



# Electrogenerative Reactors for Process Intensified Cogeneration of Power and Liquid Fuel from Shale Gas

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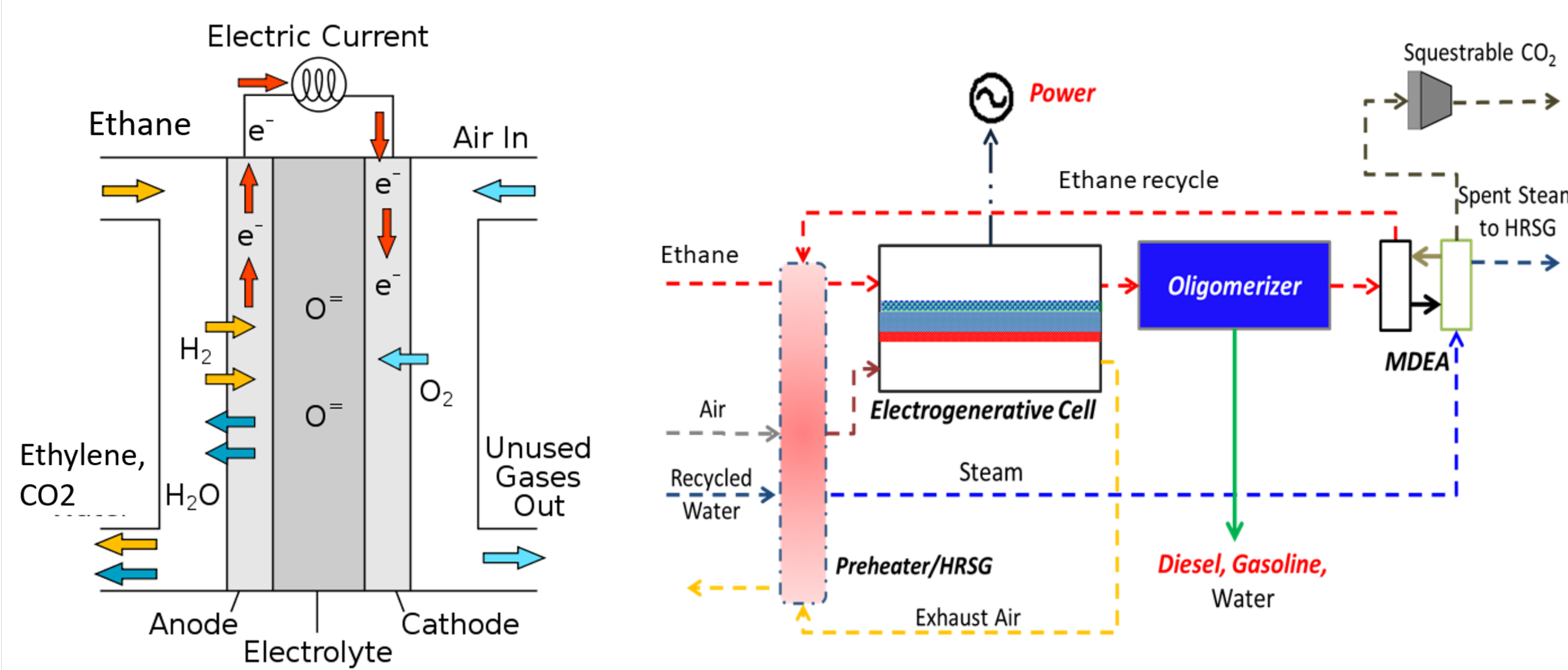
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## PROJECT OVERVIEW

New technology advances in horizontal drilling and hydraulic fracturing leads to shale gas production in U.S. to significantly increased. Much of the growth in the shale gas has been in “wet” gas, gas that contains significant amount of ethane, propane and other condensable liquids. West Virginia University and EcoCatalytic Technologies, are developing modular solid oxide fuel cell-based electrochemical reactors for the conversion of wet natural gas, specifically ethane, to liquid fuels and electrical power, to enable:

- Lowering the cost of the reactors.
- Elimination of need for oxygen separation compared to current gas to liquid facility.
- Cheaper maintenance
- Longer service life

## NEW APPROACH



Process flow diagram demonstrating that ethane and air are separate in the electrogenerative cell to produce olefins for oligomerization to diesel, gasoline and water. This can be incorporated in a typical with a heat recovery steam generator(HRS) and amine gas treatment/acid gas removal system such as methyldiethanolamine(MDEA).

## Metal oxide MIEC anode materials (WVU)

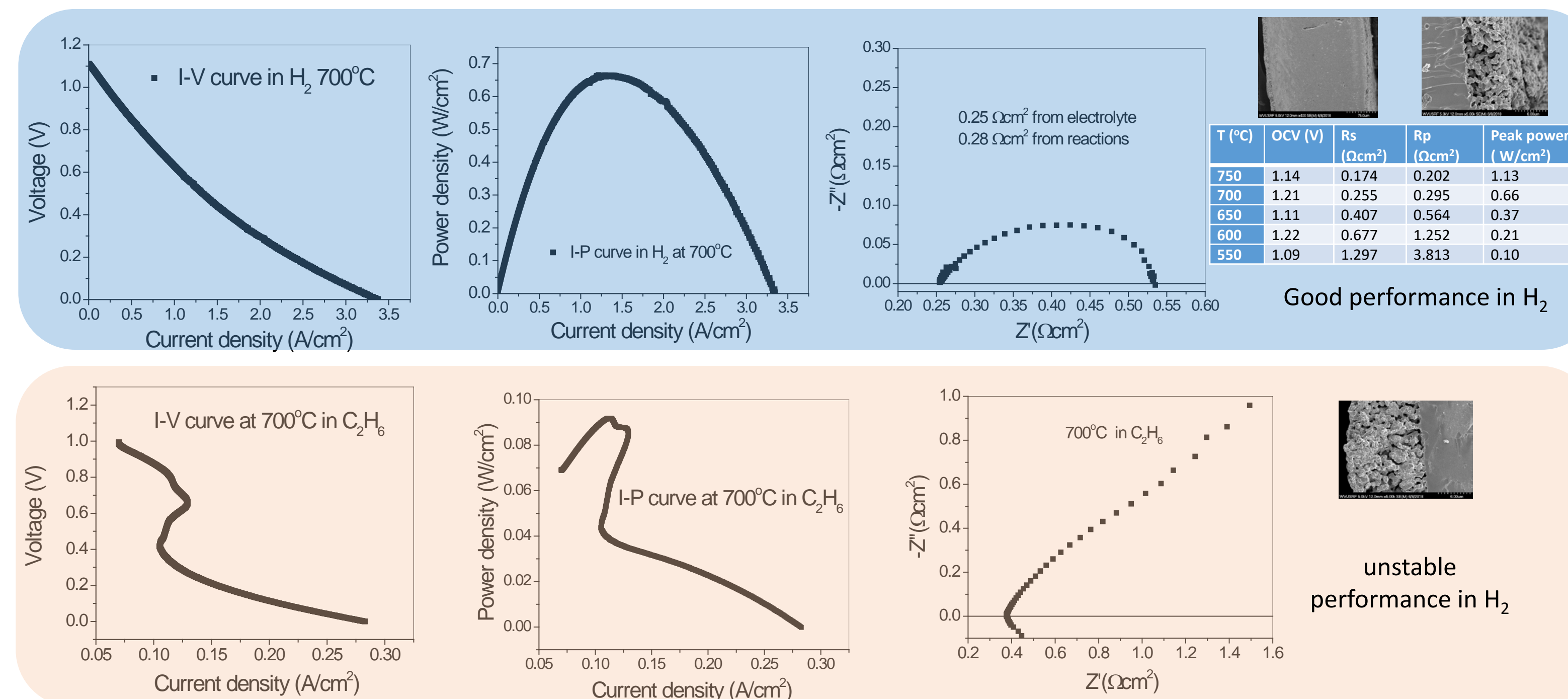
- Coking-resistance to operate in ethane
- Fast oxygen conducting to support oxidative dehydrogenation.
- H<sub>2</sub>-oxidation preference to generate power and retain olefins production

## Oxidative dehydrogenation (ODH) catalyst (EcoCatalytic)

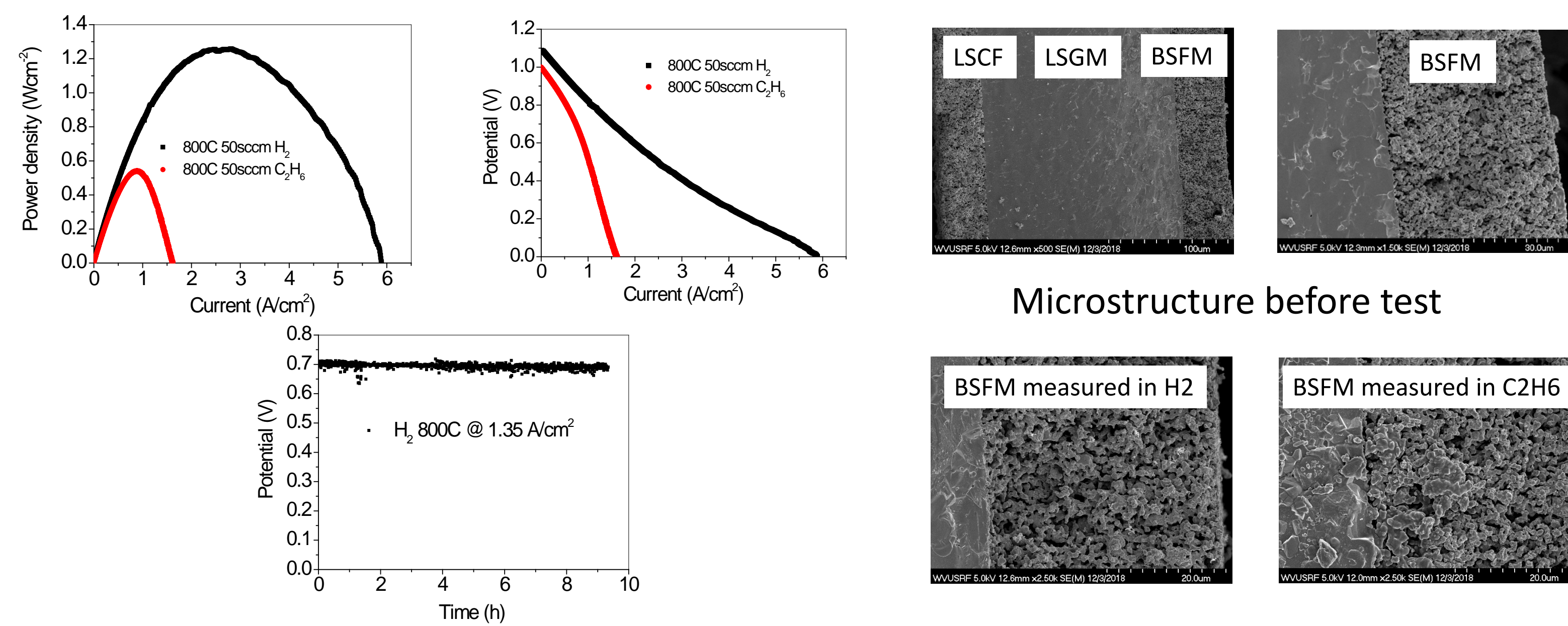
- High selectivity to desired olefins (ethylene or higher C<sub>2</sub>+)
- Tolerance to poisons from the impurity

## MIEC ANODE DEVELOPMENT

Pr<sub>0.5</sub>Ba<sub>0.5</sub>Co<sub>0.2</sub>Fe<sub>0.8</sub>O<sub>3-δ</sub> baseline MIEC



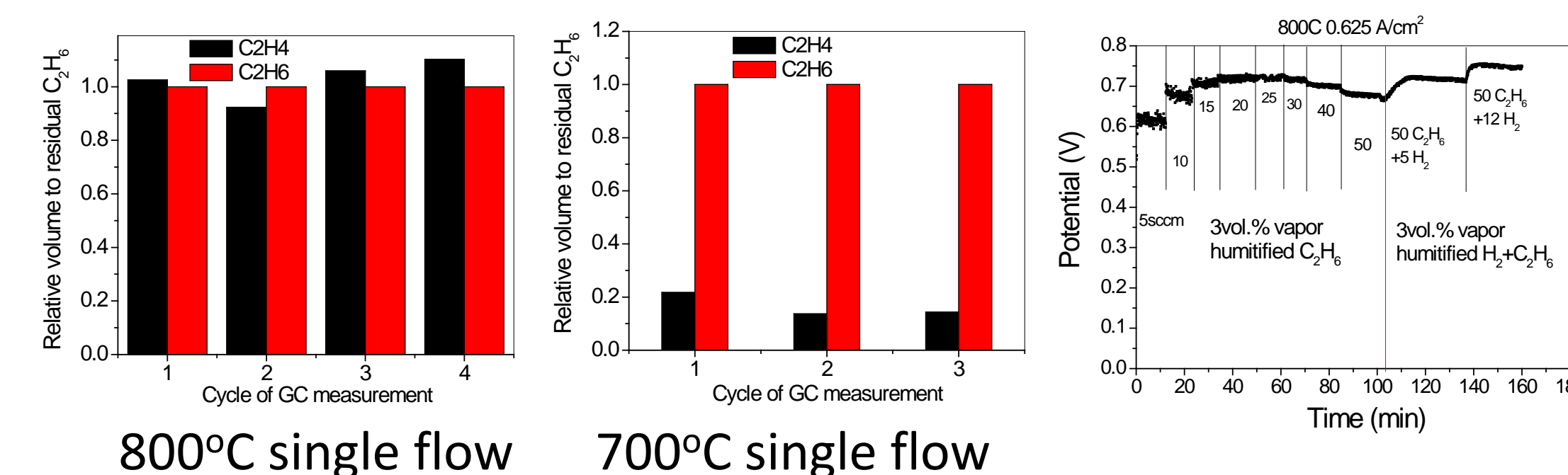
Newly developed Ba<sub>0.95</sub>Sr<sub>0.95</sub>Fe<sub>1.8</sub>Mo<sub>0.2</sub>O<sub>6-δ</sub> (BSFM) MIEC



No coking, no decomposition

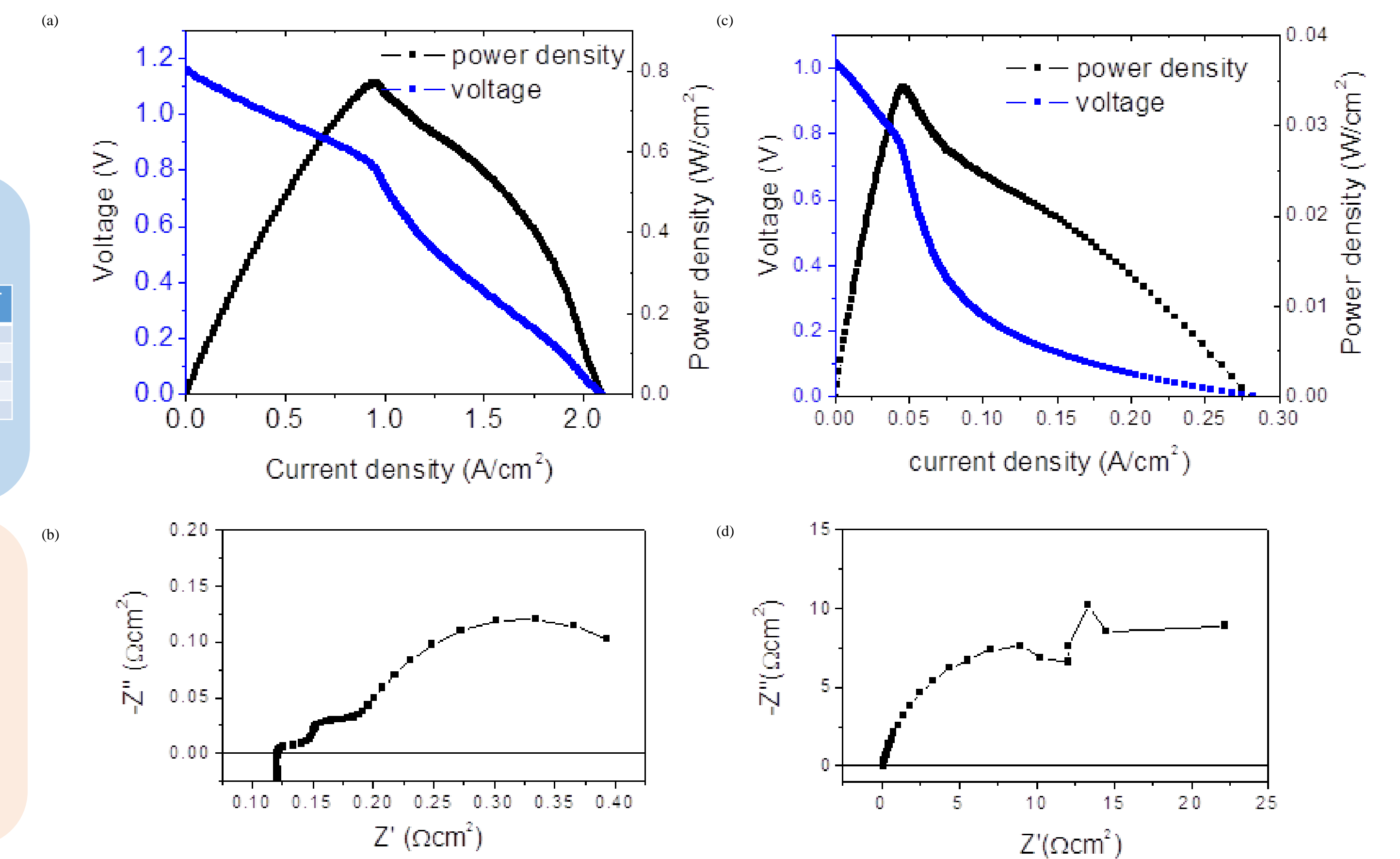
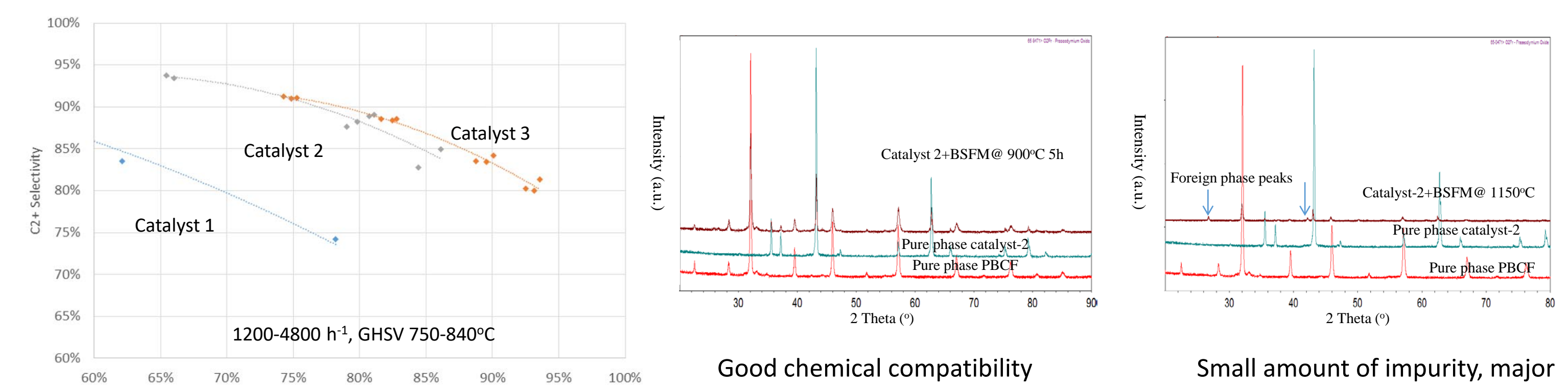
- Excellent electrochemical oxidation performance towards H<sub>2</sub>
- Low performance towards hydrocarbon oxidation
- Fragment activation process

Consume H<sub>2</sub> for power generation, retain C<sub>2</sub>H<sub>6</sub> for olefin production  
 Varying temperature can adjust the oxidation preference of H<sub>2</sub> and HC

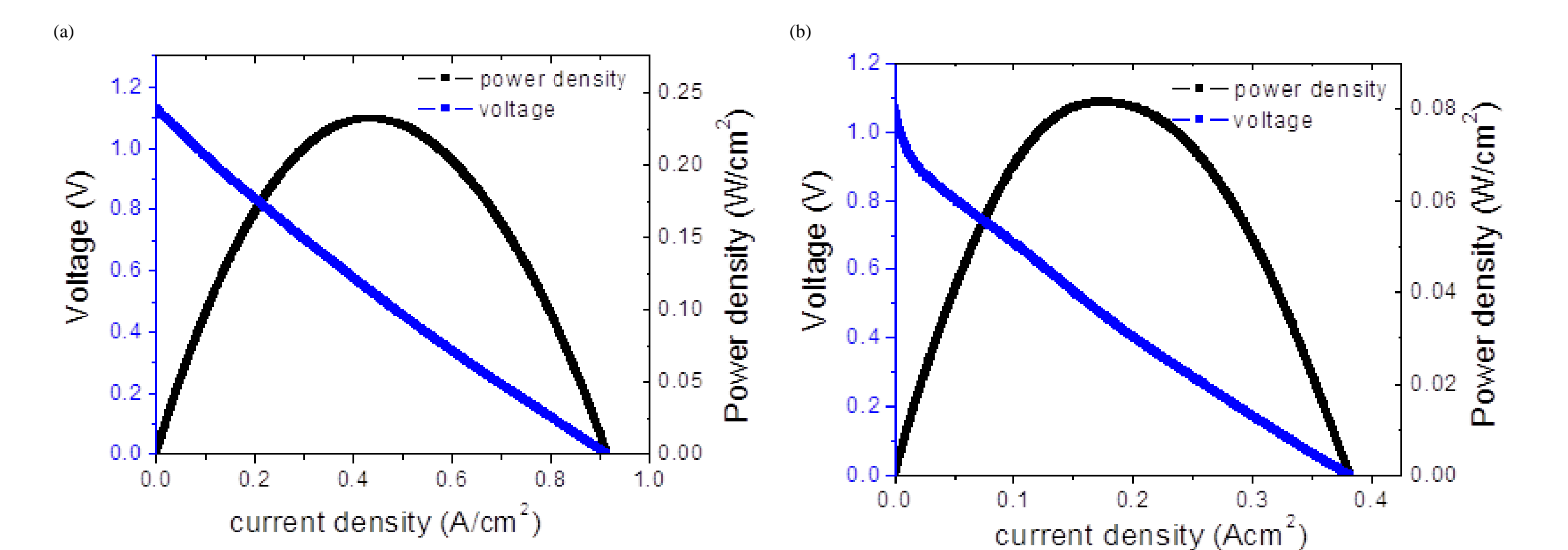


- ❖ More than half C<sub>2</sub>H<sub>6</sub> is converted to C<sub>2</sub>H<sub>4</sub> by a single pass through MIEC.
- ❖ Lowering temperature to 700°C reduces the conversion rate substantially.
- ❖ Pyrolysis of C<sub>2</sub>H<sub>6</sub> provides H<sub>2</sub> for power generation, lower temperature leads to largely decreased performance and high apparent activation energy.
- ❖ ODH catalyst is needed to promote conversion rate at low temperature

## ODH CATALYST LOADED CELLS

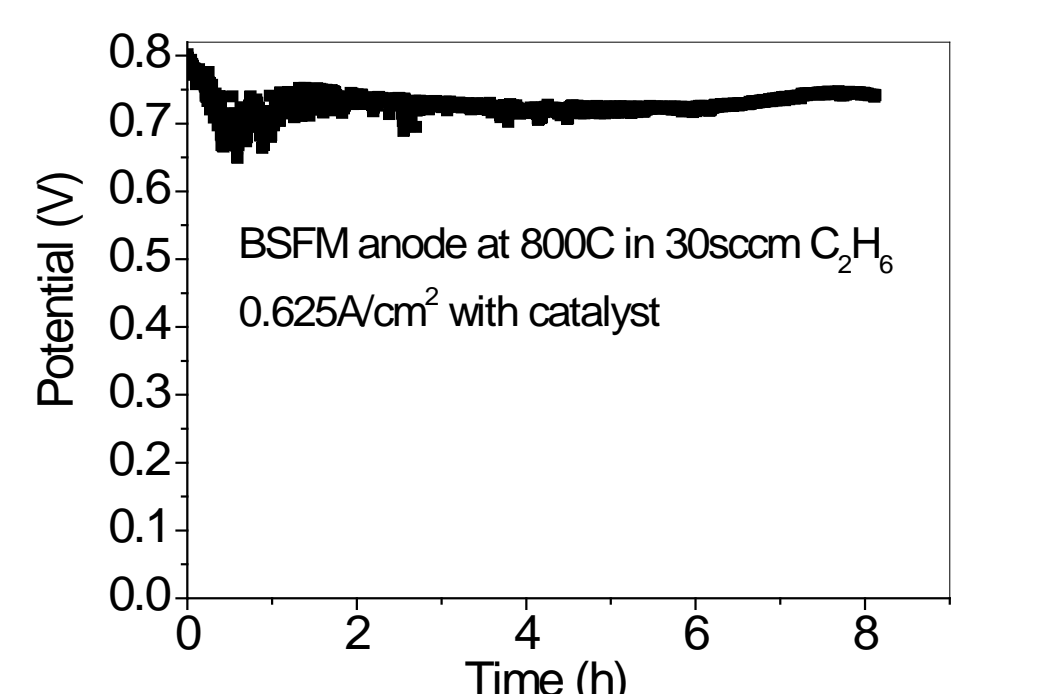


Performance of BSFM anode in (a, b) H<sub>2</sub> and (c, d) C<sub>2</sub>H<sub>6</sub> at 700°C loaded with ~8 wt.% catalyst-2 through nitrate infiltration.



Performance of BSFM&catalyst-1 co-sintered mixture anode at 1100°C in (a) H<sub>2</sub> and (b) C<sub>2</sub>H<sub>6</sub> at 700°C.

Sample	Power density (mW/cm <sup>2</sup> )	OCV (V)
H <sub>2</sub>	Pristine	420
	Infiltrated	770
	Co-sintered	230
C <sub>2</sub> H <sub>6</sub>	pristine	20
	Infiltrated	34
	Co-sintered	80



## CONCLUSION

- Excellent ODH candidates were developed by EcoCatalytic, yield C<sub>2</sub>+ selectivities in excess of 90% with over 75% ethane conversion.
- Two perovskites PBCF and BSFM were examined as MIEC anode. Excellent performance in H<sub>2</sub> was obtained in both recipes, power density as high as 1.26 W/cm<sup>2</sup> at 800°C.
- Two strategies, nitrate infiltration and powder physical mixing, were carried out to load the catalyst-2 to the BSFM anode. Both methods improved the performance in C<sub>2</sub>H<sub>6</sub> operation. The infiltration method limited the maximum loading to only ~8 wt.% to this pre-established BSFM backbone. Due to the access to oxygen in this interconnected BSFM-catalyst-2 network, the co-sintered sample improved the performance in C<sub>2</sub>H<sub>6</sub> 4 times, proving the effectiveness of such electrode structure.
- To further improve the performance towards power, liquid fuel cogeneration from C<sub>2</sub>H<sub>6</sub>, the microstructure and the composition of the BSFM-LMMO co-