Automotive X-Prize: Innovating the Auto Industry, One Battery at a Time

Imagine a world where instead of paying $40 or more to fill up your car with gas just to make it through the week, you could plug your car in overnight, get thousands of miles out of a full charge, and even help free the world from its heavy dependence on oil. Best of all, you could do it for less than what you're paying to fill up your tank now. We've all thought about such a car, but how far are we from this ideal world?

Recently the answer to this question has started to take shape in the form of the Automotive X Prize (AXP). This competition, offered by the X Prize Foundation, challenges teams to design and build 100+ mile-per-gallon vehicles that could eventually be sold to the public. By organizing this competition, the X Prize Foundation says they hope "to inspire a new generation of viable, super-efficient vehicles that help break our addiction to oil and stem the effects of climate change." Teams worldwide will compete to win the multi-million dollar prize and show that their vehicle has what it takes to become the future of the automotive industry. In order to qualify for the competition, teams will have to construct vehicles that meet the 100 mile-per-gallon mark and also must pass strict emissions and safety guidelines. In addition, each team must present a viable business plan for producing and selling their vehicle. Of the teams that meet these requirements, the winner will be determined by a series of race stages set to be held in 2010.

So far, over 50 teams have officially joined the competition. Though many of the ideas being developed are quite diverse, with competitors trying everything from super-efficient traditional engines to revolutionary hydraulics and air powered motors, the most popular source of energy for this competition is clearly electricity. Tesla Motors, a young, privately funded car company, has already proven that a purely electric vehicle is commercially viable with the release of their Roadster this past year. This environmentally friendly sports car reportedly gets 120 miles per gallon when using an electricity/gasoline equivalent conversion. However, the Roadster does not meet the emissions guidelines set forth by the X prize competition, which is why Tesla plans to enter a new model that will be more moderately priced and geared toward the mainstream auto market. Another California based company, Aptera Motors, has developed both electric and hybrid electric versions of their vehicle prototype, the Typ-1. The earliest two-seat model achieved a whopping 230 miles per gallon, well beyond today's standards. Not only does the Typ-1 drive like a car of the future, it has the strikingly futuristic looks to go with it.

Tesla Roadster

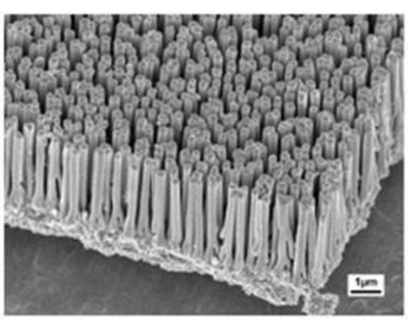
Building a Better Battery

While these examples may make it seem like the goal of the AXP competition has already been met, and with relative ease, pure efficiency is not the whole story. The greatest optimization challenges for developers of electric vehicles have been and will continue to be driving range and refueling time. When trying to improve vehicle efficiency, excess weight is usually one of the first things to go. In a vehicle powered by electricity, energy is typically stored in batteries, which tend to be very heavy and take up lots of space. Historically, small, light vehicles just don't have the battery capacity necessary to travel long distances. Another problem lies in the time it takes to charge the batteries in an electric car. The most advanced batteries widely sold up until now take several hours to charge. Compare this with the several minutes it takes to fill up at a gas pump and it is easy to see the problem.

It is for this reason the automotive industry is shining a major spotlight on battery innovation as a segway into a new era of hybrid and electric cars. Thanks to many researchers and innovators, batteries are finally breaking new ground in meeting the demanding requirements of the automobile industry.

Aptera Typ-1

Dr. Cui, a researcher at Stanford University has found a way to inject silicon nanowires into lithium-ion batteries to improve their performance. This revolutionary technology expands on the energy storage of current lithium-ion batteries, increasing their capacity by up to 10 times; the nanowires prevent silicon placed in the battery from degrading over over repeated charge/discharge cycles. Imagine a 120 MPG electric vehicle such as the Tesla Roadster coming out in 2008, packed with 6,800 Lithium-ion batteries. With Dr. Cui's "revolutionary" nanowire-batteries, the Roadster could cruise the same distance while carrying only a tenth the number of batteries, reducing the weight of the car by 800 lbs! This would in turn help improve performance and increase fuel efficiency even further. However, instead of going for extreme weight reduction of the vehicle, a more likely route would be to increase the vehicle's total driving range for practicality, giving consumers a blend of long driving range and weight reduction.



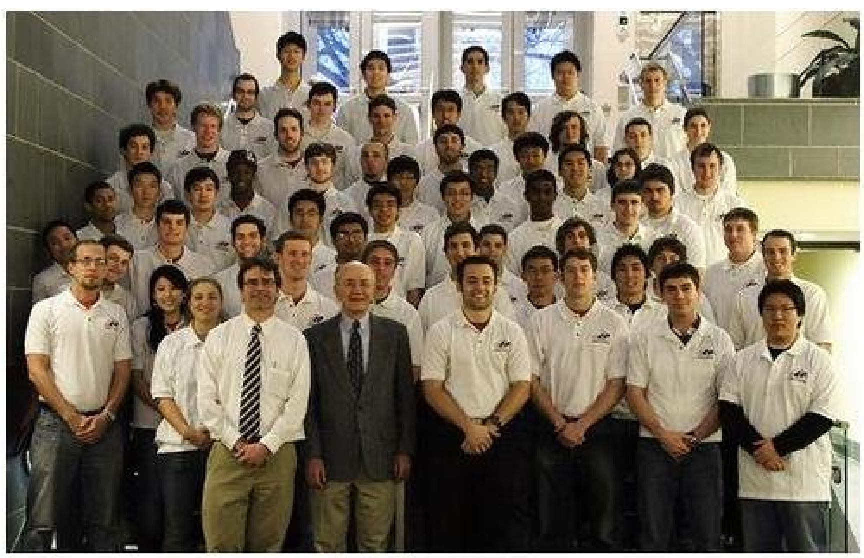
A forest of nanowires

The prospects for the battery innovation sound tremendous, but it has yet to prove its ground in some aspects. One area of skepticism lies in the predicted lifespan of the battery. In fact, this issue is the foremost concern of General Motors, which is developing an electric vehicle, the Chevy Volt. In an interview with Dr. Yi Cui from GM-Volt.com (an unaffiliated site devoted to the GM Chevrolet Volt), he stated that he is currently doing tests to see if his batteries will meet a target of 1000 cycles (better than most li-ion cells) without substantial depreciation, and that he expects to have results in the next couple of months. The implications of this kind of study are very important. So far, the only published results show that the batteries hold up very well when cycled 30 times. To bring this into perspective, the Tesla roadster has an estimated range of about 220 miles. With a range extension of 10 times, the carbon nanowire battery could bring this range up to 2200 miles on one charge. A thousand cycle lifespan would mean that the car's battery would be able to take the car 2.2 million miles without needing to be replaced, and that's quite a bit considering that the average lifespan of today's cars is only between 150,000 and 200,000 miles.

But what about charging the whole battery pack, which holds as much electricity as 6800 standard lithium-ion batteries do? If a laptop with 12 lithium-ion battery cells takes about 2 hours to fully charge, then could fully charging an electric vehicle with 6800 cells take as long as 13,600 hours?! Well, you would not be relying on a regular home appliance adaptor (100 – 240 V , 1.5 Amps) to charge such battery. For commercial electric vehicles that are available in the very near future, the average charging time, given a speacial charging station that runs on 70 Amps of current at 100 – 240 V, projects to be about 3.5 hours, which is not terrible, but not great either. Fortunately, MIT researchers are coming up with a better solution to the problem. By inserting a layer of metal (manganese and nickel) separated from the lithium by oxygen and organizing the crystalline structure of the material, the flow of lithium-ions within the battery can increase up to 10 times faster than that of an unmodified battery. Another positive aspect of this improvement is that by using manganese and nickel rather than currently accepted cobalt in lithium-ion cells, the cost of production can be much cheaper and the capacity of the battery can be much higher. *1*

A Competitive Edge

So how much of an impact will this new battery technology have on the teams competing for the X Prize? Looking at the vehicles engineered by Tesla and Aptera, they are only able to cover 220 and 120 miles per charge respectively, before needing to charge for several hours. Although this is a big improvement over previous electric vehicles, limitations of this kind may cause many consumers to doubt the utility of such a vehicle. It is this perspective that has encouraged many teams to pursue some form of hybrid electric vehicle. The inclusion of an engine running on liquid fuel provides the advantage of quick refueling during long periods of driving. At the same time, if the ability to plug the vehicle in and recharge from the grid exists, shorter trips may be completed on only electric power. This is the strategy of several teams, including a team from Cornell University, the first student team to register for the contest. Cornell AXP is working on designing a super-efficient plug-in hybrid electric vehicle (PHEV) that will focus on utilizing electrical power as much as possible. While using a



Cornell AXP Team

standard battery pack will necessitate a considerable reliance on the engine to power the vehicle, the Cornell team plans to use the best batteries they can get their hands on. If Dr. Cui's research turns out to be as promising as it sounds, a nanowire battery pack could prove invaluable to teams taking this approach.

Looking Ahead

Though the specifics of AXP's race stages of the contest have not been officially announced, it is likely that a variety of driving scenarios will be required in the competition. Slower driving over short distances, consistent with urban driving, might not put much separation between competitors. Rather, it is the longer "highway" courses that may decide the outcome. Any team employing electricity as a main source of energy will need every bit of help possible to extend the driving range of their vehicles. This is why the development of new lithium-ion batteries with ten times the capacity of their predecessors offers such an advantage for both AXP, and the industry as a whole.

However, the new battery technology does raise some concerns. One issue that will arise if a move to electric vehicles occurs is where all needed electricity to charge them will come from. Just plugging into the power grid means you will be using electricity produced mainly by burning fossil fuels. So, might a decrease in vehicles powered by gas or other fuels just mean an increase in power plants and a continued dependence on fossil fuels? As Cornell AXP's team leader Terence Davidovits points out, not quite: "Electric cars are more efficient and would likely result in a reduction in CO_2 emissions, even taking into account the fact that we burn fossil fuels to supply electricity. We also then have a vehicle fleet in place that can then be charged with sources like wind, solar or nuclear, that do not require the consumption of fossil fuels." This concern with where the power will come from will undoubtedly be important to eco-friendly car buyers.

According to the energy information administration, in 2006 almost 75% of the nation's energy consumption comes from fossil fuels such as petroleum, natural gas, and coal. Solar power has seen an incredible amount of demand over the most recent years, and is forecasted to steadily increase in growth and demand for at least the next five years. Semiconductor advancements have made widespread, cost-effective solar electricity a reality. However, the issue remains that solar power requires a large initial investment. Rising car companies like Tesla Motors plan on co-marketing sustainable energy products from other companies along with the car. It would cost about $5,000 to purchase a solar panel system that can generate about 50 miles of electricity per day. The question is, would 50 miles a day be enough to meet the needs of enough drivers, and how many people are willing to pay a premium for clean energy? It appears that the cheapest solution to powering a vehicle would be in the form of a converter that allows the vehicle owner to plug into the power grid. However, solar panel buyers would get the benefit of owning a true zero emissions vehicle. With transportation historically making up almost 30% of the nation's total energy consumption, a move towards solar technologies to power cars provides an intriguing step towards an ideal world.

Like all automotive innovations, one has to wonder whether these concepts will actually become a reality. Are these new batteries economically viable options for automobiles or are they the work of science fiction? In the GM-Volt interview, Dr. Cui shares his thoughts on where these batteries may be headed in the near future: "Silicon is the second most abundant element in the world. People know everything about silicon. The infrastructure is there, the supply source is there. With the excitement of use of silicon for batteries, the cost will be reduced dramatically." When asked how soon this technology could appear on the market Cui points out that it will take some more work, but a reasonable estimate is perhaps five years.

Dr. Cui has mentioned the possibility of starting his own company to develop these batteries, but is also thinking of working with an existing battery company. Five years just seems like too long to wait for this type of technology advancement. Cui needs to start thinking about some serious growth. With the AXP competition set to begin in 2010, we can only hope that the innovations springing from the challenge will aid in minimizing the waiting time in attaining such batteries. The consumer basis for these batteries is practically limitless, and no one wants to wait around for new technology. High demand is going to push mass production to come soon. Be ready.

---

1 Nickel: 8$/lb, Cobalt: 15$/lb, Manganese: 1$/lb, from 2007 Material database by Granta Design Limited.