High-Country Static

May 2016

News and Information Concerning Amateur Radio in Northern Arizona and Beyond

Coconino Amateur Radio Club
www.cocoradio.club

Welcome to the Coconino Amateur Radio Club (CARC) Monthly Newsletter. CARC is a non-profit club devoted to providing communication services to local volunteer agencies and events. Meetings are held the second Thursday of each month at the East side Sizzlers Restaurant Highway 66 at Fanning Dr. Flagstaff, at 7:00PM. All persons interested in amateur radio, whether licensed or not, are welcome to attend.

Coconino SkyWarn meets 1900 every Monday evening on the 146.98 repeater and at 1930 on the Navajo Mountain CACTUS repeater and 146.480 simplex.

Coconino ARES meets 1900 every Wednesday evening on the 146.98 repeater and at 1930 on the Navajo Mountain CACTUS repeater and 146.480.

Officers:

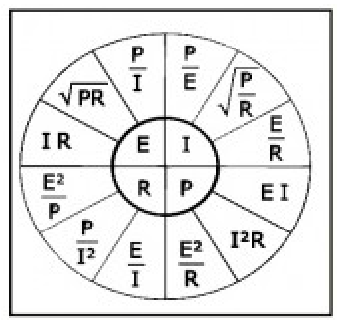
President: Sandy Meadowcroft KF4JHC

Vice-President: Tom Shehan KY7WV

Secretary: Erv Perelstein, KE7QFI

Treasurer: Pat Traber, KE7QFG

PIO: Janice Enloe, KI6WCK



E = voltage I = current
R = resistance P = power

Calendar of Events for 2016:

May	14	Ham Licensing Exam, Flagstaff Public Library, East Side
May:	20-22	Overland Expo: Demonstrations and Amateur Radio License Examinations
June:	4	Sacred Mountain Prayer Run
	25-26	Field Day (KG7OH & Team)
July:	4	Munds Park Parade
	17	Snow Bowl Hill Climb (KF4JHC)
	23	Amateur Radio License Exams at Williams Hamfest/Arizona State Convention (W7LUX)
August:	6	Toys for Tots/Fat Tire Bicycle Ride (Mike, Ron & Tom)
	13	Big Brothers/Big Sisters Run for the Magic (Bob Meadowcroft)

28 Arizona Trail Marathon at North Rim
**Northland Preparatory Academy to ISS amateur radio contact during Aug-Sep-Oct

September: 5 Williams 10K Labor Day Run
24-25 Flagstaff to Grand Canyon 100 Mile Run

October: 8 Soulstice Mountain Trail Run (KF4RKS)
15 Amateur Radio License Exams at North County Health Care (W7LUX)
?? Northland Preparatory Academy solar observing (W7LUX)

November: ?? Arizona Division of Emergency Management Exercise
?? Girls on the Run (KF4JHC)

December: 3 SkyWarn Recognition Day at NWS Belmont (UTC date) (KD8RQV)
11 Christmas party- Sandy and Bob Meadowcroft's home

Thank you and Help Wanted:

Thank you to all who have run the Monday and Wednesday night nets:
Flagstaff: Tom KY7WV, Erv KE7QFI, Mike KD8RQV, Bob KF4RKS, Janice KI6WCK
Page: Lee KF7YRS and Vince WB7UWW

If anyone one would like to help with the nets, please let Tom know. It is good practice for radio skills and the script is written for you to use.

Licensing Exams for 2015-2016:

May : 14 Flagstaff Public Library, East Side Branch
20-22 Overland Expo: Demonstrations and Amateur Radio License Examinations

July: 23 Radio Exam at Williams Hamfest

October: 15 Radio Exam. Location TBD

Remember to bring your HAM license and a copy (if you are upgrading your license), a government issued picture ID, a black ink pen, calculator with memory erased and fifteen dollars (exact change is appreciated).

http://wireless2.fcc.gov/UlsApp/UlsSearch/searchLicense.jsp

Arizona Newsletter: http://www.arrl.org **Tutorials:** http://www.arrl.org/tutorials

http://www.arrl.org/exam_sessions/flagstaff-az-86004-1221-2

Next Business Meeting:

Our next business meeting will be May 12, 2016 at the East side Sizzlers at the corner of Highway 66 and Fanning. Dinner @1800 and meeting starts @1900.

Minutes of the Coconino Amateur Radio Club

4/14 /2016

Meeting Started: 19:00

Secretary's Report: Since the minutes of the March meeting were published in the newsletter, there was no need to read them. There were no changes recommended so Joe Hobart made a motion and Scott Martin seconded the motion to accept the minutes as written. They were approved unanimously.

Treasurer' s Report: Pat Traber, our club treasurer, gave the Treasurer's Report. The closing bank balance was $3,754.75. Membership is 45 members, consisting of 41 paid members and 4 lifetime members. Scott Martin moved and J.D. Ward seconded a motion to accept the Treasurer's Report as written. Unanimously accepted.

Guests: Mark Christian, County Emergency Management Program Coordinator for Coconino County, presented a review of a project that we were requested to assist with; County Commissioner Lena Fowler's project to provide disaster communications, (VHF/ HF), to northern Arizona. He reviewed the status of the project which started about 2 years ago. The Emergency Management Office has purchased several HF radios, and Buddy Pole antennas and placed one of them in Page and another in Fredonia. Through the past year there has been a series of connectivity tests which were successful. The office is still trying to find volunteers in those locations to become HAM operators and be available for testing and real emergencies.

The VHF side of the project has not gone as well. The key repeater for Northern Arizona is the Navajo Repeater but it is not available for our use. Heber-Overgaard has a new repeater at 146.800 which promises to add increased connectivity and Forest Lakes has HF and VHF capability but the VHF is limited by the antenna replacement on Mt. Elden. The addition of the Alternate EOC on Gemini Way will increase our capability. They are running cables into the facility for our use during exercises and emergencies and have provided a small room inside to set up our station. They will not permit us to install permanent antennas outside the building but we can set up temporary antenna connected to the coax at entry points they will provide.

Mark's presentation was excellent, providing us with the status of the project and the plans for expansion in the future. Thank you Mark!

President's Report: After Introductions, Sandy told us our current Technician Licensing Class was going very well. Some class members will be taking the Technician Exam this Saturday. She wanted to thank Bill Smith for arranging the use of the North Country Health Care facility to hold the classes.

Vice President’s Report: Tom Shehan told the club that the AUXCOMM class held on April 2nd and 3rd was an excellent review of disaster communications and equipment. Joe said the instructor was very knowledgeable of problems with disaster communications and how to solve the physical and equipment problems encountered. He also recommended we hold a table-top exercise for club members who did not attend the class to learn this material.

New Business: Tom told us that Kaci Hines, from Northland Preparatory Academy, is leaving Flagstaff. She and her family will be moving to NASA where she will be the Education Coordinator. He introduced Jeff Hartig, WA7QPA, who will be taking over the projects that Kaci has initiated, especially those that CARC has been involved with; ISS Communications, and Weather Balloon Launches. The question was raised as to whether the club would like to continue supporting these projects. Scott made a motion that CARC continue to support these projects. Janice Enloe seconded the motion, which passed unanimously.

Tom reminded us about the Ham Radio project being sponsored by the National Park Service in celebration of their 100th birthday this year. It is called National Parks On The Air, (NPOTA). Some volunteer ham operators, (called activators), will set up stations on National Park Lands and all other ham operators, (called chasers), will try to contact as many parks as they can. The project will last all of 2016. You can find the entire schedule on NPOTA.ARRL.org . Bill will set up his activator site at the Grand Canyon this Sunday, 4/17. Anyone interested in meeting him there is welcome. Check for his email on the CARC system.

Old Business: Scott Martin reminded us that our mobile tower for Field Day needs some maintenance and asked for help on June 1st to make sure it is in good shape. All volunteers will be welcome.

Upcoming project review:

4/16 VE License Testing at North Country Health along with the next Technician Class.

5/ 20-22 Overland Expo: Demonstrations and Amateur Radio Exams , Tom coordinating.

6/4 Sacred Mt. Prayer Run, Janice/Bill Smith helping coordinating.

6/25-26 FIELD DAY 2016. Ron Gerlak & team coordinating.

7/4 Munds Park Parade. Pat Traber coordinating.

7/17 Snowbowl Run, Sandy coordinating.

7/22-23 Williams Hamfest, VE Testing on 23rd. Joe coordinating.

ARES Report Joe told us that the PFAC Drill scheduled for April 22 will not invite CARC to participate.

He told us that the new antenna on the Mt Elden repeater is not as large as the one removed because of snow and ice damage so don't be surprised if you don't have a good signal with it. ARA is planning on repairing the old antenna and will try to reinstall it sometime in the Spring or Summer.

Joe pointed out, once again, how popular and important it is to develop the capability to handle digital messaging on the radio. There will be another RACES test of digital capabilities on Saturday, April 16th using the EOC HF frequencies. All members who want to test their systems are welcome to join in.

50/50 Raffle: Ken Held won the raffle this month.

There being no further business, Scott moved and Joe seconded a motion to adjourn. Passed unanimously.

Meeting Ended: 20:36.

Presentations: No additional presentations this month.

Technical news from Joe, W7LUX:

The ARRL and DX Engineering have started a bi-weekly podcast of technical issues of interest to amateur radio operators.
https://www.blubrry.com/arrl_the_doctor_is_in/

Archived podcasts are also at:

http://www.arrl.org/doctor

HF nets- some ideas you may like to try are contained in an email from Joe, W7LUX:

The two Arizona RACES nets meet Saturday and Sunday morning:

Southern Arizona RACES: 0715 Saturday 3863 kHz LSB

Arizona RACES net: 0730 Sunday 3990 kHz LSB

Both may move frequency slightly to avoid other conversations. Gary, K7GH, is usually NCS for the Sunday Arizona RACES net; the Saturday net has a rotating NCS schedule.

There is occasionally a digital practice net following the Saturday, southern Arizona RACES net. This depends on availability of a digital net control station. Brian, W8JBT usually conducts the digital nets on 60 meters.

There has been some interference to a California Red Cross net using 5403.5, so the digital practice net has been using 5371.5. All 60 meter voice and digital modes must use USB (don't know about RTTY, which normally uses LSB).

The most common HF digital mode for the southern Arizona RACES group is MT-63 and either 1K Long or 2K Long. We have also tried Olivia, but it is MUCH slower than MT-63.

Another net is the daily (every day of the year) Arizona Traffic and Emergency Net (ATEN), which meets on 3986 kHz LST at 1900 MST (summer hours) and 1730 MST (winter hours). I believe they change their schedule on the same day as the rest of the country changes to/from daylight savings time. Web site:

http://atenaz.net/

ATEN is an excellent example of a well run traffic handling net. Coconino ARES will work closely with ATEN during a communications emergency.

There is also a Western States SATERN (Salvation Army) net that meets Sunday evenings at 2100 MST (0400Z) on 3977.7 kHz. Early check-ins are accepted starting after 1900 or a little later. This net was started after the 2002 Rodeo-Chediski fire and supports Salvation Army disaster relief activities.

Tesla, Edison and the War of Currents

By Michael Parks, PE for Mouser Electronics

The latter part of the 19th century saw the first footsteps in a technological revolution that would dwarf all the advances made up to that point. Electrification profoundly changed every aspect of human life. Not only did electrification change existing technologies of the time (oil lighting to electric light bulbs), but it also created entirely new products previously undreamt of such as radio. While we take our current electricity-based infrastructure and society for granted today, the path to this point was not as straightforward as we might like to remember. In the late 1880’s there was a “format war” raging much like our modern day VHS versus Betamax and Blu-Ray vs HD-DVD skirmishes. In those years Alternating Current (AC), whose figurehead was the Serbian-American eccentric genius Nikola Tesla, was battling Direct Current (DC) and it’s brilliant but arguably more business savvy Thomas Edison. In the end compromises were struck and electrification of the world was able to jump from blueprint to reality.

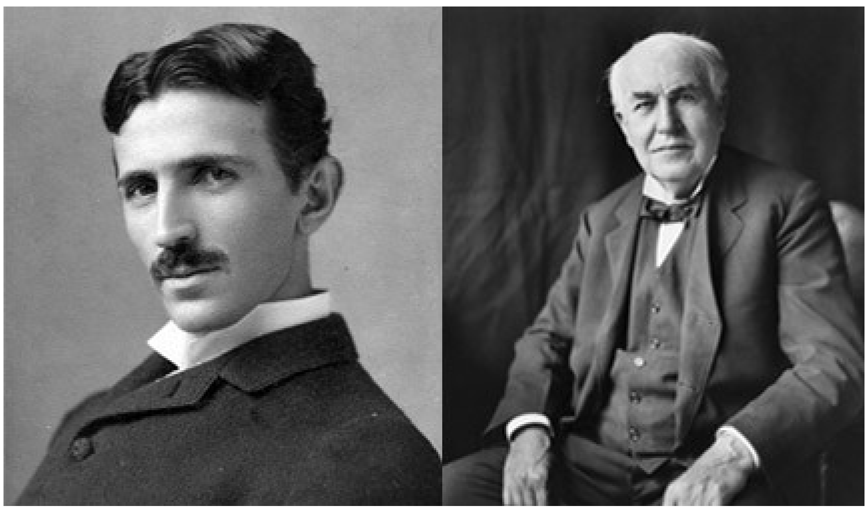


Figure 1: *Nikola Tesla (left) and Thomas Edison (right)*

AC vs DC

At the heart of the argument, the utility of AC versus DC comes down to good old engineering tradeoffs. In the 1880’s DC was less efficient to transport over long distances since line losses were significant compared to the DC voltage levels that could be generated. Thus powering the world with DC would require a larger amount of power generating stations dotting the landscape. However, for 1880’s machinery generating direct current was much simpler, giving it somewhat of a technological advantage. In contrast, alternating current required much more precise machinery to generate the oscillating electrons but AC transmission was far more efficient over large distances. These two solutions very much reflect the mindsets of their champions. Tesla tended to be more theoretical and able to invent in his mind’s eye whereas Edison was the consummate hands-on maker of his day. Elegant yet delicate design versus utilitarian practicality. In the end when it came to pushing electrons from power plant to consumer, alternating current seized victory from direct current.

AC Victory for Transmission

The key advantage that alternating current has is that the voltage level can be raised very easily with relatively inexpensive transformers. Higher voltage allows the same amount of power to be transmitted with less current.

This translates to very practical advantages. With a smaller line loss, the distance between the consumer and the power generating facility can be far greater. Having to build out a smaller infrastructure meant that it was more cost-effective and practical to use AC for power transmission.

Of course, Edison would not go down without a fight. In the latter part of the 19th century Edison famously held demonstrations in which AC was used to electrocute animals in an attempt to persuade the masses of the dangers of alternating current. In addition, the first electric chair was built for New York State by two Edison employees. Unsurprisingly, alternating current was chosen to power the chair. While these demonstrations made for good showmanship, the reality is that both DC and AC can be dangerous if the current is sufficiently large. It only takes a few milliamperes of current in the right conditions to cause heart fibrillations that lead to death.

Over the years, refinements in technology have led to an improved performance in our electric grid. Electromagnetic Interference (EMI) caused by line noise upstream and loads connected downstream can "dirty" the power. Filters based on common mode chokes and capacitors from companies such as EPCOS/TDK help to reduce EMI which is critical as electronics devices increasingly require cleaner power to operate.

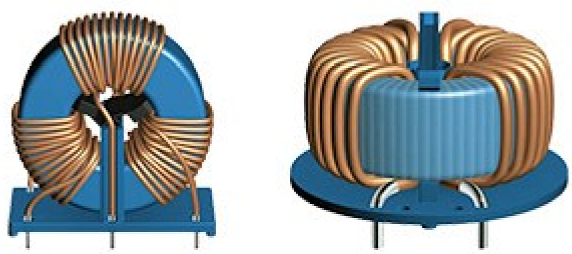


Figure 2: *Chokes help to keep power lines clear of EMI. Image courtesy of TDK.*

DC and the Digital Revolution

While alternating current may have become the de facto standard for power transmission and distribution, direct current has maintained many crucial roles in modern life. DC motors dominate many low horsepower mechanical applications. Direct current also plays a crucial role in telecommunications devices and the automobile systems (battery and inverter to convert the alternators AC to DC).

Perhaps the biggest victory for DC coincided with the digital revolution that began in earnest in the 1970's after decades in laboratories around the world. Digital technology is absolutely dependent on DC power. The 1's and 0's that power the information age rely on the presence or absence of a direct current voltage. For digital devices that get their power from an AC wall outlet, the alternating current must first be transformed in direct current. Rectifier circuits are used to perform this function in modern day devices.

For mobile digital technology that has cut the wires, batteries provide the direct current needed. Batteries rely on electrochemical reactions of its constituent components to generate a constant stream of electrons at a given voltage level. Battery life is a function of the mA-H rating of the battery and the current draw of the device. Switched DC-DC converters used in modern day mobile electronics allow for the fixed DC voltage level of battery to service multiple sub-circuits that may operate at different voltages levels. One negative side effect of switched mode DC-DC converters is the creation of RF noise that must be suppressed using special components such as RF chokes. Today, aside from our larger appliances the vast majority of the devices we bring into our home ultimately rely on direct current to perform their function.

The Future

Much has changed in the almost 150 years in terms of quality and efficiency of the equipment that powers modern life. However, the fundamental concepts have remained by and large the same. Large power generation facilities rely on converting various energy sources into electricity which is then transmitted along an electrical grid. As the electricity nears the consumer is stepped down to lower and lower voltages until it is fed into your building through a final step-down transformer and circuit breaker panel, lastly arriving at the AC wall outlet. Our devices either consume the AC directly or transform it into a more useful DC voltage that brings our electronics to life.

Figure 3: *Tesla's Wardenclyffe Tower (Image courtesy of Wikipedia)*

One methodology that has garnered much attention (and perhaps even a cult-like following) is wireless power transfer. To clarify what is meant by wireless transfer we aren't talking products like inductive smartphone chargers. These devices do indeed wirelessly transmit power, though over very short distances and are driving relatively low power devices. Rather, the notion in question is whether or not the world's entire electrical grid could be replaced with antennas that radiate electrical power much like one can "scoop" radio and broadcast television signals from the air. The altruistic-minded Nikola Tesla himself was enamored with just such a concept going so far as building the Wardenclyffe Tower on Long Island to experiment with the ideas of transmitting both information (voice and facsimiles) and power. The fundamental problem with wireless power transmission is the math. The inverse-square law for an isotropic radiator (an antenna that radiates energy equally in all three dimensions) tells us the following:

$$\text{Energy Recieved (at distance } r\text{)} = \frac{\text{Energy Transmitted}}{4 \pi r^2}$$

According to the International Energy Agency, in 2012 the world consumed 20,900 TWh of electricity. Using a very rudimentary calculation based on the inverse-square formula, it would be necessary to generate 5.1x1014 times more energy than the 20,900 TWh to account for the transmission losses. In other words, the economics and physics demonstrate that wireless power transfer is completely impractical.

So if wireless power transmission to every home, school, store and factory remains a pipedream; what are the changes that might actually come to change our world? To look forward, sometime we have to look backwards.

At the same time as Edison and Tesla (and his champion George Westinghouse) were fighting the AC versus DC battles, other concepts were being explored. High Voltage DC (HVDC) technologies were being explored as early as the 1880s but the technology of the time meant HVDC equipment was expensive to manufacture and maintain. Flash forward a century later and technology began to catch up with the theory. The introduction of solid state technology (e.g. insulated-gate bipolar transistors and integrated gate-commutate thyristors from companies such as Infineon Technologies beginning in the 1970s meant conversion of AC to high voltage DC (as high as 800KV) became practical. While the AC-to-DC conversion technology at either end of an HVDC transmission system is expensive, the cost of the DC transmission hardware in between becomes much more economical at distances over 400 miles as you do not need to run cabling for three phases or account for skin effect. An HVDC system could also be used to interconnect unsynchronized AC transmission networks, adding some capacity handling capability lacking in current disconnected grids. However, system reliability for HVDC systems is not quite yet on par on with their AC counterparts. Coupled with the fact that HVDC technology is still advancing quickly, operating an HVDC network requires maintaining a significant spares inventory that may or may not be interoperable with various HVDC systems.

Figure 4: *Solid state devices such as IGBTs from Infineon help to make HVDC a practical reality (Image courtesy of Infineon)*

It's also possible that the future of power transmission is no transmission hardware at all. Renewable energy sources are being increasingly harvested closer and closer to the energy consumer. It is no surprise that photovoltaic panels are popping up on the roofs of houses all across the world. As efficiency increases and breakthroughs in energy storage emerge, it is not unfathomable that living "off the grid" will become more common than not. But here is where it gets very interesting. Photovoltaics produce DC voltage. Therefore, to tie it into your home it must first be converted to AC. Significant losses are incurred at each conversion from AC to DC and vice versa. There is work being done through industry alliance, such as the EM Alliance to advocate for local DC distribution. In short, the wall outlet of tomorrow might just be a USB port and not the three prong AC outlet that is the standard today. In the end, it's possible that Tesla won the most battles, but Edison will win the war.

The War That Never Was, Perhaps

The world of today has been undoubtedly shaped by the pioneering work of both Nikola Tesla and Thomas Edison. Modern life was made possible thanks to our ability to harness the power of the electron. Both AC and DC have found their respective use cases in our high tech world. We have learned how to exploit the technological and economic advantages and disadvantages of both technologies to our benefit. Fortunately for engineers and technology companies we are on the threshold of a second electrical revolution. As the world begins to seriously look at harnessing renewable sources to become better environmental stewards and energy independent, we will have to integrate solar, wind, geothermal, and tidal-based electricity generating technology into the grid. Understanding the advantages and disadvantages of AC and DC transmission with respect to how these sources generate electrons will be a key factor to our future success. It would seem both Tesla and Edison would be justly proud of the contributions that AC and DC offer to building a better tomorrow.

The Future of Portable Power

By Steven Keeping

Lithium-ion technology is the best power source yet devised for today's consumer electronics. But contemporary batteries have their limitations and superior solutions are under development in labs around the world.

Smartphones represent the peak of portable electronic design. These powerful cellular- and Internet-enabled devices boast computing power and memory capacity that matches the spec of desktop PCs and Macs from only a few years ago. An Apple iPhone 6S, for example, sports a dual-core, 1.8-GHz, 64-bit processor, plus 2 GByte RAM and 128 GByte Flash.

But today's smartphones have an Achilles Heel; their batteries. Lithium-ion (Li-ion) batteries have struggled to maintain an energy density (Wh/kg) improvement of around seven percent per year.

For example, the original iPhone weighed in with a 620 MHz 32-bit processor with 128MByte RAM, 16GByte Flash and a 5.18Wh battery, while today's iPhone 6S sports a 6.55Wh cell. The electronics of the latest Apple smartphone represent a dramatic leap in performance compared with the first model while the battery energy density has improved by only around 26 percent in eight years.

According to Apple's specifications, the Li-ion battery in the iPhone 6S has a capacity of 1715 mAh and is capable of around 11 hours of Internet browsing or high definition video playback. It's an impressive level of performance, but still not sufficient to stop travelers, for example, diving for the charger at the first sight of an airport terminal mains socket in order to top up.

Is the big leap in LI-ion battery technology just around the corner or does the technology represent only a waypoint on the journey to a power source offering weeks or even months of service between recharges?

Developing the Li-ion battery

It's taken over 40 years to develop the Li-ion technology that powers today's portable products. Lithium-based batteries are successful because they combine high capacity with low weight, resulting in more energy per kilogram than any other metal.

During charging, lithium ions are energized and move from the $LiCoO_2$ to the carbon. When the battery is in use, the ions move back the other way causing liberated electrons to travel in the opposite direction round the circuit to power the load. (See Fig. 1.)

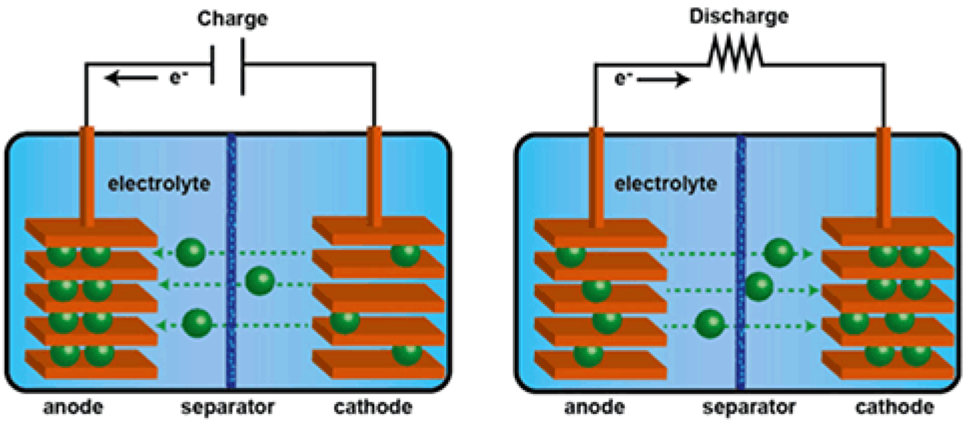


Figure 1: In a conventional Li-ion battery, lithium ions (green) move between the electrodes while liberated electrons power the load. Charging moves the ions back to the negative electrode.

However, a key weakness of Li-ion batteries is their fragility. Each time ions are shifted, some react with the electrodes and remain forever embedded in the material. Eventually the supply of free ions is depleted and the battery fails. Each charging cycle also causes some volumetric expansion of the electrodes which stresses the structure and causes microscopic damage, diminishing its ability to 'store' ions. Consequently, Li-ion batteries can only be recharged a limited number of times. Moreover, overcharging can 'force' so many ions into the electrode that disintegration of the material can occur. It's important to properly manage the charging and discharge rate of Li-Ion batteries in portable devices using a power management IC such as the bq40Z50-R1 Li-Ion Battery Pack Manager from Texas Instruments.

Early versions of Li-ion batteries employed a liquid electrolyte to separate the electrodes, later using a porous separator soaked in an electrolytic gel. This allowed the batteries to have a sandwich construction leading to the thin designs common to today's mobile handsets. Further development led to Lithium polymer (Li-Pol) cells that used a solid polymer as the separator. One downside of Li-Pol batteries is that the ions travel more slowly through the solid polymer than liquid electrolyte, so charging takes longer.

Building a Better Battery

Millions of research dollars continue to be spent to improve Li-ion batteries. Scientists focus their efforts on enhancing characteristics such as energy density, self-discharge rate, peak demand and pulse performance, charging time, and tolerance to deep discharge, together with improving device safety.

Developments have primarily targeted two areas: alternative materials for positive electrodes, negative electrodes and electrolytes--with a view to packing more lithium ions into the electrodes, making it easier for the ions to move in and out, and easing the passage of the ions through the electrolyte--and overcoming the technology's inherent safety challenges.

Positive electrode materials nearing commercialization include lithium nickel manganese cobalt oxide ($LiNi_xMn_yCo_zO_2$), which has an energy density about 20% greater than $LiCoO_2$ but at higher cost, and lithium nickel cobalt aluminum oxide ($LiNi_xCo_yAl_zO_2$), which has an energy density about 35% greater than $LiCoO_2$. Experimental negative electrode materials include lithium titanate ($Li_4Ti_5O_{12}$) (which has low energy density but higher recharge cycles), hard carbon (greater storage capacity), tin/cobalt (energy density), and silicon/carbon or pure silicon (energy density).

There are also several interesting initiatives for improving the *mobility*of the ions. One example comes from the University of Illinois at Chicago (UIC) and replaces the thin, almost two-dimensional, positive- and graphite negative-electrodes of a conventional Li-ion battery with three-dimensional porous nickel structures. $LiMnO_2$ and nickel tin (NiSn) are plated onto the structures to form the positive- and negative-electrodes, respectively. The result is electrodes that can hold many more lithium ions than a conventional device with greater freedom of movement. The university claims this battery would be 30 times smaller than a device of the same capacity and could be charged 1000 times quicker.

UIC is also doing some pioneering work replacing lithium ions (which carry a +1 charge) with magnesium ions (which have a +2 charge). The result could be a battery with a considerably higher energy density than Li-ion cells and can withstand many more recharging cycles.

Researchers have also concentrated their efforts on employing nanoscale (10^{-9} m or nm) materials to improve the mobility of lithium ions through electrodes and electrolytes. For example, scientists at South Korea's Pohang University have built a prototype battery from pumpkin-shaped molecules organized in a honeycomb-like structure which can be used as a solid electrolyte. The molecules have a thin channel (measuring 75 nm in diameter) running through them which enables lithium ions to diffuse far more freely than in a conventional electrolyte. (See Fig. 2.) In tests, the porous electrolyte demonstrated lithium ion conductivity of around three times that of conventional commercial solid electrolytes.

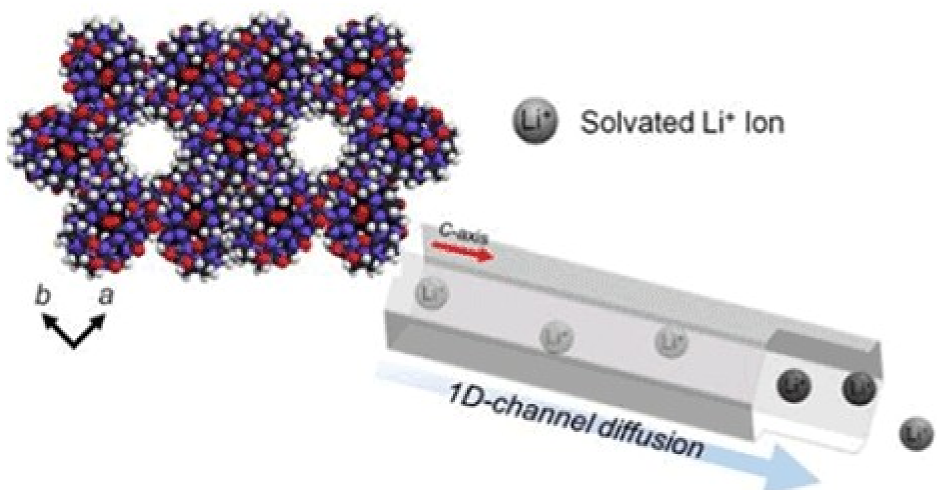


Figure 2: South Korea's Pohang University's electrolyte enables lithium ions to diffuse far more freely than a conventional electrolyte. (Credit: Pohang University)

Another example of nanomaterials at work to improve Li-ion batteries comes from Massachusetts Institute of Technology (MIT). Researchers Byoungwoo Kang and Gerbrand Ceder at the institute claimed that by using nanoball electrodes, batteries could be charged about 100 times as fast as normal Li-ion batteries, resulting in a smartphone that could charge in 10 seconds. The 50-nm balls of lithium iron phosphate dramatically improved ion mobility and the MIT researchers further accelerated the process by coating the balls with a thin layer of lithium phosphate.

Carbon nanotubes might already be at work inside smartphone batteries. The exact composition of most positive- and negative-electrodes are currently held as trade secrets, but the level of commercial production of carbon nanotubes hints that Li-ion batteries are already taking advantage of their properties. Carbon nanotubes exhibit greater surface area, higher conductivity and better mechanical stability than bulk carbon. Other developments include eliminating the carbon altogether and replacing it with silicon or germanium nanowires to further increase the surface area of the negative electrode. This again boosts the mobility of the lithium ions and allows more to be absorbed during charging without volumetrically stressing the material (enabling more recharge cycles).

'Nanostructuring' generally increases the surface area-to-volume ratio, which improves both energy- and power-density due to an increase in electrochemically active surface area and a reduction in ion transport lengths. The downside is an increase in side reactions between the electrode and the electrolyte, causing higher self-discharge, fewer recharging cycles and shorter shelf life.

Prototype batteries using nanomaterials exhibit much higher energy densities than today's commercial batteries. But at present materials are expensive and the manufacturing process is difficult to scale to industrial levels.

The Next Generation of Lithium Battery

One development that brings together all the strands of current Li-ion battery development is the Lithium-sulfur (Li-S) battery. This device takes advantage of developments in materials, 'three-dimensional' electrodes and nanomaterials to improve on today's Li-ion products. Current developments target electric vehicles, but the hope is the technology can be shrunk such that the battery is suitable for portable products like smartphones.

The negative electrode is a thin sliver of lithium while the cathode is lithium oxide (Li_2O_2) in contact with

active sulfur. The reason for such keen interest in the technology is the predicted maximum energy density. The best contemporary Li-ion batteries produce about 200 Wh/kg and the technology has a theoretical limit of around 320 Wh/kg. The theoretical limit for Li-S is around 500 Wh/kg. The key advantage for these types is that the sulfur can 'host' two lithium ions compared to the 0.5 to 0.7 for conventional intercalation materials - resulting in the superior energy density.

Beyond the Battery

Other power sources for portable power include supercapacitors and fuel cells. A supercapacitor is a high-capacity capacitor that bridges the gap between electrolytic capacitors and rechargeable batteries, such as the EDLC 5.5V EDLC Supercapacitor from TDK. Supercapacitors offer higher energy storage and power density than conventional capacitors, making them excellent for burst or pulse load applications like an LED flash, power amplifiers, or certain audio circuits. SuperCapacitors can also provide power for devices that draw very little current over a long time, such as the Real-Time Clock (RTC) and Watchdog FRAM Supervisory ICs from Cypress Semiconductor.

Although very promising, supercapacitors have two main disadvantages over batteries. First is a voltage range of 2.5 to 2.7V (compared to 3.5 to 3.7V for Li-ion batteries). To achieve higher voltages, several supercapacitors are connected in series which increases complexity by demanding careful voltage balancing. Moreover, the voltage of a supercapacitor decreases on a linear scale from full to zero which results in some stored energy remaining in the device once the voltage drops below a usable threshold. The second drawback is the supercapacitor's low energy density. Compared with the Li-ion battery's 200 Wh/kg, even the best supercapacitors struggle to exceed 10 Wh/kg. That means that a bank of supercapacitors will take up much more space than an equivalent Li-ion battery.

Fuel cells represent perhaps the most esoteric attempt to steer portable power sources away from conventional batteries. Invented in 1838 and cemented into popular perception during the *Apollo 13* crisis, fuel cells have long been used as a method of converting the chemical energy of fuel into electricity, and are considered a good option for electric vehicles. However, due to their size portable fuel cells are inappropriate for mobile electronic products at this time.

Li-ion batteries are a rapidly maturing technology that lie at the heart of the most capable portable consumer electronic devices. But while providing satisfactory service, consumers crave longer life from batteries. That's stimulating ongoing research to develop and refine the chemistry and physics to ensure that Li-ion technology continues to evolve. Some of that research promises to yield lithium-based batteries with double the run time of existing cells in like-for-like applications. However, even that might not be enough to satisfy the demands of future consumer electronic products, so expect to see alternative technologies like supercapacitors, fuel cells, energy harvesting, and yet-to-be-invented power storage devices enter the fray.

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