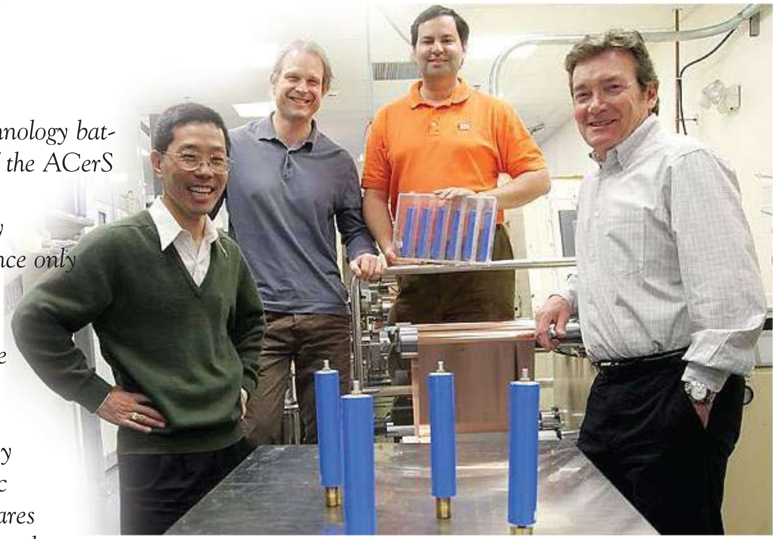
A123 Systems: Eight hard years for an 'overnight success'

An interview with Yet-Ming Chiang

A123 Systems is currently one of the leading advanced-technology battery companies in the United States. The company, winner of the ACerS 2009 Corporate Technical Achievement Award, manufactures powerful lithium batteries based on a proprietary nanophosphate technology. Although A123 has been in existence only eight years, its products already have made inroads in the power tools, transportation and energy grid sectors. Its batteries can range in size from small packs for rechargeable drills to trunk-sized kits for hybrid automobiles to tractor-trailer-scale systems for electrical utilities.

Although privately owned since it was cofounded in 2001 by ACerS Fellow Yet-Ming Chiang along with Bart Riley and Ric Fulop, A123 made business headlines just weeks ago when shares of the company were first offered for sale in the stock markets and in an eagerly anticipated initial public offerings.

But the IPO wasn't the only big news for A123 in 2009. In August, it was one of only a few U.S. companies selected by the Department of Energy to receive a major grant to help them evolve into businesses that can compete worldwide in the vehicle advanced-battery market.



A123 Systems cofounders, from left, Yet-Ming Chiang, Bart Riley and Ric Fulop, along with CEO David Vieau.

Chiang, who is a full-time professor at MIT, was recently interviewed by Bulletin editor Peter Wray about how he became a ceramist, the evolution of the science behind A123 batteries and what it's like to be both a researcher and successful entrepreneur.

ACerS 2009 Corporate Technical Achievement Award

The Society established its Corporate Technical Achievement Award to recognize a single outstanding achievement made by an ACerS corporate member in the field of ceramics.

Indeed, A123 Systems' nanophosphate technology has shown significant merit and represents a gain to society through its commercialization.

This year, Yet-Ming Chiang, representing A123 Systems – winner of the 2009 CTAA – will make a presentation on the award-winning technology at 8:20 a.m. on Tuesday, Oct. 27, as part of ACerS Emerging Opportunities for Ceramic Science and Engineering Session.

Chiang will also participate in a panel discussion during the Opening Session of MS&T'09 on Monday, Oct. 26. The panel will begin following the keynote presentations.

Both events will take place in the David L. Lawrence Convention Center in Pittsburgh, Pa.

Can you explain how you first became interested in materials and ceramics?

I came to the U.S. when I was six. My family settled on the East Coast in New Jersey. I ended up at MIT in 1976. My sister was already at MIT. I decided to major in materials, because, even in high school, I had an interest in metallurgy. I did a lot experiments in my bedroom at home, including, for example, learning how to case-harden steel parts. I learned about hardening, because I liked to make machinery and little tools and gadgets at home, and I found that they actually wore out. I found this concept of hardening and thought, "What a neat thing."

I found out only after coming to MIT that what was actually going on can be found in the phase diagram, that allowed this to happen. I learned about the iron–carbon phase diagram from professor Robert Olgilvie. As I majored in materials science and engineering, a lot of the really interesting research at that time was in ceramic materials.

I started working with David Kingery as an undergraduate. I was a junior at the time, but I spent my sophomore summer in an internship at a West Coast company. They really didn't know what to do with MIT undergraduates who were relatively untrained and unskilled. So I spent much of the summer enjoying the California sunshine but also coming to the realization that I'd better go figure out what to do with my life. When I came back to MIT that fall, I decided to try out a couple of research projects. One of them was with David Kingery, and, in pretty short order, it really developed into a passion of mine.

I was supervised at the time by the late Anders Henriksen who completed his Ph.D under Kingery.

Kingery sent me to the University of Texas at Austin to do an experiment with an Auger spectrometer that professor Harris Marcus had in his lab. I went to Austin, Texas, for three days of experiments, came back, and published my first paper in 1981 – a paper on grain-boundary segregation in magnesium oxide. That's where I really got started in the ceramics field.

Later, I went on to graduate school at MIT and became an assistant professor in 1984. It was a magical time to be in ceramics because I and others were surround by luminaries, such as Kingery, Rowland Cannon, Robert Coble, Donald Uhlmann and Kent Bowen.

So, at some point you start becoming interested in lithium materials?

In the early 1990s, after I had received tenure at MIT, I started looking around for things to work on. Most of my work up until then had been on the fundamental aspects of ceramics, but I started looking more for research opportunities in areas the DOE today would call "use-inspired" research. I started thinking about use-inspired materials. Materials particularly for new technologies. In the mid-1990s, I started to become interested in lithium battery material, because there was an eye-opening collaboration I had at that time with three other MIT faculty, Gerbrand Ceder, Donald Sadoway and Anne Mayes.

What I started to learn was that many of the materials that stored lithium were, in fact, oxide compounds. These were ceramic compounds. They weren't much thought of as ceramics, but they were used in an engineered-powder form. The fact is that lithium cobalt oxide, then the baseline material for positive electrodes for lithium-ion batteries, is an ordered rocksalt compound. What was interesting was that, having done earlier research in my career on magnesium oxide, a rocksalt compound, I looked for interesting technological examples of rocksalt compounds. Frankly, there weren't that many. Spinels, for sure. Perovskites, there were many. But rocksalt compounds – there just weren't all that many materials of commerce.

The fact that lithium cobalt oxide is an ordered rocksalt compound that plays a central role in technology caught my research and teaching interest. But, I went on to find out that spinel compounds, lithium manganese spinel, a structure near and dear to the heart of ceramists, was also a foundational material in lithium-ion technology. Subsequently, olivines, as well.

So it began with this interest in oxide compounds for positive-electrode materials for lithium-ion batteries, and the recognition that these compounds were certainly ceramic compounds. Many of the researchers in the field were not from ceramics, and, so, I thought there was a lot of room for research and innovation, and taking a ceramics perspective on how to develop, how to design and how to engineer these materials for better batteries.

A123's aftermarket Hymotio
Some plug-in hybrids can ac

What was the time frame this was going on?

I believe that our first papers published on battery materials were in the mid-1990s, in the 1995–1997 time frame. My work with A123 started in the 1999–2000 time frame. In my lab, we were working on a couple of different concepts related to batteries. One developed as I learned something about how batteries were made. It's a fairly straightforward process.

Let me back up here. First of all, the vast majority of the materials used in batteries today are powder-based. These are powders, maybe ceramic powders, carbon powder, occasionally silicon or metal powders. There is a lot of powder processing and suspension formulation going on in this field, which, of course, also is near and dear to the hearts of ceramists. The manufacturing process involves making laminates and winding them into laminated cells.

We started thinking about how to control colloid chemistry and to do something very radical, which is to try to get batteries to self organize. The idea of this came out of research I had done over a number of years on surface forces with colleagues such as Roger French at DuPont, Cannon and others, who had spent many years thinking about interfacial forces. French was the first to expose me to the symbol A_{123} for the Hamaker constant scaling the van der Waals force between two dissimilar materials, 1 and 3, separated by material 2.

Of course, this was also central to much of the ceramics research around

n packs can convert standard hybrid automobiles into plug-in vehicles.
hieve over 100 miles per gallon of gasoline

grain boundaries and microstructure development in silicon nitride and other silicon ceramics that Fred Lange, David Clarke Manfred Rühle and Rob Ritchie have also extensively studied.

The basic idea we started thinking about was how you might use surface forces to produce batteries that would "organize" in the sense that the cathode and anode materials might repel themselves and spontaneously form an electrochemical junction.

In searching for materials for this concept, we started looking at optical and dielectric properties of lithium storage compounds. It was easier to find electrode materials of high refractive index, carbon and many metals. These could be used as the negative electrode, but the hard part was finding materials of low refractive index and also those that could be used as the positive electrode of the junction.

We started looking at olivines, because, of all of the compounds known to be useful as electrode materials that we screened, these had the lowest refractive indices.

So, that led to some work we did looking at olivines – lithium iron phosphate, lithium manganese phosphate, lithium nickel and lithium cobalt phosphate, that family of compounds.

We wanted to see if we could use the properties in a way to produce a self-organizing system. In the end, we were able to produce an interesting lab demonstration of that concept. It has not proceeded, at this point, to a full-scale device development. But in studying these materials, I and my then-postdoc Sung-Yoon Chung and then-graduate student Jason Bloking found we could also produce olivine compounds that, in a lithium-ion cell, allowed charge–discharge rates that were considered very high at the time.

How high of discharge–charge rates are we talking about here?

This is a fast-moving field. Back in the 2001–2002 time frame, a rapidly charging and discharging battery was considered to be one in which you might be able to charge and discharge at a 5C rate, or one-fifth of an hour. A twelve-minute rate then was considered to be really high powered.

We found that with certain compositions of olivines, which we produced in a very fine powder form, with primary particle sizes on the order of 50 nm or less, that we could charge and discharge at rates up to 20C or three minutes. In the lithium-ion battery field at the time, this was a significant achievement. Just to show you how far we have come from then until now, researchers now talk about charge–discharge rates of 200C. So subminute rates are possible.

A123 even has a product that was used this past year in Formula 1 racing, in which 80 percent of the theoretical energy of the battery is discharged in about six to eight seconds. That was used by the Vodaphone McLaren-Mercedes team.

So, high-powered batteries have come a very long way. The emphasis [before 2000] in lithium-ion batteries had been toward relatively low-powered but long run-time devices. We thought there was an opportunity to address an entirely different application area. Not cell phones, laptops and PDAs. But large, high-power systems, starting with power tools, then electric vehicles and hybrid vehicles, plug-in vehicles, and then – something I didn't anticipate at all at the time – grid stabilization systems. These are really large lithium batteries that are used to buffer short-term, high power fluctuations.

But the engine for all that was the work on nanoscale olivine compounds from which we thought we could extract the high rates of charge–discharge, and also take advantage of some other attributes of these compounds, namely their inherently better safety and longer life over other carbon compounds at the time.

From a functional point of view are we now blurring the distinction between a battery and a capacitor?

Yes. That Formula 1 battery delivers levels of power, if you take it in terms of power density, which is units of watts per kilogram, of more than 10,000 watts per kilogram. That is a value that people, up until now, considered achievable only with capacitor technology.

The thing about these high-powered batteries is that they also have several times the energy density of the best capacitors available. You get that power at a much higher energy density level. So, yes, that is blurring those distinctions.

Did you have any training on the business side? When you started getting into the issues of licensing the A123 technology from MIT, was that leap difficult?

First of all, I want to reinforce your starting point, which is that what is special about A123 is that it was founded, and still is based on, materials innovation. It's not only me. My cofounder, Bart Riley, got a degree from Cornell with David Kohlstedt in ceramics and

A123 Systems Hybrid Ancillary Power Units can be rapidly deployed to energy grids worldwide to hybridize a power plant and provide frequency regulation and synchronous reserve. These units respond in milliseconds and free up power-plant capacity reserves.

geology. Many people in ceramics know Kohlstedt and his excellent work.

Riley first went to American Superconductor after he first got his Ph.D. That was the first company I was involved in cofounding. Very quickly after A123's foundng, our CEO David Vieau joined us, and he had a background in mechanical engineering. From the very beginning, we had a lot of technical leadership, particularly in the materials area.

Then, the first new employees at the company were graduates from my department at MIT. Even today, we probably have more materials scientists than any other battery company in the world.

What we did was to supplement that materials expertise with people who had a lot of experience and deep knowledge in the field of batteries. That was how we built the initial technical team at A123. And that philosophy persists today.

On the business side, I never had taken any business classes and I don't have a business degree. But my first experience being a part of a start-up, with American Superconductor, was a great learning experience. I started to learn how these ventures are pulled together. How you finance it. How you get the right people involved. And, honestly, that's the key thing. You need the technology and you need the people and you need the financial backing.

One thing I've learned is that you shouldn't expect and you don't need to do it all yourself. What has made it successful for me is finding good partners. The folks I just mentioned have really performed as an excellent team. Every one of us brought something different to the table. As the academic researcher, I wasn't involved in A123 for my business acumen, right?

What happened was that my other cofounder, Ric Fulop, catalyzed the whole thing by coming to my office one day and announcing to me that he was interested in developing a venture based on new battery technology, and he wanted to know if I was working on anything that had that potential. What he really did when he arrived at my office was to prompt me to start to commercialize things that I might otherwise have waited longer to do, waited for a higher level of development.

Now, because of my day job was and is at MIT, Bart Riley was instrumental because he came on board to drive the laboratory development team. Ric was the business catalyst, who got exposure for us as a new venture to a broad cross section of the venture community.

In the summer of 2001, Ric, Bart and I probably visited 30 venture capital investors, and we were really fortunate to get some top-notch investors out of this exercise. Opening those doors was certainly something I couldn't have done myself.

When you are making a pitch to a venture captial group, are you explaining the science and Bart is explaining the engineering and Ric is discussing the business deal?

It is important to convince an investor that even the technical guys understand what the impact of this can be. You're right, at first, but over time the boundaries blurred a great deal. Ric became an expert in the technology very quickly, and I learned a lot about the business side from Ric and Dave, and it was mutually beneficial. So, I was able to help with business development as well as the technology, as was Bart. And it wasn't as if the business development folks had a boundary around them. They knew and could recognize technical issues and bring them up.

You end up with overlapping spheres of expertise. What makes the whole team gel is that you are able to get people together, learn from each other and blur those boundaries.

When it comes to licensing with an institution like MIT, is it just a standard agreement and there aren't really negotiations to enter into?

Yes, well that's another area I had to become quite familiar with through firsthand experience: How does technology make it from laboratory out to commercial development? In fact, I am currently on a committee at MIT called Technology Transfer for the 21st Century, and we are looking at exactly this. What are the policies that allow MIT to best meet its technology-transfer mission of disseminating technology and creating societal impact with it?

Licensing is a key part of that.

A start-up company typically needs some exclusivity. We struck an exclusive license for the patents that had been generated in my lab at MIT. That was part of the foundation of getting a start-up going. The terms that typically go into a licensing agreement for a start-up include some ownership in the company for MIT. It includes a royalty structure and regular payments, as well as an up-front fee. So, the three pieces are equity, royalty and fees.

Over time, I have learned a lot about how to structure these agreements so that it works for everybody.

So, there isn't one blueprint for the licensing. There are some negotiations about how to exactly structure it in a way that addresses all three components?

That's right. It really depends on the technology and the business. Certainly, at MIT, our licensing office wants to understand what the model is. There is also an attempt to create some flexibility, because sometimes in the beginning you are not exactly sure what the model will be for turning the technology into a business.

Was having the Obama administration come into office create a turning point for the company, given its outlook on energy and alternative transportation?

I think it was an important piece rather than a turning point, because, prior to that election, A123 was already engaged with multiple automakers and over a dozen specific automobile projects.

We were producing the Hymotion plug-in conversion pack. We were already producing the BAE hybrid bus pack for the Daimler–Chrysler Orion VII bus –there currently are over 1,000 of these on the streets in U.S. cities. So, when the election took place we were already in that business. We were already underway with our grid-stabilization product that is a 53-foot tractor-trailer-size type of battery, used in a lineup of six or a dozen or more, and that project was with AES in southern California.

So all of those pieces were well underway. The stimulus package did have a huge impact on the company's ability to build manufacturing capacity going forward, which is necessary to be a global competitor.

For sure, you need technology and you need customers, but building factories is very expensive. Already, because of the activities with the U.S. automakers, there were thoughts and plans to have manufacturing in the U.S., in Michigan, in particular. We were already manufacturing in Massachusetts at that time. So, it wasn't as if we waited until the stimulus funds arrived to consider manufacturing in Michigan. Those plans started to gel well before that.

There were very good economic and business reasons for that. It was not a decision based on political calculus. But it was very helpful that there were going to be loans and grants available from the stimulus package to help us raise further capital and compete globally.

The endorsement of the DOE through awarding of a manufacturing grant – in which we received $249.1 million, the second largest of the battery manufacturing grants – was a real endorsement that we were on the right track.

But what led up to that was years of work with the DOE. We had multiple projects in the automotive battery area with the DOE and had demonstrated that we could deliver. So, it wasn't a situation where out of the blue we applied for a large grant and received it. There was a lot of ground laying prior to that, getting smaller grants – and A123 delivering on those grants.

Didn't some of your competitors make promises that they would move manufacturing in if they got the award?

Well, the criteria were quite clear. The phrase "shovel-ready" was used, and I think we were able to demonstrate that to the DOE.

I assume your team is quite happy with the technical and business success of the company to date.

Yes. I look at it a little bit like it's an overnight success that took eight long, hard years of work for everybody involved. It's been an incredible amount of work to get to this point. Everyone in the company who contributed to that feels a great sense of accomplishment.

Looking ahead, how much of A123's future depends on new technologies and how much is it in perfecting the manufacturing process side?

One thing about A123 that is quite unique amongst other companies is that we really are vertically integrated. We make our own value-added electrode materials that goes into our batteries, all the way up through a complete system.

Initally, we knew we could make the value-added materials, but we started to make cells rather than to be a materials producer and a materials supplier to cell makers. After we got in the cell-making business, we found many customers needed some expertise in designing packs – and then systems. We became a pack and systems company as well.

An example of this is the grid stabilization product that goes by the initials HAPU, which stands for hybrid ancillary power unit. These units produce two megawatts of power and have half a megawatt-hour of stored energy. It uses our workhorse cells, but also contains a great deal of thermal, mechanical and electrical engineering.

Regarding the future, I think that you will see progress on all fronts.

The company's approach is one of being vertically integrated, and I would say that we are working on all parts of that vertical integration.

The reason I asked was because of some comments from Emanuel Sachs, another MIT professor, who has been postulating that in regard to photovoltaic panel production, that assuming you are using the best amalgam of technologies available, the future is all about making process improvements, and that will ultimately drive cost down. What do you think?

In comparison to that, let me add a touch of detail to what I said earlier. I couldn't agree more that process improvements are very important for getting costs down.

But with battery technology, if you can store more energy with less material, that lends itself directly to reduced costs. The metrics are dollars-per-watt for high-power applications, and dollars-per-watt-hour if it's an energy-focused application, and these costs are amortized over the life of a battery. So, being able to store more energy and deliver more power with less material over a longer lifetime, that helps to produce a reduction in cost, in addition to a reduction in manufacturing costs.

What is the status of the Michigan plant, currently?

There are two primary products that will come out of the planned Michigan plants. One is a cylindrical cell and one is a prismatic cell.

(Editor's note: A fan of his company's products, Chiang gave the interview while driving his Toyota Prius equipped with one of A123's Hymotion, an after-market plug-in module. This module allows the vehicle to get more than 100 miles per gallon while producing one-half of the CO_2 emissions of a comparable car during Chiang's 40-mile daily commute to MIT.)

In a project with BAE, A123 powers over 1,000 hybrid municipal busses.