Discussion

Shigenori Mitsushima

Q: For the 50kW Ballard's fuel cells you showed, am I right to think that with 30% efficiency it would have 100kW of waste heat to get rid of?

A: For the stack itself the efficiency is almost 50%. But the efficiency for the system to produce hydrogen from hydro carbon fuels is around 80%. For the fuel cell system as a whole, it will be approximately 30-40% of efficiency. The waste heat at the fuel cell stack must be first removed and rejected to environment at the other part of the system

Q: So, that means this waste heat is all removed with chilled water?

A: It is not chilled water. Heated water in gas phase or steam can be used.

Q: What is the source of energy to increase the temperature of the system?

A: For fuel cell stack, as mentioned, 50% of hydrogen energy is changed into heat and this heat will brings up the cell temperature. The problem here is rather to remove this heat. You can manage fuel cell temperature without extra source of energy. For hydrogen production, you may use combustion heat of the unused hydrogen from the fuel cell stack as a source of energy.

Q: You mentioned the membrane can handle differential pressure. I am wondering if you could give what potential is for the differential pressure on the anode and cathode? And the second question is how is this membrane at very low temperature, say 20 ºC bellow zero or 12 ºF. What is the potential to produce power at those low temperatures?

A: For ionic gel electrolytes, the mechanical property depends on the composition of ionic gel. By having higher polymer content, the mechanical strength can be improved, but its ionic conductivity decreases. On the other hand, it is vise-versa when you increase its ionic liquid content. I think that we have to find optimized condition.

For the property of ionic gel electrolyte at low temperature, we have the property data on liquid phase only. Some type of the ionic gel can be used at temperature even bellow minus 20ºC, but some are only at above room temperature. It depends on the structure of cation and anion.

Q: When do you expect these fuel cell systems will be fully developed and put into practical use?

A: I think it will take a long time. Even for the polymer electrolyte systems currently being developed, I think that it would take more than 10 years from now. So, I would like to catch up the PEFC technology with the new electrolyte system proposed here.

Q: I have heard that for polymer electrolyte systems some problem in maintaining its long cycle life exists due to humidity control required for polymer electrolyte membrane. I understand that for your new electrolyte material, it does not need humidity control so that it would be very good for long cycle life. What do you think of it? Also, do you think that the increased operation temperature for your system may affect its long cycle life?

A: As you pointed out, there is no need for humidity control in our newly developed material systems. Though we expect that this would help improving the cell life problem, we do not have, so far, any long time operation data so that I cannot say anything confirmed as to its cycle life.

Q: In the experiment you showed in slide 19, you are not using porous gas diffusion electrodes. I think that the porous gas diffusion electrodes are most common in practical fuel cells. Do you have any plan to test the performance of your new materials in an electrochemical cell with porous gas diffusion electrodes?

A: With the experimental set up in slide 19, we intended to study the property of the materials only so that the flat type electrodes can be used without problems. The experimental set up in slide 18, on the contrary, consists of porous gas diffusion electrodes. Also, we are developing an analytical code in order to check the relationship between the reaction kinetics and the performance of porous gas diffusion electrodes.

Nobusuke Toukura

Q: I think it really exiting people actually test driving these vehicles. I am wondering if I am test driving one of these cars, how do I feel about this car? And if I turn the key and it does not start, what would be the most likely reason?

A: The reason for the time lag in car start-up is that we need to check and to give certificate for the system reliability by self checking hydrogen sensors, pressure sensors and valve sensors, and by making sure if all the actuation operation work properly. We need even more time. The other reason is the time required for filling up fuel cell stack with hydrogen. Although the fuel cell stack needs to have high concentration hydrogen before start-up, it takes long time.

Q: I understand that Toyota has launched hybrid vehicles, but Nissan has not. Is that true?

A: True.

Q: If the ultimate goal is hydrogen, what would hybrid vehicles do to this goal?

A: Though Nissan has no hybrid vehicles so far, I can tell you that you will see them very soon. The power manager, battery and driving motor system for fuel cell vehicles are actually common with those for the hybrid engine vehicles. We believe that the commercialization of hybrid vehicles is a necessary step for fuel cell vehicle commercialization. So, Nissan has started producing hybrid vehicles and is now accelerating the development.

Q: I am interested in the durability target for light duty vehicles. We often hear that a target of 4,000 or 5,000 hours would be enough for the life time of a vehicle over about 15 years. We have seen some statistics shown that a car is driven for about 1 hour per day in the U.S. So that, maybe, 5,000 hours would be adequate. Could you comment on this?

A: I believe that much longer durability target would be necessary for "full commercialization" since automotive companies in general will give you a 20 year or 30 year warranty for conventional vehicles.

Q: You showed a Nissan “X-trail” based fuel cell vehicle. Could you tell us the reason why you choose this type of car for fuel cell vehicles? Is it just because of its size, or is it because you think that cars for recreation purposes will be the first target of future product for fuel cell vehicle application?

A: You can see this Xtera and X-trail are very similar in style to each other. Nissan was then very anxious about what kind of fuel cell vehicle we should produce for the first time. In 2001, there were several fuel cell prototype vehicles in the world. The examples are Honda’s FCX that is based on“EV plus” and Ford’s “P2000”. They are actually small compact cars. We assumed that people would want to see its realization and commercialization not only for small compact cars but also for other type with something different. So, we decided to show the possibility of fuel cell vehicles in its user friendliness. Also, technically speaking, since Nissan X-trail has enough room for hydrogen tanks, it is much easier to use as a baseline car for our fuel cell development.

Q: Regarding social approach, do you have any plan for this kind of activity?

A: Nissan is now trying to reveal the possibility of fuel cell vehicles in several occasions. For example, Nissan made an entry with fuel cell vehicles for the “Michelin Challenge Bibendum” held in China in this October. This kind activity is the opportunity for Nissan to make announcement for the social usability of fuel cell vehicles.

Q: I understand that fuel cell vehicles are a solution for the reduction of fossil fuel consumption. However, how do you evaluate the fuel cell vehicles in view of recycle and re-use of materials?

A: As main part of current fuel cell stacks, Nafion® or fluoride based membrane have some difficulty in view of material recycle or reuse so that we think it necessary to modify the chemical composition of membrane. In general, since Nissan has already applied many recycled parts to conventional cars, the same policy is being applied to fuel cell vehicles, too.

Q: I am one of the people who is worried about the safety of hydrogen. Is there any recent improvement in safety measures for hydrogen related system; for example, high pressure hydrogen tanks?

A: The most important thing is to make sure that there is no leakage from high pressure part of the hydrogen system since the molecule size of hydrogen is very small. Thus, hydrogen is dangerous only under pressurized conditions. From this point of view, we designed the hydrogen storage-supply system in such a way that pressure is significantly reduced right after the hydrogen tank so that we can concentrate on only high pressure part; that is the storage tank. This storage tank design has been tested under severe conditions, and has been already proved for safety and reliability.

Q: I would like to make a comment as a researcher in metal hydride storage. From the point of view of hydrogen storage, I think that pressurized hydrogen tanks occupy a large volume of your car design. For storing 7kg of hydrogen in a pressurized tank, one can estimate that approximately 300L is needed. I think that this would limit the capacity of the language space in the car. On the other hand, when metal hydrides are used as hydrogen storage material, the storage volume will be one-third of the pressurized tank volume. Toyota has already demonstrated the metal hydride system on their fuel cell vehicles. Also, a lot of intensive research activities are going on to improve the potential of metal hydrides and more complex systems.
A: I think that many of us would be happy to have you progress in your research.

Timothy E. Lipman

Q: In your analysis presented, what kinds of assumptions are you making in terms of cost?
A: Besides first cost of vehicle, we should care about the life cycle cost of vehicle. It may cost you more up front like a hybrid car, but it saves you more over the time because of its higher efficiency. Our analyses demonstrated that the life cycle economics can be competitive with conventional vehicles even if the first cost is higher. So, I think that it is important to re-educate consumers to consider this life cycle economics. Also, we should consider the air pollution externality from social perspective.

Q: I think that oil companies are the ones to produce hydrogen. If we get to the point where it starts replacing gasoline, would it be more profitable or less profitable for them? Because, I think that would decide whether they would go for or against this idea. How do you see this trade-off for them?
A: As you pointed out, oil production is profitable. As we have seen in this last year, even with the very high oil prices, oil companies made record high profit. Also it really depends on hydrogen production method, natural gas cost and clued oil. I can't give you a complete answer. But according to energy companies, they say "if there will be demand for hydrogen vehicles, they would be there with hydrogen". I believe that they think they can make money on it. But, I do not know how they assume the cost structure for hydrogen.

Q: Is there any hydrogen production being made currently from biomass, winds, solar or any of these alternative techniques?
A: Yes. There are some though they are mainly in demonstration scales. For instance, there is a project in California where a water-electrolysis device was installed besides the wind mills to produce hydrogen. Also, there are quite a lot of activities in Germany with renewable hydrogen production from both solar, wind and biomass. So, there are some but they are not big yet.

Q: The economic modeling seems to be based on the assumption that cars developed for mass market will be replacing gasoline cars. Is there any thought on the existence of niche markets like urban mass transit, taxi cabs in cities and something like that.

A: You can think three applications for niche markets. They are captive market vehicles refueled in the central locations, streetcars and hydrogen buses. Examples are a transit bus demonstration program in Europe, and the London taxis running on hydrogen. Another niche market has been considered is off-road type applications. For farm vehicles, tractors, ground keeping vehicles, compared to diesel engines, fuel cell driven vehicles are being considered as clean engine. John Deere, an American company, is actually doing a lot of works on it. So, fuel cell companies are looking at those markets, too.

Q: What would you start with if you have the power to make decision for this plan?

A: Since the environmental impact of hydrogen energy varies so much depending on how you make it, I would really like to see hydrogen in the context of overall clean energy strategy with the use of renewable energy being encouraged. Without renewable energy, we cannot see the benefit of hydrogen. So, I would start with clean energy strategy that strongly encourages renewable energy production and then fit hydrogen into that system. As a transition strategy, we can consider natural gas distributed production. Producing hydrogen from natural gas is useful for setting up early stage of hydrogen system, but it is not what we need to be as an end.

Q: Can hydrogen be used as fuel for airplane? Also, since there will be a lot of resistance against a new infrastructure and system, what idea do you have for driving the adoption of hybrid vehicles?

A: Because hydrogen is bulky, the on-board storage is the problem for air plane application. There is only a limited effort, but there is an interesting project with application to a self-sustaining satellite-like airplane. The plane will make its own hydrogen from electrolysis with a solar panel on its wing, and store the hydrogen during day and at night it use the hydrogen stored to stay up for a couple of month time. For hybrid vehicle adoption, it is first the cost barrier that is a key for a lot of people. In this respect, if the government could continue to subsidize for some time longer, it would make them attractive for consumers.

Q: For fuel cells, what level of cost and what ability level you are talking about in your analysis? Also, I think that the durability of fuel cells is an important issue.

A: We assumed here is that today's fuel cell cost for stationary power may be three or four thousand dollars per kilowatt, relatively high. The automobile's target is something around fifty to sixty dollars per kilowatt which is incredibly challenging. If we can get the stationary cost come down to several hundred dollars per kilowatt that is when the business model for distributed power generation for fuel cells starts looking attractive. Then, for the durability of fuel cells for stationary, we assumed forty or fifty thousand hours for the base cases.

Q: I think that you showed hydrogen prices in dollars per in GJ. My brain thinks in dollars per kilogram. Do you know roughly what your conversions are?

A: It is about seven to one. There are seven kilograms of hydrogen in a GJ. If hydrogen cost is 20 dollars per GJ that is about three dollars per kilogram.

Q: What would be the incentives associated with government programs? In particular, can you imagine any kind of such program that might work to help the development of these technologies in the state of Michigan?

A: First of all, with regards to the incentives in the state of California, there has been a very intensive effort. That announcement has been made in this April 2004. Since then there are a number of project teams working on gathering a lot of data shifting through it and coming up with cost projection of infrastructure and cost of vehicles for different applications. But there have been no specifics about what type of incentives will be available. In California, due to the major financial crisis, we cannot expect the state to provide enough budget, so we are hoping that there will be the federal government support. Then, I think that Michigan is one of the leading states in the country. They have been setting up an enterprise zone called NEXT Energy where they are giving a tax break to the companies locate there to work on hydrogen and fuel cell development. So, you can look into that Michigan is very aggressive already.

Frank Lomax

Q: How much cost does the purification add to the net cost of hydrogen production?

A: It depends on how big the hydrogen machinery is. For distributed hydrogen production, a reasonable cost for a hydrogen station is in the order of 500,000-600,000 US dollars in any kind of medium level of implementation, for instance 50 to 100 stations. The cost of purification itself is negligible compared to the production cost, but testing can be very expensive. For instance, the cost of on-line mass spectrometer in capital cost, would be 20% of the installation cost plus maintenance. As for the purification technology, these machines are capable of meeting the purification requirement.

Q: I realized that somebody made this stringent standard for purification. How do they measure to follow this, it they do not have it?

A: That is a good question. I do not know. I think that they simply pick the number. Even they admitted that it is impossible to measure the values they set.

Q: I think that the potential of fuel cells seems to be really incredible, but also it seems that it will take at least in next fifteen or twenty yeas down the road before we see any real tangible facts. So, prior to their full implementation, is there any idea fuel cells can be used as the way to avoid dealing with other issues?.

A: Automotive companies are very concerned about proper margins when automotive companies expend 400-500 million dollars a year in. So, I think that their research is extremely serious. In terms of progress, ten years ago, fuel cell vehicles and fuel cells were all a dream in future, but now we are discussing them actually. We have made a huge progress. For codes and standards, if we formulate them now, I think it would be provably 10-15 years from now that they will trip ourselves. Those sort of things become difficult to change even with concerted effort.

Q: I was making analogy between this and water purification. Water comes out absolutely clean out of the station. But most of contamination comes from pipes, water tanks and inside fridge. How much is this the issue for fuel cells? What happens after it leaves the station?

A: Mr.Toukura saw that one of the major issue is the nitrogen diffusing across the membrane of the fuel cells and diluting the hydrogen. We can deliver the hydrogen product with impurity of less than ten ppm. Actual operation of fuel cell might introduce several percents of nitrogen as the result of purging process. I think that the major concern of fuel cell manufacturers is the contaminants that only we introduce, for instance carbon monoxide and sulfur. Because those certainly do not come from air or from vehicles fuel tank. With respect to air gases, most of actual contamination comes from fuel cells itself.

Q: I was certainly intrigued by this idea of having a fuel cell as a purity tracker. Since I think that the degradation of fuel cell is a slow process, how quickly does such sensors detect? Can you explain a little bit more how you think it might work? .

A: The sensitivity is much higher in cold. If you run the fuel cell at an ambient temperature, you will have a thousands fold increase of sensitivity. Also, you could have a sensor, provably easily, by reducing the catalyst loading and reducing the operating temperature. But somebody has to productize that to make it robust and to certify that it is acceptable for verifying hydrogen purities. That is not two dollars.

Q: You mentioned absorbent and filters. Are you saying that there are known technologies and basically we just need to engineer these things right. Is this really an easy?

A: The technology exists to remove most of the targeted impurities. Reactive metals or sol-gel may be most effective but least appetizing for vehicle manufacturers. For cuprous chloride or supported metal amines, those materials are very effective, too. So, it is largely an engineering problem. But also it is the question of whether Ford or Daimler Chrysler wants to put yet one more small component on the vehicle.

Q: I guess when you have to assume on the part of Nissan or Daimler Chrysler to do it in the car, you could lay a requirement for guys making a tank to deliver to the car. You know, could be purified before it leaves the station.

A: But we still need to certify that it is pure.

Q: In the construction industry, solar energy was developed for building installation about 15 years ago. Although solar energy has many advantages, I think that it has not become popular yet. In the light of this, how do you see the future perspective for hydrogen energy?

A: Hydrogen energy has worse track record than solar energy. The fuel cell was first invented in 1838. Even after 170years, it has not been commercialized yet. However, since companies like United Technologies, Nissan, Daimler Chrysler are spending a significant amount of research budget in it, I think they are getting close.

Q: I have read about a fuel cell for laptop computers. Can you comment on it?

A: I think it possible to make a small fuel cell to replace batteries. There are a lot of efforts in developing small scale direct methanol fuel cells or fuel cells with metal hydride storage for devices like calculators, cell phones and laptop computers with the idea of replacing a fuel cartridge less frequently than a battery needs to be. I think there is a lot of promises there, but like any other applications, there is a lot of things to do before meeting the market requirement, in particular, cost. Actually, a Japanese electronics company is working on it. Also, for military application there are a lot of efforts.

Q: From a view point of hydrogen purification, how do you think about liquid hydrogen?

A: Liquid hydrogen cannot meet the target purity, too. Also, hydrogen liquefaction requires 25% of its energy content so that you cannot expect no green house gas benefit for vehicles on liquefied hydrogen.

Q: Is there anyone thinking of applying fuel cells to a human powered airplane?

A: There are some development efforts in replacing a two-stroke engine scooter with a fuel cell driven scooter. We have known no attempt for the application to a human powered airplane.