December 20, 2019

To: HydroGEN Community

Subject: AWSM Benchmarking Newsletter: 2019 Workshop Summary

The second annual workshop for the HydroGEN benchmarking project was held October 29-30 at the Scottsdale campus of Arizona State University. About 90 people attended, with representation very evenly distributed across the water splitting technology areas. While the workshop was open to international attendees, a specific effort was made to engage at least one international representative for each technology to summarize related initiatives in Europe and encourage communication and awareness. A key goal is to promote and maintain coordination across the field, to minimize duplication of effort, and to avoid the development of conflicting standards, benchmarks, protocols, or roadmaps. Plenary sessions were held each day, which included two international talks.

While the first workshop was more open-ended because it aimed to gather information and prioritize work to be done, the 2019 workshop was more focused around reviewing and finalizing the documents that have been developed in the past year. Breakout sessions for each technology concentrated on protocols as well as a draft roadmap for each technology, which have been drafted to date, and there was one dedicated breakout session for several cross-cutting topics. There were a total of 46 breakout sessions, plus five recap sessions (one for each technology and one for cross-cutting).

Several general themes were noted that apply to multiple technologies.
1) It is essential to make sure that the protocols are easily accessible to the community electronically, through publication or similar means.
2) A “marketing strategy” is also needed to communicate these protocols broadly.
3) At the same time, a mechanism for verifying the methods and providing and incorporating feedback are needed. This is important so that the released protocols can be living documents and not become frozen and unchanging. A concerted, funded effort for protocol validation is strongly encouraged in order to maintain critical momentum.
4) International buy-in and harmonization is also critical as mentioned above.
5) Geographic considerations such as altitude should be taken into account, when selecting standard conditions, to avoid specifying conditions that cannot be met in all labs.
6) Finally, to encourage careful experimental procedures and attention to critical details, it would be helpful to include more of the reasoning for specific steps or parameter settings and related caveats, especially common pitfalls.

Specific themes for each technology area were also identified. For LTE, there was general agreement that porous transport materials are a key area for development. In addition to the base component, corrosion resistant coatings should be developed to allow the use of lower cost materials than titanium. There was also strong agreement that for the alkaline systems, there is a need for consistent anion exchange membrane materials. Some attendees also thought that hydrogen evolution catalysts with low or non-platinum group metal content should have more attention. For the protocols, the same themes above were discussed in terms of leveraging international efforts to reduce duplication and conflicting protocols and including the technical rationale for prescribed test conditions and parameters. Similarly, it was recommended to include guidance on specific areas to prevent known errors in testing.

Finally, for new protocols, accelerated testing and standards for post-mortem analyses were discussed as priorities.

The HTE breakout session discussed cell components and testing approaches and the need to move towards device testing in order to better understand materials performance and degradation under realistic operating conditions and realistic steam utilizations. There was strong agreement that scaling cell size up should become a priority. For solid oxide electrolyzes, performance maps and TEA mapping and operating boundaries were discussed, and a strategy for choosing operating parameters was suggested. The consensus was that proton conductors are at a very early stage with many unknowns; for proton conducting cells the faradaic efficiency must always be measured and reported. For protocol development, the focus would remain both on materials characterization and button and large cell testing. In addition, protocols on durability testing, cycling testing, thermal and mechanical stress testing are urgently needed. Accelerated stress testing was agreed to be important, but would require a high throughput testing system and a good understanding of each degradation mechanism.

For PEC, there was a lot of discussion on the technology roadmap in terms of its timeline, connection to protocols and the need for separating roadmaps for established materials vs. emerging materials. As a result, a PEC Roadmap team was established to meet regularly to further develop the roadmap. There was general agreement that device stability and scalability are the bottleneck for the technology, and protocols related to these areas should be in the priority list. In addition, scaling studies should also inform/guide materials processing pathways & component performance criteria. It was recognized that many PEC protocols relate to basic materials properties were well established in the community and can be implemented into the SOP format for easy use. Protocols relate to real world conditions, such as varying illumination, temperature and low concentrated sunlight conditions were identified as gaps. It was recommended to leverage and bridge with LTE specifically on membrane and catalyst related testing protocols, but also recognized that membrane and catalyst stability testing should include illumination and diurnal cycles for PEC. There was also general agreement that advanced spatially resolved techniques, such as pH imaging, are important and there is opportunities to leverage beam-line facilities for new techniques and advanced measurements.

For Solar thermochemical hydrogen (STCH) there were discussions about metrics, standards (beyond the state-of-the-art ceria), measuring the thermodynamics of the redox active material, measuring kinetics, efficiency calculations, durability, and the role and challenges for materials discovery using Density Functional Theory (DFT). Those discussion focused on draft protocols and what will be required before the protocols can be expected to be publication ready. In addition, there were breakout discussions about a high level roadmap for materials, for reactors and systems, and for ancillary components. It was agreed that there is still no consensus on optimal operating conditions or how to achieve them and as a result, moving from a material to efficiency to cost remains a difficult challenge for the community.

A full report on the workshop is being prepared and will be made available to the community. A survey of the workshop has been conducted, similar to last year. The team found this feedback highly valuable last year and plans to follow up on actions developed during the recent workshop and through the survey. Questions were included on how participants hope to be involved in this effort. To date we have had many researchers contribute to this project, which is critical to its success, and brings recognition and important scientific advancement to the community. We appreciate these efforts and highly encourage anyone interested in contributing to contact the PI for their technology listed below to find out more on how to be involved (emails also listed below).

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