Tales of Fixing the Tails

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"I don't like this face mask. It looks very ugly on me", rebelled Vedant, a selfie-conscious teen, while having a family evening stroll in the smoggy lawns of IIT Delhi.

"Papa, why everyone walks-with-these-masks", exclaimed Aarav in rhyming style, while jumping in the bandwagon of curiosity with his elder brother.

"Look, my boy", I started to explain, but was cut short immediately by *The* lady of the house, "No technical jargon, please", pleaded the student of literature.

"OK", I promised in order to earn a green nod from my lady. "So, these masks save us from the pollutants present in the air. Vehicles around us exhale many dangerous gases from their tails", I said.

"Oh, like dragons fire from their mouths", wondered the movie buff Aarav.

"Yes, but that will be more fitting for chimneys of factories", I responded.

"Can't we fix these polluting tails and appear again like humans on our evening walks?", was the most difficult question of the day asked by a visibly upset Vedant.

He awakened the researcher inside me and I responded enthusiastically, "Yes, people are trying and I am also playing a part in the solution. My research is focussed on developing materials for alternate power sources that are non-polluting and efficient." I guess, the discussion made their mom conscious and turning around she signalled for concluding the walk and the talk, both. Obviously, we obliged with silent gestures of continuing later.

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On the way back home, I remembered many intense discussions held in our research scholars' room on the delicate situation of our environment. Overdependence of human race on the fossil resources for the survival and the unsustainable growth has nearly depleted the rich coffers of earth, which took millions of years to deposit, within a century. Moreover, our hunger for energy-intensive essentials and comforts of life are severely polluting the air, water and land systems. Till date, the extraction of energy from these non-renewable fossil resources has been very inefficient, like in thermal power plants (roughly 30%) and automobile engines (20-30%). Nuclear and hydro power sources have their own complications, viz, safety concerns and disastrous ecological footprints. Undoubtedly, we need cleaner and efficient sources of power to extend our survival on earth. Solar cells seem to be rising on global scale but they too struggle with their efficiency issues.

Fuel cells and specifically, Solid Oxide Fuel Cells (SOFCs) are among the most promising candidates, which produce power very efficiently (approx 80%) and more importantly, they release only pure water vapours from their tails (exhaust), when run on hydrogen and oxygen. They have been successfully tested on all conventional fuels including gasoline, LPG, coal and biogas and have the added advantage of efficient extraction of power from these fuels as compared to conventional routes.

"So, what you develop in your lab?", thus started the questions of big boy, as we entered in our lobby.

"OK, just settle down and listen", I started to explain the partial intricacy of my graduation journey to our school boys. "You know it well, how much we are dependent on electricity in our daily lives but do you know how much power is lost midway before it reaches our home? It is more than one-third. Even the vehicles around us burn their fuel very inefficiently and worse, we also get life-threatening pollutants like NOx, SOx and particulates from them.

Now, just imagine a power-producing device that has no moving parts, no irritating noises and is thin as a paper of sheet. Interestingly, this compact device have a very clean tail (say exhaust) giving out pure water vapours. And it is not even like your gadget's battery that drains every now and then. As long as you supply it the fuels (say gases), you can generate clean electric power silently. A small suitcase-size unit of it can power our entire house, non-stop. It is called solid oxide fuel cell or SOFC, in short"

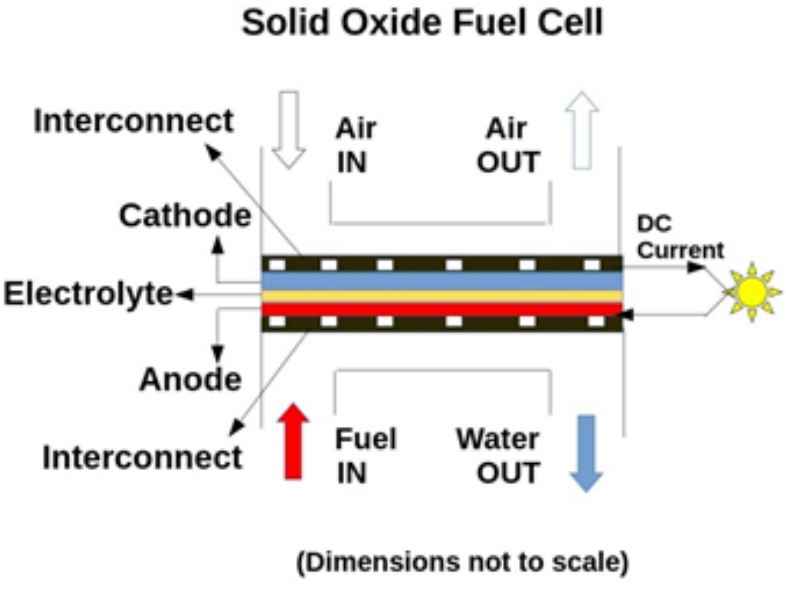
"Oh, is it so?", asked the surprise in his eyes. Vedant continued, "So, is that what you make in your lab?".

"Yes, we do that but partially. I mean, we develop and test the performance of some components of these solid oxide fuel cells", I responded.

My response made him wonder, "Do you mean that this paper-size fuel cell has many components, really?".

"Of course, a single SOFC has a solid electrolyte sandwiched between two electrodes", I told.

"Sandwich! Oh yeah…hhh, my favourite", shouted the younger one, making us laugh with his unwavering attention to catch possibly the only meaningful word that made sense to him.



"Look, this is a rough sketch of SOFC", I drew on a paper, as shown above.

"To get some useful chunk of power, we need many cells because a single cell of one square centimetre area can generate only around 1 watt power. So, another component known as interconnect comes to our aid and depending on the requirement, we join multiple cells using these interconnects. Though, the electrolyte and electrodes of a SOFC are made up of ceramic materials (as they have to transport ions across them), the interconnects can be made using metals also, while operating at lower temperatures."

"What do you mean by lower temperatures?", interrupted Vedant.

"Oh, I forgot to tell you that latest generation of SOFCs operate between 600-800□. Wait wait…, I got your 'why' signal. It is because the chemical reaction, rather the electro-chemical reaction (as it involves electrons), needs that much temperature to take place. Actually, for this reaction, the ions need to be pushed across the reluctant solid electrolyte and thus, that much thermal push is necessary to overcome the ionic distaste of electrolyte.

Thus, single unit of SOFC is a layered structure consisting an interconnect, anode, electrolyte and cathode, as you can see in the drawing. Combination of many such cells is known as the Cell Stack. Now, let me explain about my contribution in this context", I set the pace.

"But papa, do we need some special fuel to run this device", was the confusion of Vedant.

Also, I noticed that the younger one was already zooming in his dreams, so I tranquilised him with little heavier dose, "In ideal case, hydrogen gas on anode and oxygen gas on cathode will yield the maximum power output and pure water vapours from exhaust. But for practical purpose, air can be used at cathode side and many common fuels like biogas, syngas and gasoline can be efficiently utilised on anode side. Extra heat can also be put to use, if the situations demand".

So, as I mentioned earlier, metals can also be used as interconnects. But, they face many restrictions in their selection. In addition to their good electrical conductivity, they must have matching thermal properties with other ceramic components and must be stable in both hydrogen and oxygen environments in such hot condition. My work is related to improve the properties of such metallic interconnects, so that the life and performance of SOFCs stack can be enhanced."

"Hmmm…", he nodded slowly.

"We fabricate specific grade stainless steel alloys and study their degradation behavior under operating conditions of SOFCs. We have developed new and innovative routes to fabricate such alloys. Also, in our lab we test the interaction of these interconnects with cathode materials at high temperatures to look for their compatibility. And I can say that till now the results have been promising at lab scale", I finished so and it was taken as my concluding gesture.

"Yes, I think that much is enough for today. Though, I can't claim to understand everything you said but at least your 'tales of fixing the tails' seem interesting and are definitely part of the solution. I will read more about solid oxide fuel cells and get back to you with more doubts", he hummed slowly and slipped into his bed swiftly.

"You people are still talking. Look at the clock! Switch off guys", commanded the slumberous voice. Lights went off immediately.