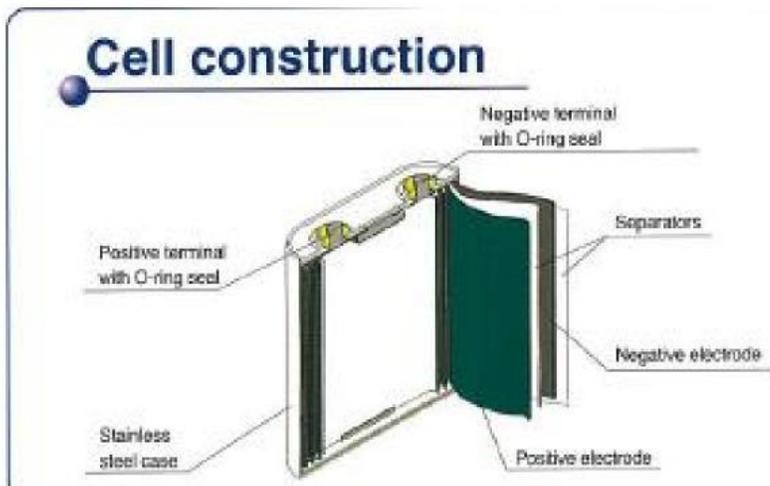


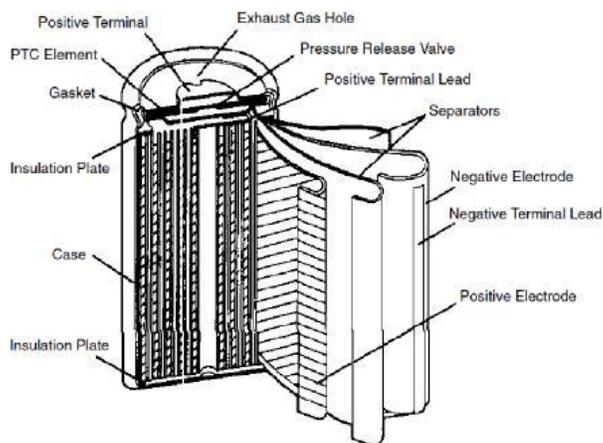
GES TECHNICAL SUMMARY, 1 JANUARY 2016

The transformative advance that GES has made in the field of electrochemical cells, i.e. rechargeable batteries, supercapacitors and fuel cells is due to an unprecedented reduction in resistance to flow of electricity within their structures. It will only be understood by first addressing the sources of that resistance. Common to all three categories is ‘ohmic’ resistance to electron flow from a place where they and ions are exchanged in chemical reactions on a surface of solid material to the metal terminals of the cell. In the case of batteries and fuel cells there is an additional resistance to an obligatory flow within the cell of charged atoms or molecules, i.e. ions from the same surface locations to an electrode some distance away. We have virtually eliminated the ohmic component, lowered a barrier to ion exchange with electrolyte and speed ion movement between electrodes as expensive membrane separators are not needed in our architecture which also shortens the distance ions must travel. Consequently, higher electrical current translates into higher power and shorter battery recharge time.

For the first time, GES electrochemical cell architecture can use advanced and emerging graphene electrode low resistance structures, e.g. carbon nanotubes (CNT) and nanothin graphene sheets having solved the problem of connecting them to metal terminals with equally negligible ohmic resistance. Advances in chemistry for energy storage, virtually without exception in the state of the art (SOA) are mixed with carbon powder for electrical conduction and PTFE binder to form a paste applied to membrane or metal surfaces to comprise high resistance electrodes on metal current collectors. Pastes can also contain catalyst particles embedded in graphene spheres, i.e. ‘buckyballs’ in a membrane electrode assembly (MEA) for a fuel cell. We use these advanced materials but we do not use them as pastes. To appreciate the difference the following illustrations will help.



GS Yuasa Lithium Power, Inc. typical folded electrode battery⁽¹⁾

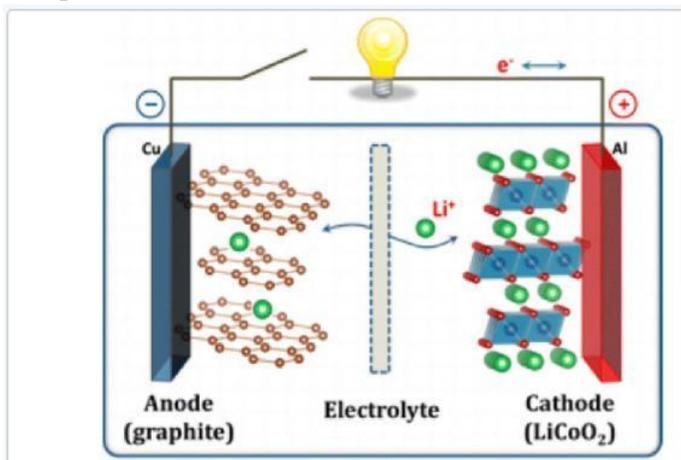


Panasonic NCR18650B typical spiral wound electrode battery⁽²⁾

Thin positive and negative electrode sheets are separated by expensive ion selective semipermeable membranes to prevent short circuit that cause ignition. Pastes are applied to metal in thin layers over large area to contain a sufficient amount of active energy storing material in available volume. They must be thin to limit electrical resistance that remains unacceptably high in any case. GES graphene electrodes are thin enough to shorten the path for essential ion flow, have no obstructing membrane and as 3-D high voltage stacks hold maximum energy storing material for energy capacity optimization. These electrodes are protected by issued and pending patents.

SOA battery electrodes use expanded area and low electrical current density of 10 to 20 mA (milliamp)/cm² electrode area because thicker pastes increase both ohmic and ion kinetic resistance. Heat producing resistance requires cooling and has some influence on energy storage for a given volume and weight but definitely limits power for both discharge and especially recharge.

The picture shows a vertical dashed line as a membrane that allows only Li⁺ ions to cross in electrolyte between electrodes. It has to prevent particles in one electrode from crossing to the opposite electrode because those will short circuit the cell and cause ignition. Membranes selective of Li⁺ ions are expensive cost drivers and add resistance to the flow and exchange of charges required for a battery to function as a source of electrical current shown as electrons flowing in one direction to light the bulb and in the opposite to recharge the battery.⁽³⁾ Paste coatings of the metal surfaces add even more resistance. It is noted in the reference that typical 4 mil or 100 μm (micron) coatings cause equivalent cell resistance of 10 ohms for 1 cm² of electrode surface. High resistance is embedded within SOA Li-ion battery paste architecture and is not expected to much improve. Goodenough⁽³⁾:



Each cell of a battery stores electrical energy as chemical energy in two electrodes, a reductant (anode) and an oxidant (cathode), separated by an electrolyte that transfers the ionic component of the chemical reaction inside the cell and forces the electronic component outside the battery.

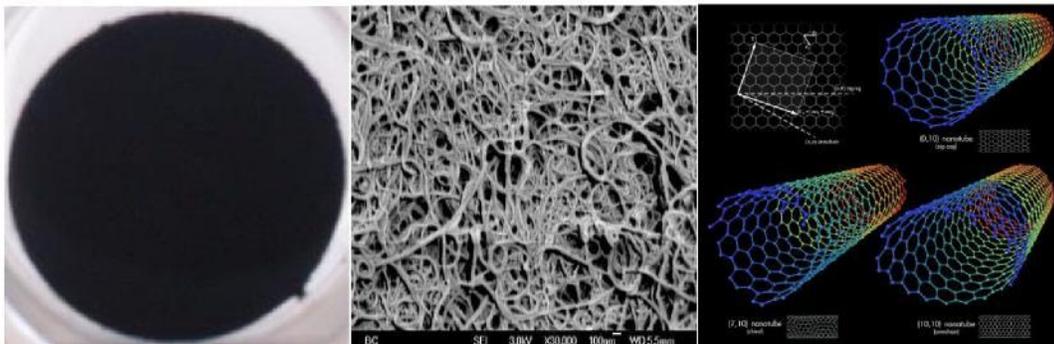
“**Chemists are contributing to incremental improvements of** the conventional strategy by investigating and controlling electrode passivation layers, improving the rate of Li⁺ transfer across electrode/electrolyte interfaces, identifying electrolytes with larger windows while retaining a Li⁺ conductivity $\sigma_{Li} > 10^{-3} S cm^{-1}$, ...”, i.e. 10³ Ohm-cm. This authority deserves special emphasis. It is not widely appreciated that battery electrode resistance is that high. 1 amp/cm² causes more voltage loss than the battery produces.

Examples⁽⁴⁾ of advanced Li-ion cathode paste tested for energy storage capacity at various current densities show ion exchange and transport kinetics has less influence on total electrochemical resistance where resistance is ≈ 10 ohm-cm² on a projected electrode area basis; confirming the result previously stated. It rises with current demand as expected to > 15 ohm-cm² as ion flow is understood to lag behind. Gaberscek⁽⁵⁾ provides further confirmation, in virtually every case, showing ohmic resistance dominates current density for the relevant paradigm. Muenzel⁽⁶⁾ tested many commercial 18650-format Li-ion batteries holding ≈ 200 cm² electrode area with negligible variation from 0.05 ohm per cell or 10 ohm-cm² electrode area resistance. On the other side of the scientific divide claims of near magical breakthroughs, especially for batteries, e.g. <https://www.youtube.com/embed/WFacA6OwCjA> serve to confuse the picture and mislead the public by omitting relevant facts. Graphene truly is as remarkable a material as claimed in the U-tube video and we use it to great advantage as further explained. Clipping onto single sheets may light diodes but it won't run a car. That requires many sheets holding a great deal of faradaic, i.e. battery cathode and anode material between layers to comprise the required electrodes⁽⁷⁾. In that form present art cannot connect electrodes to metal terminals of an actual battery with low enough resistance to be an advantage over pastes. It is the problem GES has solved using graphene sheets and tubes, i.e. CNT.

Supercapacitors are not limited as to power by ions traveling between electrodes as are batteries⁽⁸⁾. But the value of supercapacitors is dependent upon a related resistance commonly referred to as equivalent series resistance, ESR or complex impedance because they are used to move electrical power in and out of their structure quickly. GES uses graphene structures with low complex impedance to enhance performance. Most references report resistance as high as 20 ohms per cm² for pastes due mainly to poor connection of high internally conductive material to the metal terminals required in any electrochemical cell. SOA connection of graphene structures have lower contact resistance but not yet sufficient for the level of performance required by the industry. GES has reduced resistance by four orders of magnitude below standard paste architecture and at least three orders of magnitude for all categories of electrochemical cells. They are now capable of meeting market demand.

We have measured bulk plus metal (current collector) contact resistance of many sample-SOA graphene based electrodes under conditions in which they are normally used and find none that would not have less than 1/2 ohm resistance for 1 cm² of positive and negative electrode pairs. GES electrode pairs have less than 10⁻³ ohm for 1 cm² paired electrode area. It is less than 1/1,000th the resistance for graphene structures used in supercapacitors and 1/10,000th compared to pastes used in batteries. The importance of these values cannot be overstated and is expected to be quickly recognized by experts in the field of electrochemical cells because it means insignificant heat generation for battery discharge and recharge which is equivalent to a major improvement in safety. It also means tolerance for much higher electrical current per cm² of electrode area which translates into much shorter time to reach full battery recharge. Also improved energy capacity for operation of supercapacitors due to high graphene electrode surface density at lower resistance is now possible. The same high electrode current density makes smaller fuel cells possible for a given power rating.

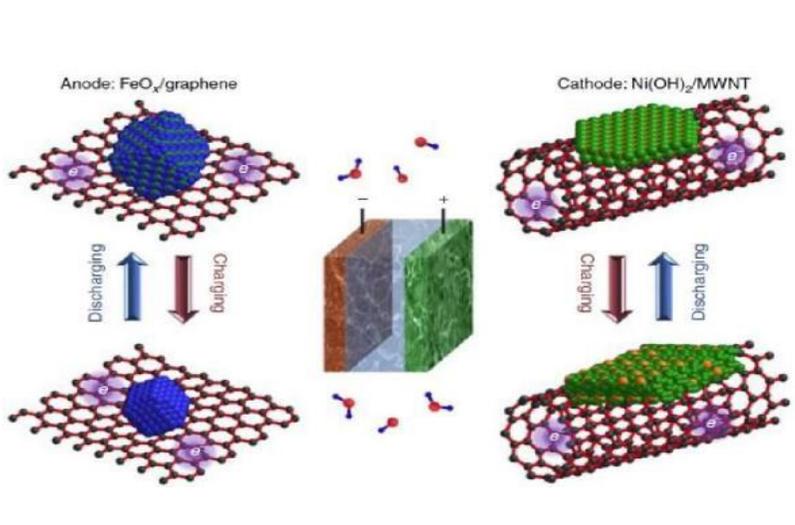
To achieve these remarkable results we use graphene structures known in the art; mainly single or multiwall carbon nanotubes, CNT or graphene sheets⁽⁹⁾ although CNT is much cheaper in today's market. CNT is simply graphene, i.e. a single atomic layer of carbon rolled into a tube as long as human hair but 10,000 times thinner; produced as a tangled nonwoven web of cohesive paper below, well infused with electrolyte illustrated above. Not shown is high resistance attachment of active material to the metal plate. It is the problem GES has solved.



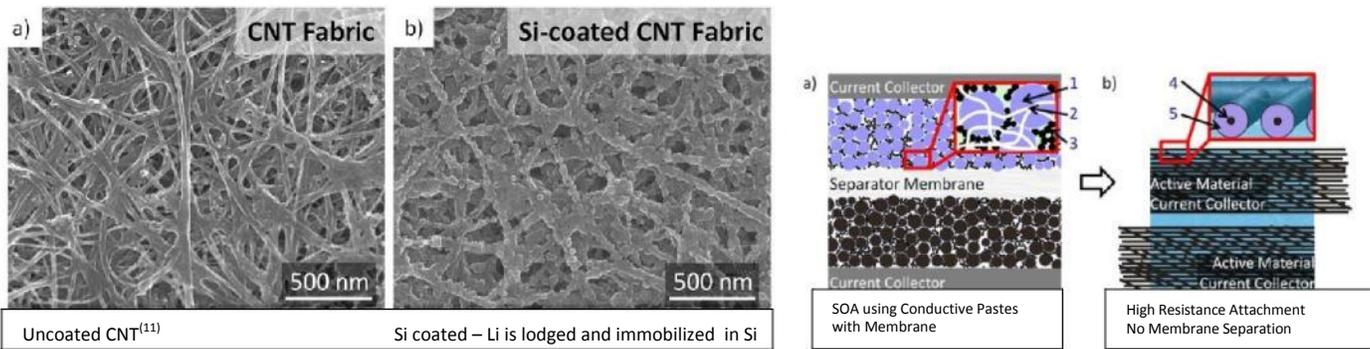
CNT buckypaper⁽⁹⁾ is alongside 30,000 magnification of what it actually is. Under even higher magnification strands look like a Wikipedia picture on the right.

NanoLab, Inc.⁽⁹⁾ Buckypaper cohesive nonwoven CNT paper SEM 30K magnification of 'Buckypaper' Wikipedia – CNT

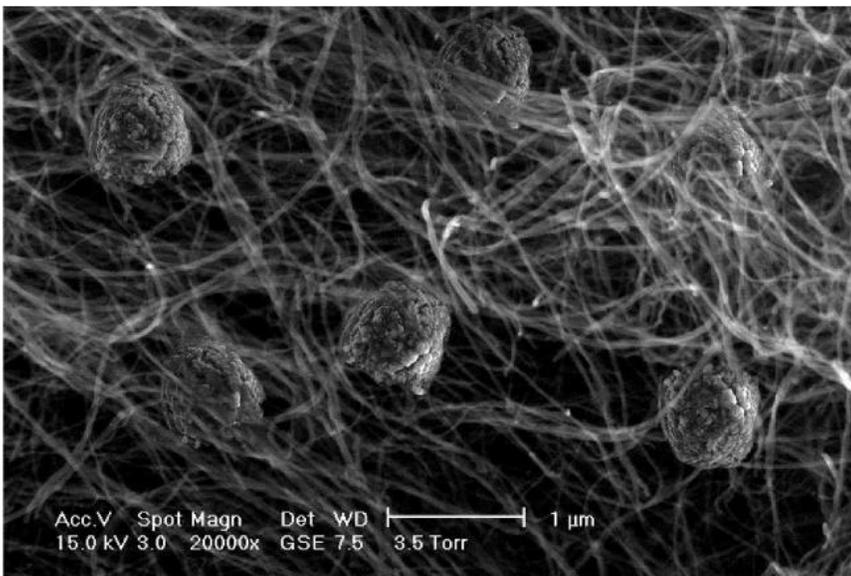
Nanoscale materials promote chemical reactions occurring on surfaces. The more surface area/cm² of electrode the more concentrated is the chemistry and the higher is electrical current density. It is possible to produce the unrolled version⁽⁷⁾ in large high tensile strength sheets 50,000 times thinner than a human hair but it takes many such sheets to make an electrode at higher cost. We use these materials to make supercapacitors without adding anything but electrolyte to the mix. Batteries need faradaic material as do high capacity pseudosupercapacitors⁽⁸⁾.



Schematic drawing of the ultrafast charging Ni/Fe battery made from inorganic carbon hybrid CNT and graphene materials⁽¹⁰⁾. Ni(OH)₂/MWCNT was used as the hybrid cathode and a FeO_x/graphene was used as the hybrid anode. The active faradaic (battery) materials are strongly coupled to each type of graphene structure and exhibit inherently fast galvanic (D.C. battery) activity but advantage cannot be taken in actual embodiments unless the layers can be attached to metal plates as shown in a previous sketch⁽³⁾ for the essential purpose of collecting electricity. That is what GES has accomplished.



Strongly coupled coatings on CNT can be used to lodge and immobilize active material shown for an anodic electrode⁽¹¹⁾, -b). It is proffered that coated CNT, -b) can serve the additional function of current collector to replace high resistance pastes, -a). In reality there are no Li-ion intercalation cathode CNT coatings without a high resistance connection to metal. GES has solved that problem with extremely low resistance connections using intercalation particles, thus being able to take advantage of the stable anode coating. Si holds 10 times as many Li atoms as carbon alone.



Many of the most powerful battery materials can only be made as particle formulations. It is especially true of cathodes on the electron absorbing side of the battery. SOA architecture can only use these advanced and emerging formulations in pastes using binders that cause high ohmic resistance. GES has discovered how to lodge and immobilize faradaic and catalyst particles within cohesive galvanic electrodes without additives, binders or a separating ion selective membrane. An example is shown in an accompanying SEM photo of a CNT electrode made in our facility using particles similar to those shown in the photo. It will enable entirely new battery technology. It is further noted

that these particles are stably lodged within the electrode even under electrolyte permeation of 1 cm/second flow through the galvanic membrane which will be useful for GES compact high power density fuel cells.

The advantage of GES's ultralow impedance battery may be appreciated by comparison to popular examples of present competitive art such as the standard Panasonic NCR18650B Li-ion⁽¹²⁾. Cited references and seller's data put the electrochemical resistivity of many similar batteries at $\approx 10 \Omega\text{-cm}^2$ for electrodes having typical material coating thicknesses of $\approx 100 \mu\text{m}$, e.g. 50 milliohm, $\text{m}\Omega$ for 200 cm^2 of electrode area. Only large area reduces net cell resistance of these batteries to reported values. Manufacturer's specifications for charging and discharging are used here. The battery's usable capacity, C is 3.25 Ah, ampere-hours at 3.6 volts.

Conservative 0.5C charge/discharge profiles are fairly linear with an average discharge voltage of 3.55V terminating at cutoff voltage of 3.0V and 3.1 Ah discharge capacity or C-rate before voltage drops off quickly. 11 Wh net capacity at 94% of 3.25 Ah rated capacity is used here for purposes of an energy storage metric in accordance with the recommended cutoff at 3 volts. This fast charging profile starts at 3.5V and peaks at 4.2V in fairly linear fashion for 2 hours. Current is regulated at 1.625A until the peak voltage cutoff at 4.2V. Thereafter, current drops quickly. This is clearly maintaining $\sim 0.5\text{V}$ above battery voltage throughout the 2 hour charging cycle. Once peak battery voltage is reached faradaic charging sites are mostly used up and current is limited by

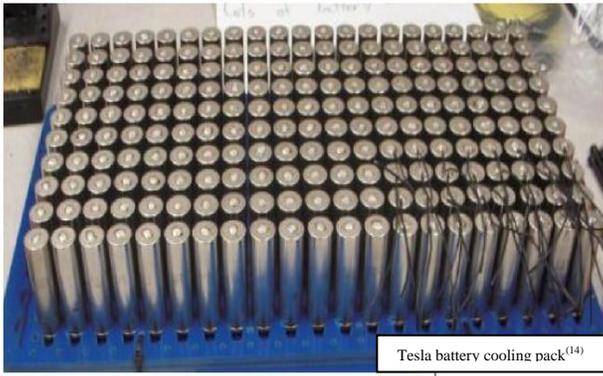
ion exchange kinetics which act as battery impedance seen by a charger maintaining a regulated limit of 4.2V. Further charging just adds i^2R heat but little energy to the battery. So the 2 hour cutoff seems appropriate. In that period the charger has delivered average energy of 3.85V times 1.625A for 2 hours or 12.5 Wh. The extra 1.5 Wh or steady 0.75 watts went to heat. That is why Tesla⁽¹³⁾ spaces batteries for a 50% volume form factor to accommodate cooling. That reduces the energy storage capacity from an individual battery 0.67 Wh/L to about 1/3rd Wh/L for a 7,100 cell pack. 0.75 watt heating at 1.625A implies a battery charging resistance of 0.284 ohm which is ≈ 5.7 times slow discharge or slower recharge resistance. The same battery capacity can be provided without a cooling volume requirement by an ultralow resistance GES battery at about 1 Wh/L.

Another way of making the calculation considers the actual 0.5V above battery voltage producing a constant 1.625A. R has to be 0.308 ohm which is only 8% higher than the previous estimate to emphasize the fact that these are estimates; reasonable, but estimates all the same. High net cell resistance is the result of pushing charge/discharge cycles faster than trickle current levels when pastes contain low concentration of conduction additives and high concentration of active faradaic particles in order to achieve higher energy storage density. High current (power) density was demonstrated⁽⁸⁾ using graphene and CNT coatings but these have not been successfully connected to metal battery terminals at the macro level until now with GES's patented technology.

The Panasonic battery is a typical spiral winding. Electrode area is about 200 cm² which uses the cell's 6 cm height and an internal 33 cm spiral length. Muenzel⁽⁶⁾ shows disassembled batteries to confirm these estimates. An internal volume of ≈ 14 ml and 200 cm² area leaves 0.7 mm for thickness of 2 metal current collector sheets, 2 separators, a center spindle and 2 faradaic coatings. That leaves about 300 μm for 2 coatings which is typical thickness to accommodate the required faradaic material mass for the battery's energy storage rating. Charging current density is 8.125×10^{-3} amp/cm². The comparison to a comparably designed GES battery follows.

We do not recommend a 18650 form factor for wide distribution packaging of low resistance electrodes in high voltage batteries, e.g. at 360V but the number is important because Tesla designed its motors around that voltage for good reasons by stringing 100 unit-cell voltage batteries in series to charge them in that profile. GES can arrange 100 low resistance unit-cells in a single 18650 form factor cell with the same electrode area and at least the same energy storage. However, this cell has 100 times the current density at ≈ 0.8 amp/cm² and an option for 100 times unit-cell voltage. Either way charging is 100 times faster or 1.2 minutes instead of 2 hours. A charger has to deliver 1.625A at 420V which is 682 watts or 162.5A at 4.2V which is the same power but more difficult because the wires have to be so thick. Power required is about half hair dryer wattage. Any combination of voltage and current can be designed at the same wattage. Volume available to material for storing energy at about 1 Wh/L is somewhat higher than the basic Panasonic and there is no reduction for cooling volume.

What is relevant is heat generated by so much power being applied to the same size cell. If 0.5V above unit cell voltage is used, it starts at 350V and increases up to 420V to produce 1.625A in a cell with 5×10^{-2} ohm ($100 \times 10^{-3}/2$ cm²) resistance. The heating effect is $i^2R = 0.132$ watt or 0.02% of delivered power and only for a little more than a minute, i.e. negligible. But there is no getting around the fact that at an average 385V and 1.625A, 626 watts is flowing into the cell with very little being diverted to heat. The one question that this configuration raises is electrode current density computed at 0.825A/cm². 1.625A is the same total current passing through the area cross section of all 100 series connected unit-cells in Tesla's 18650 form factor battery pack. But that is less than a typical 10 milliamp/cm² current density for similar batteries with paste electrodes to avoid i^2R heating. In the GES battery that is not a factor but ion kinetics, i.e. exchange between electrodes must be taken into account. Here, thin electrodes, no separating membrane and short gap width between electrodes work in favor of fast ion exchange kinetics whereby diffusion time constant is related to the second power of a diffusion path length (i.e. increased concentration gradient and shorter path to travel). Thus, even extending charging time to 5 minutes and a very conservative 0.2 A/cm² current density, one can appreciate how much faster charging can be. Tesla could wire 7,100 high voltage GES batteries in parallel and use its 120 kW supercharger to deliver 300A at 400V. 93% of full charge would take 46 minutes due to limited charging power. In actual practice GES would offer the battery in an integrated rectangular form factor to conserve volume energy density.



With present technology cooling is a serious issue. Pictured here is part of a typical Tesla battery pack with spaced apart batteries to allow for substantial cooling flow. Half the package volume has to be used for that purpose. Energy density drops from 0.67 Wh/L to 0.33 Wh/L or about 1/3rd of GES's 1 Wh/L when a solid brick form factor is used. That is only possible because of negligible heat load. It is especially important since an effective 1 kWh/L energy storage capacity for the GES Li-ion batteries will take the Tesla Model S 750 miles instead of 250 miles or take up 1/3rd the volume of the present Tesla battery pack.

Tesla recommends a 30 minute charge⁽¹³⁾ using its supercharger at 4.4A per cell. We saw that Panasonic's recommended 'fast charge' current is 1.625A which results in a cell charge resistance of 0.284 Ω . 4.4A would cause even higher resistance as measured by Muenzel⁽⁶⁾ of not less than 0.3 Ω . Thus, each cell produces i^2R heat of 5.8W times 7,100 cells or at least 40 kW or 1/3rd of the 120kW being provided. Cooling required is formidable but to make matters worse, only 40 kWh goes to charge the cell in 30 minutes. Based upon its 85 kWh rating 30 minutes will take the battery from 10% depth of discharge to less than 60%. Our battery will go to at least 80% capacity using the same charge parameters or 60% in 20 minutes without the prodigious heat load. If higher power chargers, i.e. 1 to 2 megawatts, MW were available, GES batteries would add 500 miles of range to the Tesla Model S and take a full charge in 5 minutes or less. The real problem is charging a battery with that much energy (even without heat loss) without draining it from an already overloaded grid.

As a product for sale it is entirely reasonable to arrange 100 unit-cells in block form as 4 to 8 series connected groups for 14V to 28V with each group comprising any number of parallel connected unit-cells. That would avoid the high voltage hazard for unit sales. It is also possible to use a square rather than circular cross-section for a parallelepiped rather than cylinder form factor for better energy packaging density since the heating load is so radically reduced. It is further noted that GES can use similar technology to manufacture fuel cells powerful enough to supply electrical charging current and voltage to fully charge GES batteries with 2 MW power using natural gas or propane available at widely distributed service stations.

GES technology cited for Li-ion can be used with any other galvanic chemistry including emerging multivalent compounds to provide higher energy storage density. The electrochemical process can store and return energy with efficiency approaching and in some cases exceeding 90%, is favored by government regulation and is preferred as a matter of popular acceptance for its environmental benefits in E.V's. However, prior art for galvanic electrochemical cells to store and convert chemical energy to direct current electricity has not reached predicted market potential because they are too expensive, large and heavy. In most applications they are unreliable or pose ignition hazards. Internal combustion engines cannot exceed 25% efficiency and suffer from many mandated restrictions. GES issued and pending patents covering the technology described above include batteries, fuel cells and pseudosupercapacitors. Rechargeable batteries and supercapacitors are the easiest to implement and we can offer very cost effective examples for testing and proof of concept. Fuel cells have much higher energy storage and power density and will use GES low resistance technology. They are more likely to be the future system of choice for electric vehicles.

For those unfamiliar with this technology the following analogy may convey what GES inventions have achieved. Energy stored in a water reservoir above falls through generators to one below. Competition may be understood as an expensive narrow platinum or gold pipe conveying water against gravity from the reservoir below to the one above at height. Water at the bottom of the pipe is now under pressure and can do work limited in amount only by the size of the reservoirs. However, power or the rate at which work can be done is limited by the size of the pipe. GES has altered electrochemical architecture so the pipe can be made much cheaper and larger to provide energy at higher power and with much less energy draining resistance in the pipe.

SUMMARY AND CONCLUSION:

Batteries in today's market as sold and actually used in EV's, tools and computers (not the ones promised as research novelties in laboratories) must contain so much mass of active faradaic materials as paste coatings on metal terminals in order to achieve a useful amount of energy stored in limited volume, there is little room left over for conductive material to mitigate electrical resistance. It is accepted practice that resistance shall remain 10 ohms for each cm² of electrode area and net cell resistance is reduced to a suitable level in a given application by dividing (spreading) that number over a large electrode area. The price of that architecture is heat and limited power. GES has invented and patented a way to incorporate the same or somewhat more mass of energy storing material in an electrode with 1/10,000th the resistance. Not only is heat production negligible, thus eliminating ignition or explosion hazard, power density is high enough to permit unprecedented short recharge time. The same architecture is used for supercapacitors with improved energy storage capacity at high voltage. Direct oxidation fuel cells using a wide range of fuels can be substantially more compact based upon an architectural feature that allows electrolyte convection for exceptional energy storage and power.

GES, LLC is an advanced technology company offering patent licensing opportunities to manufacturers seeking to compete with transformative and disruptive products in the fields of secondary batteries, supercapacitors and fuel cells. Our technology can be proven by independent investigators with low cost prototype testing. Further information will be provided in response to inquiries by qualified parties subject to execution of an appropriate confidential disclosure agreement (CDA) for the purpose of enabling independent investigation. We will cooperate with manufacturers in joint development agreements (JDA) if offered and funded. Our ultimate objective is a negotiated license with a manufacturer for royalties.

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 - (13) <https://www.teslamotors.com/supercharger>
 - (14) <http://instar.berkeley.edu/wp-content/uploads/2012/10/BatteryPack.jpg>
- See: <https://www.google.com/search?q=tesla+battery&biw=1228&bih=603&site=webhp&tbn=isch&tbo=u&source=univ&sa=X&sqi=2&ved=0ahUKewicz4C1r4zLahXHl0MKHUvgADIQsAQIPO>

Partial list of patents issued and pending:

<u>High Current Density Electrodes</u>	U.S. Patent No. 9,337,474
<u>High Current Density Electrodes -2</u>	Patent Pending
<u>Electrochemical Cells With Convection</u>	Patent pending
<u>Electrochemical Cells for hydrogen production using water electrolysis</u>	Patent pending
<u>Electrochemical Cells for flow batteries using particulate electrolytes</u>	Patent Pending
<u>High Voltage and Current Galvanic Cells</u>	Patent pending
<u>Ultralow Resistance Electrodes for Electrochemical Cells</u>	Patent pending
<u>Electrochemical Cells Utilizing Taylor Vortex Flows</u>	U.S. Patent No. 8,017,261
<u>Electrochemical Cells Utilizing Taylor Vortex Flows</u>	U.S. Patent No. 8,283,062
<u>Galvanic Electrochemical Cells Utilizing Taylor Vortex Flows</u>	U.S. Patent No. 8,187,737
<u>Fuel Reformers Utilizing Taylor Vortex Flows</u>	U.S. Patent No. 8,187,560
<u>Chemical Process Accelerator Systems Utilizing Taylor Vortex Flows</u>	U.S. Patent No. 8,147,767
<u>Direct Reaction Fuel Cells Utilizing Taylor Vortex Flows</u>	U.S. Patent No. 7,972,747
<u>Dynamic Accelerated Reaction Batteries Utilizing Taylor Vortex Flows</u>	U.S. Patent No. 7,964,301
<u>Cross-Flow Electrochemical Batteries</u>	U.S. Patent No. 8,158,277
<u>Thick Electrode Direct Reaction Fuel Cells Utilizing Cross-Flows And Taylor Vortex Flows</u>	U.S. Patent No. 8,124,296
<u>Galvanic Electrochemical Cells For Generating Alternating Current Electricity</u>	U.S. Patent No. 8,394,518
<u>Flow Batteries and Water Electrolysis</u>	U.S. Patent Pending