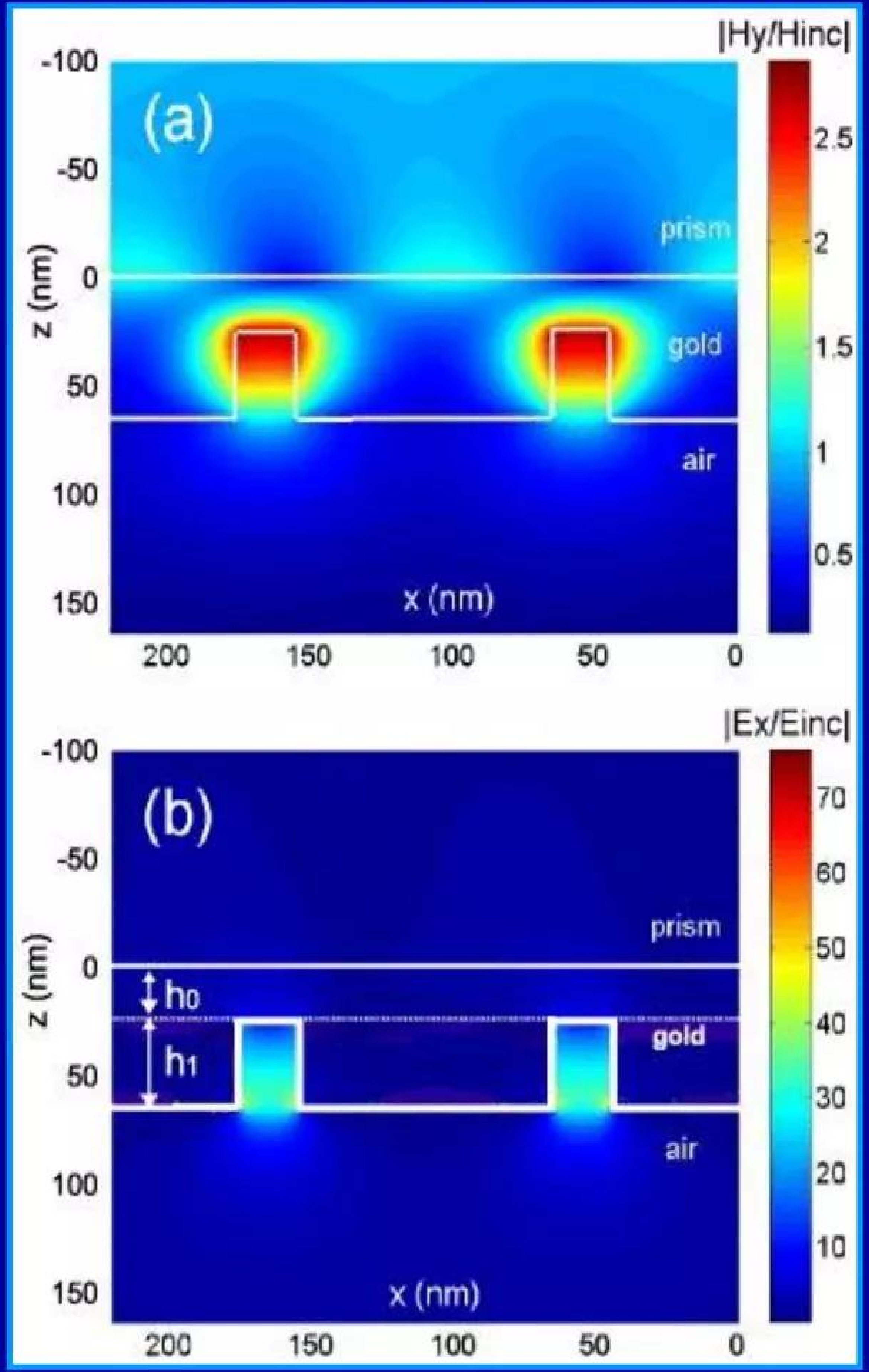
These previously disparate technologies are now beginning to overlap

- ✓ **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

- ✓ **Low energy nuclear 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)

Lithium-based batteries in e-cigarettes can explode

Three domains of technology all involve energy releases

Differ in main purpose, source, energy-scale of reactions, and rates

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	Batteries can generally be operated safely only at temperatures < 200° 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.
Low energy nuclear 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 ~3,700° to 5,700° 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

Lithium-based batteries in e-cigarettes can explode

LENRs can occur

in Lithium-based batteries

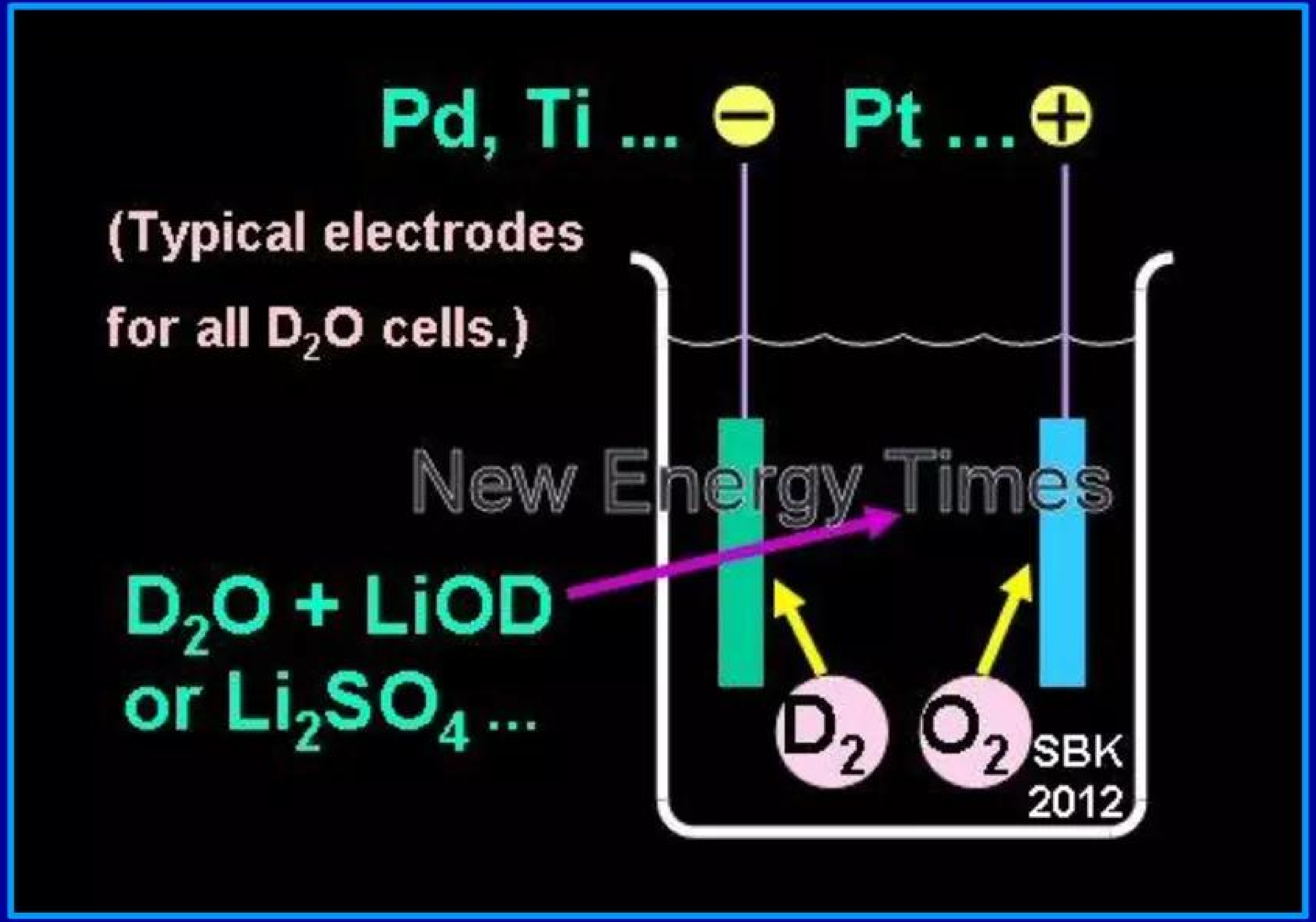
Lithium-based batteries in e-cigarettes can explode

Incidents more common during charging because of LENRs

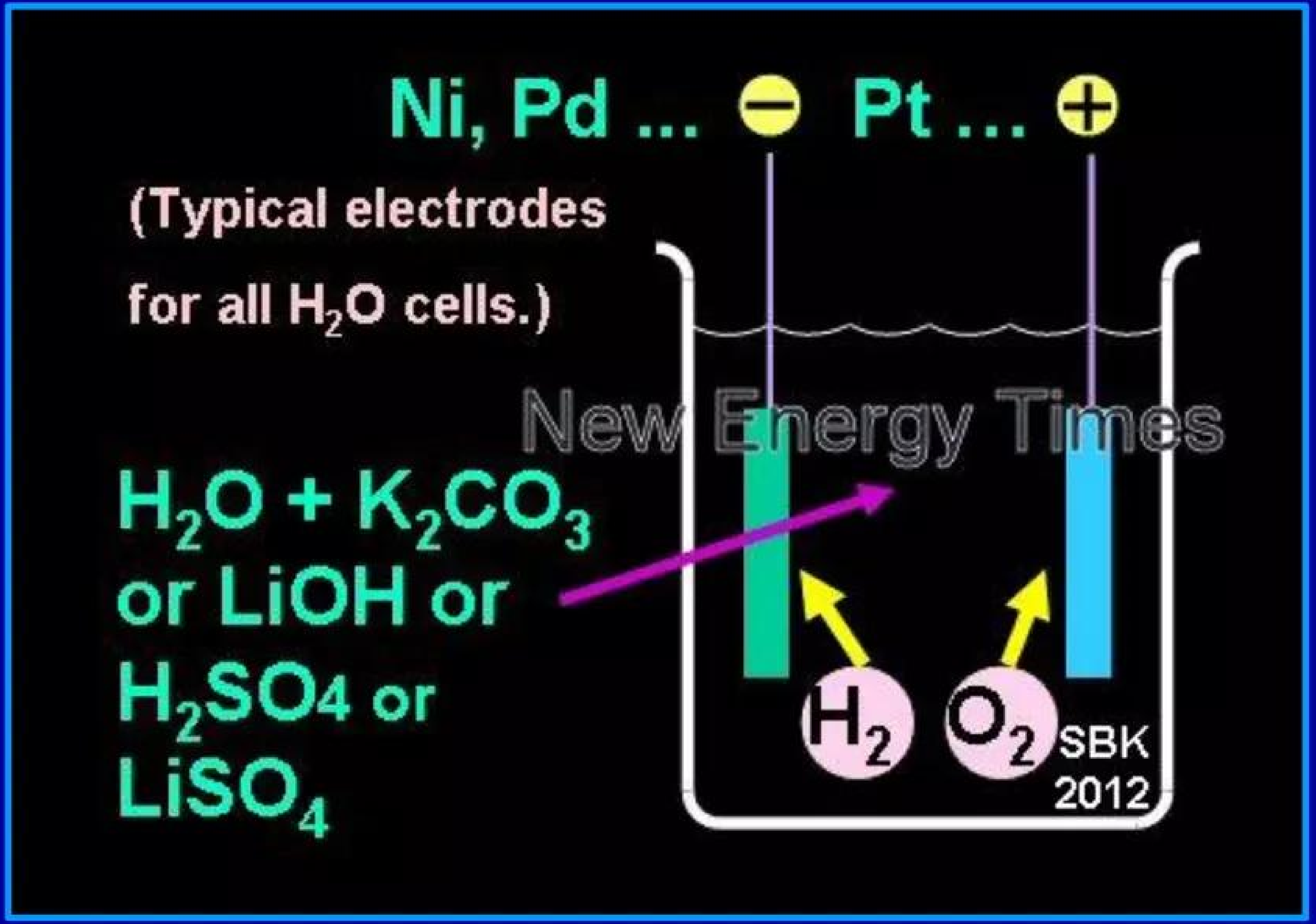
LENR experiments with electrolytic cells similar to charging batteries

For over 20 years, LENR researchers have been reporting credible experimental data providing evidence for nuclear transmutations in electrolytic chemical cells. Some such experiments, e.g. Miley *et al.* (1996) have produced outstanding results

Example 1: Heavy-water P&F-type electrolytic cell
Electric current provides necessary input energy



Example 2: Light-water P&F-type electrolytic cell
Electric current provides necessary input energy for LENRs



Source: html version is http://newenergytimes.com/v2/reports/Index-of-LENR-Experimental-Methodologies.shtml
pdf: http://www.slideshare.net/StevenKrivit/lenr-methodsdistributioncopyrightnewenergytimes20130522-21707257

Lithium-based batteries in e-cigarettes can explode

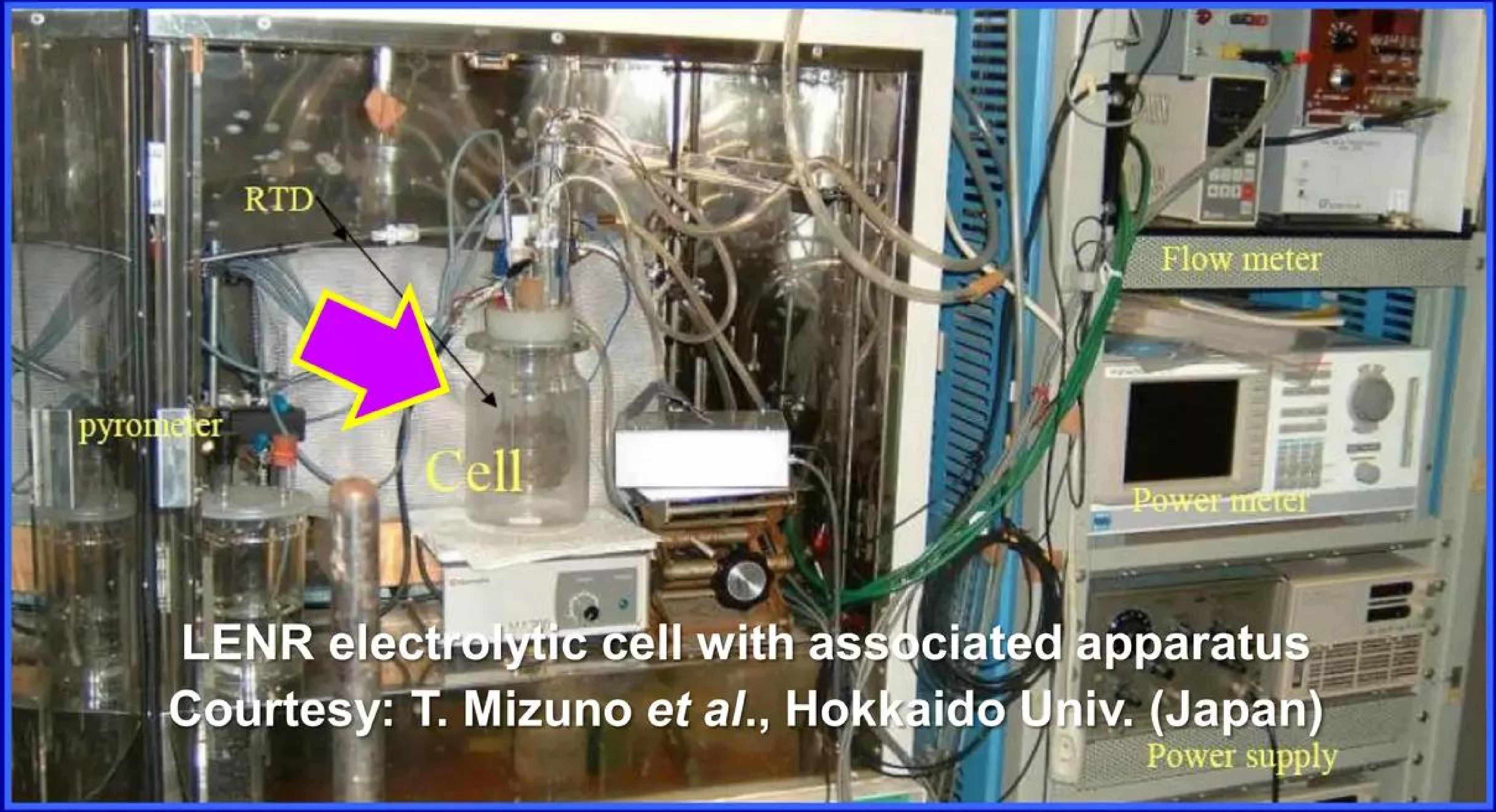
Parallels between LENRs and Lithium-based batteries

Many types of LENR experiments; electrolytic cells are close to batteries

Majority of LENR experiments with electrolytic cells had Lithium somehow present in the electrolyte; forms intimate alloys on surfaces of metallic cathodes. In classic Pons & Fleischmann-type experiments with Pd cathodes, ultra-low-momentum neutron captures on Lithium and Palladium produced most excess thermal energy measured with calorimetry

Example 1: Heavy-water P&F-type electrolytic cell
Electric current provides necessary input energy

Example 2: Light-water P&F-type electrolytic cell
Electric current provides necessary input energy



Lithium-based batteries in e-cigarettes can explode

Parallels between LENRs and Lithium-based batteries

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

Widom & Larsen's 2006 *European Physical Journal C* paper shows the following Lithium-seed LENR network cycle:

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

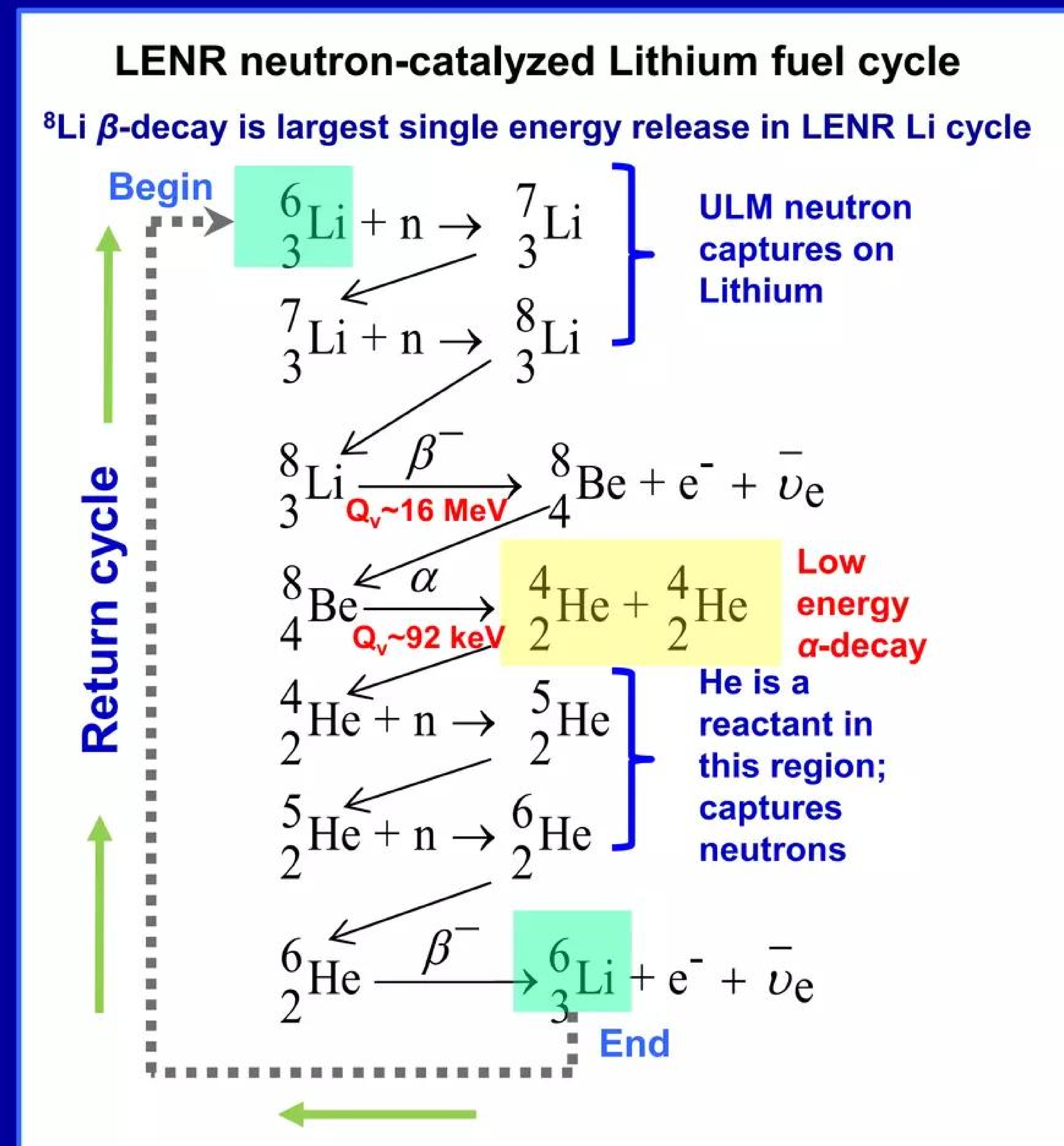
This particular cyclical LENR pathway can release about the same amount of energy as the D-T fusion reaction without creating any MeV-energy energetic neutrons, hard gamma radiation, or radioactive isotopes. Although a portion of the 26.9 MeV in excess nuclear binding energy released is lost ("haircut")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

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

See:

"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



Lithium-based batteries in e-cigarettes can explode

Parallels between LENRs and Lithium-based batteries

Use of catalytic neutrons enables vast variety of LENR fuel targets

Aspect or characteristic	Advanced Li-ion polymer electrolyte battery pack Comments		Conceptualized LENR-based heat-producing device Comments	
	Store electricity in chemical bonds		Power generation: release nuclear binding energy	
Anode?	yes	Graphite (Carbon)	effectively	Nickel, Titanium, etc.
Cathode?	yes	Li-iron phosphate	effectively	Nickel, Titanium, etc.
Electrolyte?	yes	Carbon-H polymer	equivalent	Aqueous fluid w. metal salts; H_2 gas
Hydrogen (H) in electrolyte	yes	H in Carbon-H polymer (C_n-H_n)	yes	Either H or deuterium (D) in H_2O/D_2O or ionized gas – need H or D to make ULM neutrons
Key chemical element	**Lithium** shuttles electrons	Used as an ion found in a compound, e.g., $LICoO_2$ or Li_2FePO_4	**Lithium or alternative** release nuclear binding energy	Can be 'burned' as target nuclear fuel source– present in electrolyte
'Fuel'	Electrons	Charge-up from electrical power source (e.g., grid); then discharge	Electrons, Protons, Li Nickel, Titanium, or any element or isotope that can capture neutrons	Reactants 'burned' as nuclear fuels – in anode, cathode, and/or electrolyte – having no electrical charge, **neutrons are promiscuous nuclear particles that can readily be captured by almost any element or isotope, which triggers release of nuclear binding energy**
Typical energy levels per reaction	eVs	Simply chemical electronic energies	MeVs	Nuclear binding energies – Lithium (Li) target: its nuclear reactions release ~27 MeV; other elements release much less binding energy
Principal output	Electricity	Various voltages	Thermal heat	Must convert into usable electricity
Uses nanotech?	yes	e.g., fabrication	yes	e.g., fabrication, materials, preparation of fuel nanoparticles
Thermal mgmt. circuitry	yes	Prevent thermal failure events	yes	Prevent extreme overheating and thermal failure
Microprocessor controlled?	yes	Uses sensors to control power	yes	Uses sensors to manage and control power output
Eco-green?	yes	Safe disposal in landfills	yes	No radiation or 'hot' radwaste

Lithium-based batteries in e-cigarettes can explode

Battery industry is encountering LENRs

LENR-active hotspots in electrolytic cells or batteries hit 3,700 - 5,700^{o} C

- ✓ Conditions conducive to initiation of LENRs occur in microscopic, micron-scale regions in random scattered locations on dendrites and other types of growing nanostructures and nanoparticles inside lithium-based batteries and electrolytic cells
- ✓ Although radiation-free, LENRs involving neutron captures on stable lithium isotopes are extremely energetic nuclear processes – can release up to 27 MILLION times more heat than even the most exothermic types of electrochemical reactions
- ✓ Microscopic 100 micron LENR hotspot can release 5^{+} Watts of heat in less than 400 nanoseconds; nuclear processes raise local hotspot temps to 3,700 - 5,700^{o} C
- ✓ Batteries: micron-scale LENR-active sites that happen to be located close to a plastic battery anode/cathode separator (with or without a ceramic layer) will vaporize and flash-ionize a local region of separator which can in turn trigger an internal electrical short discharge at that particular location ; similarly, an LENR patch occurring on surface of a Lithium cobalt oxide cathode or carbon anode can potentially directly trigger irreversible combustion of an affected electrode

In rare events, LENRs can either induce internal electric arcs and/or directly trigger catastrophic thermal runaways in advanced batteries of many different chemistries

Lithium-based batteries in e-cigarettes can explode

Battery industry is encountering LENRs

Detailed description of LENR processes in batteries

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.

Lithium-based batteries in e-cigarettes can explode

Battery industry is encountering LENRs

Detailed description of LENR processes in batteries

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 many mutually competing 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 "thermal fratricide" that can occur between many cells

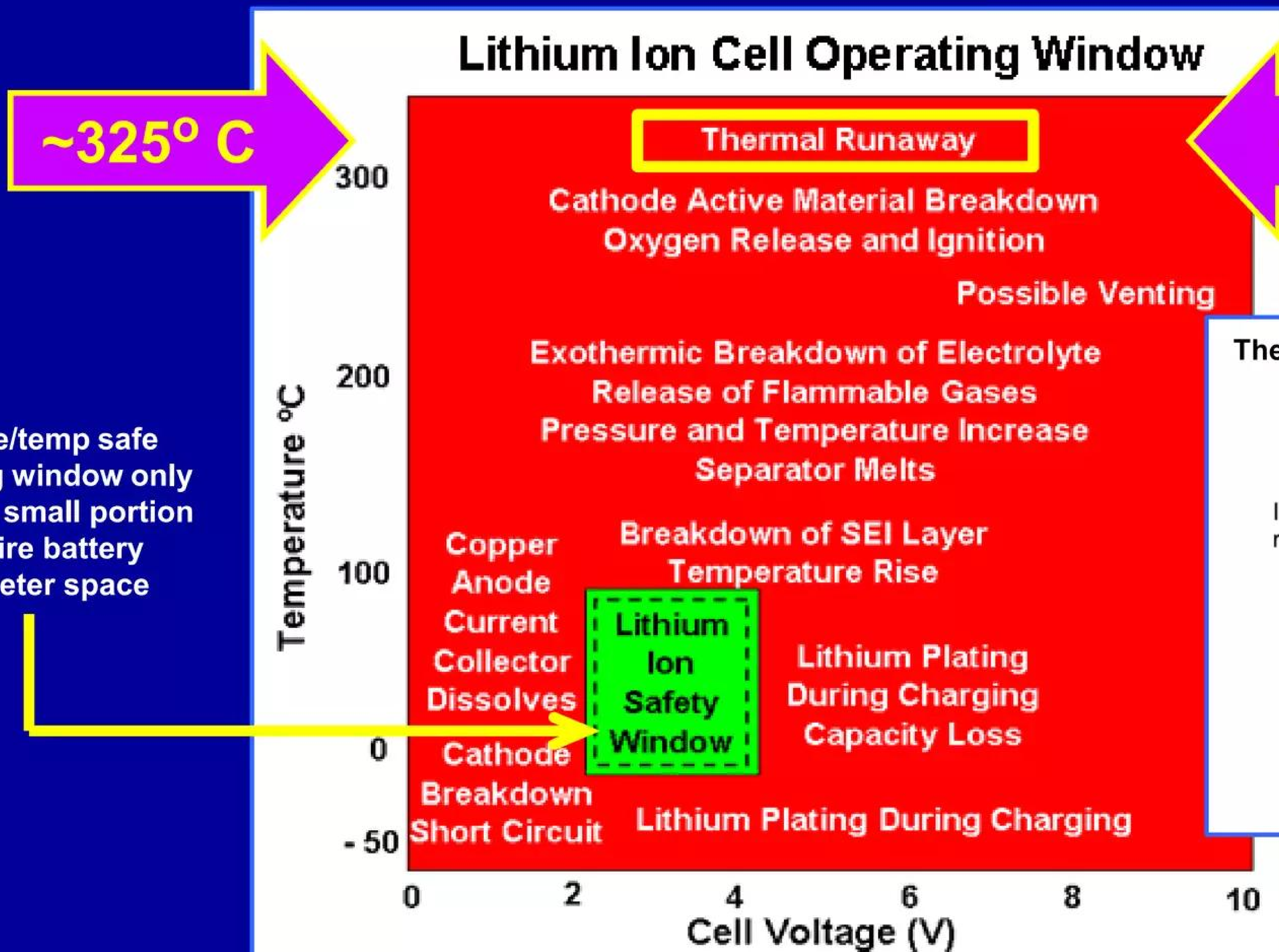
Evolution of such complex chemical systems is very rapid and incompletely understood - quite unpredictable with respect to final results: outcomes can range from minor thermal damage to single cell; to combustion of flammable electrolytes and charring of materials inside case and outside via venting; 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

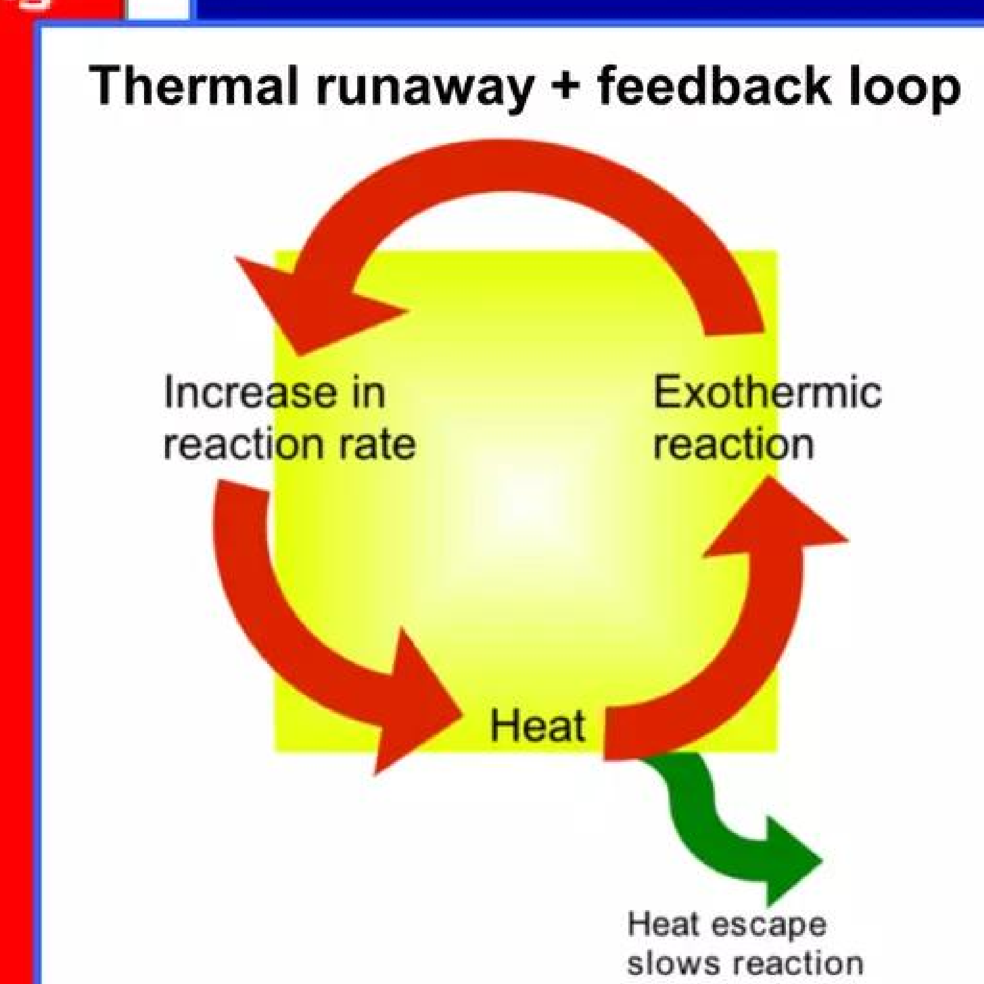
Lithium-based batteries in e-cigarettes can explode

Battery industry is encountering LENRs

Lithium-ion battery cells only have relatively small safe operating window

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





Lithium-based batteries in e-cigarettes can explode

Battery industry is encountering LENRs

Intense heat is an enemy of batteries; it is a friend of LENR devices

- ✓ In unpublished work, Lattice did a rough theoretical calculation of a 50% 'burn' of Lithium fuel target atoms covering an LENR-active patch measuring 30 microns in diameter on a suitable metallic surface (30 microns is ~.001 inches - about a thousandth of an inch in diameter). This particular calculation indicated that ~7 Watts of heat might be produced from each such hotspot in < 400 nanoseconds. Five microscopic LENR hotspots going-off near-simultaneously would create a very damaging 35 Watt heat-pulse inside a battery cell
- ✓ It is not hard to imagine how a handful of LENR hotspots could cause local electrical shorts and/or even full-blown thermal runaways if they occurred deep inside an advanced Lithium-based battery. Being unaware of LENRs, battery scientists presently do not design and engineer commercial batteries to survive extremely energetic internal spot-heating events
- ✓ Interestingly, key objective in condensed matter LENR devices is creation and control of extraordinarily strong local electric fields > 10^{11} V/m on nanostructures and surfaces; this is what determines the ability to produce useful fluxes of catalytic ultra-low momentum neutrons that are captured on local atoms to release massive amounts of nuclear binding energy manifested as intense heat. By contrast, designers of advanced batteries avoid generating unnecessary heat; a warm battery is good for speeding chemical reactions --- up to a point. Beyond that, excessive heating causes a myriad of battery problems, not the least of which are dielectric breakdown events: local charge imbalances can cause short circuits, electric sparks or arcs between internal microstructures and/or across damaged separators

Lithium-based batteries in e-cigarettes can explode

High battery runaway temps

create energetic materials

Lithium-based batteries in e-cigarettes can explode

High thermal runaway temps create energetic materials

Leave domain of stable electrochemistry when batteries heat-up enough

"Burn 'em all --- let God sort 'em out." [1.]

"You can run, but you can't hide." [2.]

LENRs are themselves energetic materials; can create many other energetic materials

- ✓ Batteries cannot withstand star-like local temperatures created by electric arc discharges or LENRS and remain stable; LENR-based power systems can be designed to handle this, e.g. dusty plasmas
- ✓ Creation of nightmarish local "witches' brew" cauldrons of inter-reacting compounds and ions in some regions of failing batteries; very fast, hyper-accelerated reaction rates in superheated zones
- ✓ Witches' cauldrons can generate their own supplies of Oxygen to support combustion processes that propagate spatially within and between battery cells via fast-moving, autocatalytic flame-fronts coupled with intense emission of thermal infrared and UV radiation
- ✓ Arc- and/or LENR-heated regions' behavior is almost more akin to chemistry of stellar atmospheres than everyday electrochemistry

Adapted from U.S. military motto:

Popularized by U.S. special operations forces during the 1960s Vietnam war

1.. Underlying motto unofficially adopted by various military groups; originally, was modernized from Latin, "Caedite eos. Novit enim Dominus qui sunt eius" which literally translated means "Kill them all. God will recognize His own." Quote attributed to Arnaud, Abbot of Citeaux, in reply to question asking how one might tell Cathar heretics from orthodox Catholics during siege of Beziers in Albigensian Crusade (July, 1209)

2. Threat made to Mad Max by a murderous character named "Wez" in Mel Gibson's cult-classic film, "The Road Warrior" (1981)

Lithium-based batteries in e-cigarettes can explode

High thermal runaway temps create energetic materials

Al + HF reaction below releases ~5x as much thermal energy as TNT

Curse of the pyrotechnics and thermites

Examples of two classic very exothermic thermite reactions:

$$Fe_2O_3 + 2\ Al \rightarrow 2\ Fe + Al_2O_3$$

Al_2O_3 $\Delta f\ H^o$ (solid) = - 780 kJ/mol.

$$3\ CuO + 2\ Al \rightarrow 3\ Cu + Al_2O_3$$

- ✓ Please recall that LiF can be formed in some battery cells; when it is heated enough beyond its B.P. (1,681° C) in witches' cauldrons it can decompose to form HF, which can then enable the following:

AlF_3 $\Delta f\ H^o$ (solid) = - 1510.4 kJ/mol.

$$2\ Al(s) + 6\ HF(g) \xrightarrow{400\ -\ 600^oC} 2\ AlF_3(s) + 3\ H_2(g)$$

- ✓ Highest-temperature regions in and around localized witches' cauldrons (almost star-like in many ways) can be hot enough to liberate metal ions which can then react with Oxygen to effectively create burning metals, which is often a high-temperature process:

- ✓ Cobalt metal burns in air at ~2,760° C; Aluminum at ~3,827° C; Iron at ~870° C; etc. --- bottom line: burning metals spells big trouble

Note: Al, Fe, Cu, and O are all available somewhere inside many types of batteries; potential to form various energetic materials in or near witches' brew cauldron areas

material	energy density	
	by mass: MJ/KG	by volume: MJ/L
aluminothermic incendiaries		
Thermite ($Al + Fe_2O_3$)	4.13	18.40
Copper Thermite ($Al + CuO$)	4.00	20.90
nitro-aromatic explosives		
TNT (Trinitrotoluene)	4.61	6.92

Can potentially synthesize explosive nano pyrotechnic mixtures in localized regions

Note: many thanks to J. Bruce Popp of FedEx for sending Lattice down this fruitful line of inquiry

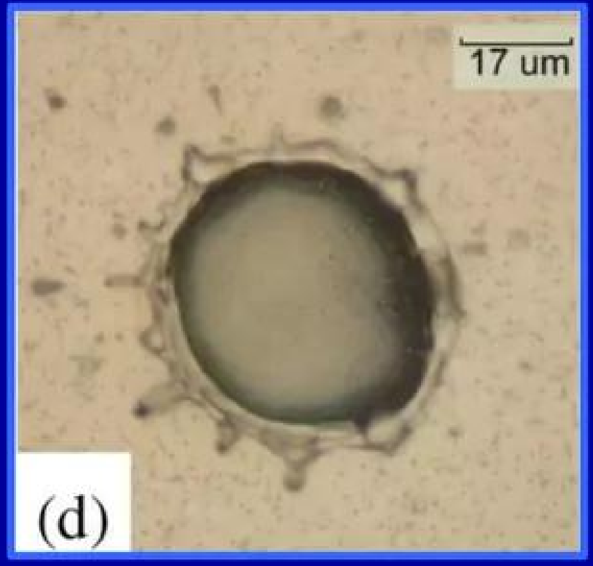
Lithium-based batteries in e-cigarettes can explode

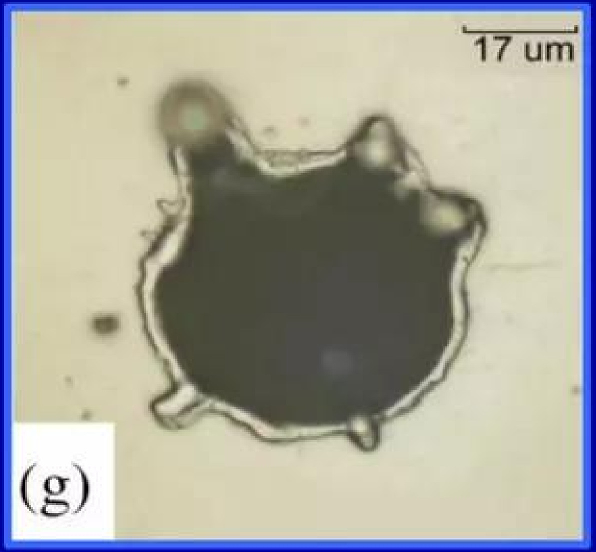
High thermal runaway temps create energetic materials

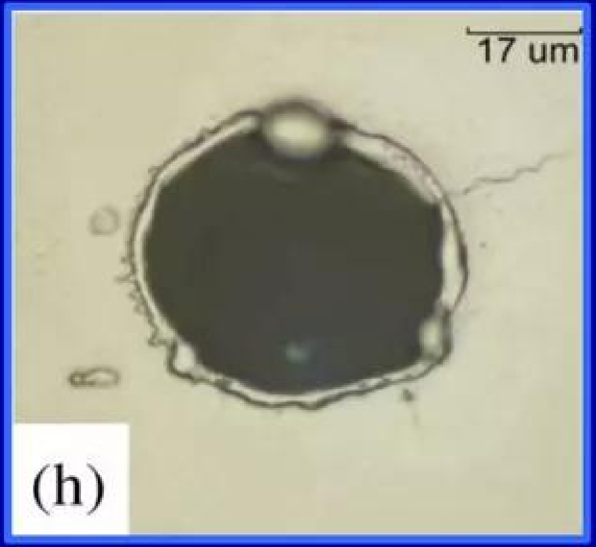
LENR-active surface sites can flash-vaporize refractory metals

Curse of the metallic phase explosions

Hendijanifard & Willis







Intense heating by nuclear processes during short lifetimes of micron-scale LENR-active sites on metallic substrates can result in local flash-boiling of metals in what is also known as a phase explosion. In such events, a local region of metal is vaporized; depending on which metal, heated material expands by 40,000 to 70,000 times its previous volume as a solid. Vapor cloud can cool and condense into tiny droplets, creating microspheres seen in SEM images

"Phase explosion and Marangoni flow effects during laser micromachining of thin metal films"
http://lyle.smu.edu/~mhendija/index_files/Hendijanifard%20SPIE2008.pdf

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)**

Additional reading

for the technically inclined

Lithium-based batteries in e-cigarettes can explode

Additional reading for the technically inclined

Convergence of advanced batteries, energetic materials and LENRs :

"Large increases in battery energy densities drive convergence between energetic materials, LENRs and batteries"

L. Larsen, Lattice Energy LLC, September 6, 2013 [110 slides with detailed table of contents]

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-increased-energy-densities-drive-convergence-of-batteries-and-lenrssept-6-2013

Lattice document concerning LENR-based power generation systems vs. fission and fusion:

"Truly green nuclear energy exists – an overview for everybody: no deadly gammas … no energetic neutrons … and no radioactive waste"
L. Larsen, Lattice Energy LLC, v. #4 updated and revised through June 28, 2013 [109 slides]

http://www.slideshare.net/lewisglarsen/powering-the-world-to-a-green-lenr-future-lattice-energy-llcapril-11-2013

Index to large collection of documents re LENR theory, experimental data, and the technology:

"Index to key concepts and documents" v. #14
L. Larsen, Lattice Energy LLC, May 28, 2013 [88 slides] Updated and revised through September 12, 2013

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-index-to-documents-re-widomlarsen-theory-of-lenrsmay-28-2013

Lithium-based batteries in e-cigarettes can explode

Published papers re Widom-Larsen theory of LENRs

Paper	Subject matter
"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 - 112 (2006) Author's copy: note - first uploaded to the arXiv in May 2005 http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006	Except for gamma suppression, <u>all</u> core concepts of W-L theory and key details of its weak interaction physics found in this refereed paper; includes mass-renormalization of SPP electrons, B-O breakdown, etc.
"Absorption of nuclear gamma radiation by heavy electrons on metallic hydride surfaces" A. Widom and L. Larsen (Sept 2005) http://arxiv.org/PS_cache/cond-mat/pdf/0509/0509269v1.pdf	Covers W-L theory of hard gamma photon absorption and conversion to infrared in condensed matter LENRs
"Nuclear abundances in metallic hydride electrodes of electrolytic chemical cells" A. Widom and L. Larsen (Feb 2006) http://arxiv.org/PS_cache/cond-mat/pdf/0602/0602472v1.pdf	Explains Miley transmutation data with Widom-Larsen optical model of ULM neutron absorption in condensed matter
"Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces" A. Widom and L. Larsen (v2. Sep 2006) http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf	Theoretical calculations of W-L ULM neutron production rates; agrees well with best available experimental measurements
"Energetic electrons and nuclear transmutations in exploding wires" A. Widom, Y. N. Srivastava and L. Larsen (Sept 2007) http://arxiv.org/PS_cache/arxiv/pdf/0709/0709.1222v1.pdf	W-L theory of weak interactions applied to high-current exploding wires; explains Wendt-Irion experimental data (1922)
"Errors in the quantum electrodynamic mass analysis of Hagelstein and Chaudhary" A. Widom, Y.N. Srivastava and L. Larsen (Feb 2008) http://arxiv.org/PS_cache/arxiv/pdf/0802/0802.0466v2.pdf	Hagelstein & Chaudhary published their criticism of W-L theory; our response clearly refuted all of their arguments
"High energy particles in the Solar corona" (April 2008) A. Widom, Y.N. Srivastava and L. Larsen http://arxiv.org/PS_cache/arxiv/pdf/0804/0804.2647v1.pdf	Applies many-body collective, magnetically dominated W-L theory to explain the anomalous heating of the solar corona
"A primer for electro-weak induced low energy nuclear reactions" Y. N. Srivastava, A. Widom and L. Larsen, *Pramana - Journal of Physics* 75 pp. 617 - 637 (2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf	Summarizes all of the W-L theoretical concepts found in previous 6 papers at slightly lower levels of mathematical detail
Note: initial versions of all these papers are available online at the Cornell physics preprint arXiv	

Lithium-based batteries in e-cigarettes can explode

Lattice has been working to commercialize LENR technology and its many ramifications for more than a decade; believe that we have achieved a unique understanding of safety issues and risk mitigation with Lithium-based batteries

"In a revolution, as in a novel, the most difficult part to invent is the end."

Alexis de Tocqueville

"The Recollections of Alexis de Tocqueville", Alexis de Tocqueville, pp. 71 Macmillan (1896)