Solid oxide fuel cell, Heat engines Dw204

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Efficient Energy Conversion

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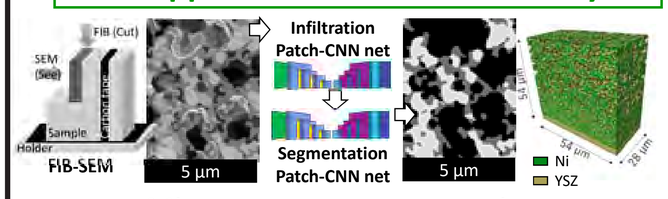
Electrode Microstructures of Solid Oxide Fuel Cell (SOFC) & Electrolysis Cell (SOEC)

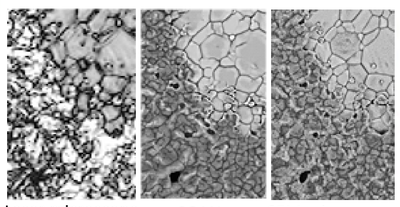
Electrode microstructures strongly affects the performance and reliability of solid oxide fuel cells (SOFCs) and electrolysis cells (SOECs). Machine learning, e.g. CNN, CGAN, UNIT, LSTM, PINN etc., as well as numerical simulations such as lattice Boltzmann, phase field, kinetic Monte Carlo and discrete element methods are developed to optimize the characteristics of the electrodes from initial powder to long time operation. Three dimensional microstructures reconstruction by FIB-SEM and operando observations play inevitable role for understanding the phenomena and model validation.

Machine learning in SOFC research

ML-supported microstructure analysis

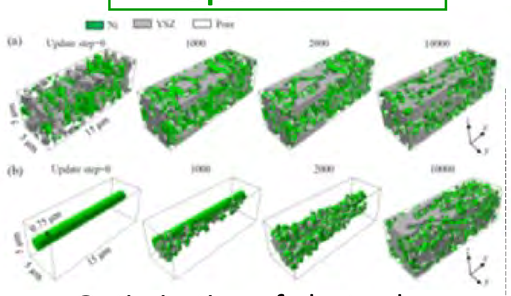


Microstructure segmentation



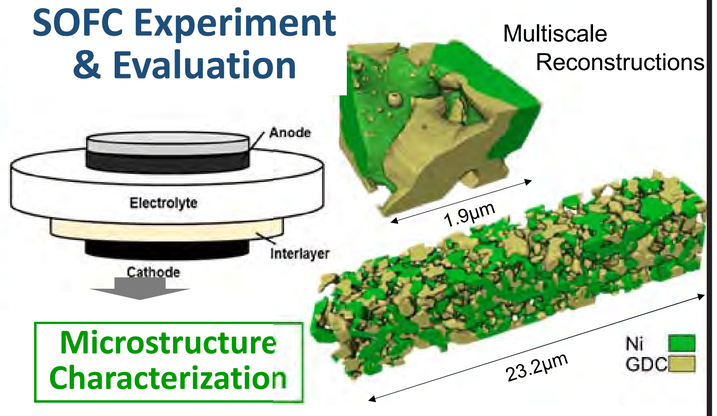
CGAN super resolution

Optimization



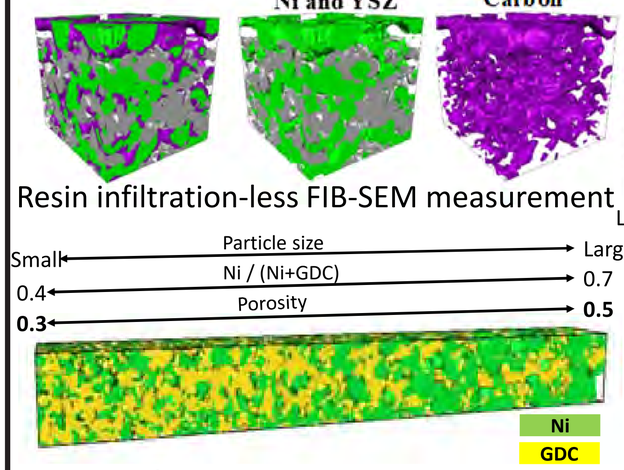
Optimization of electrode microstructure by adjoint method

SOFC Experiment & Evaluation



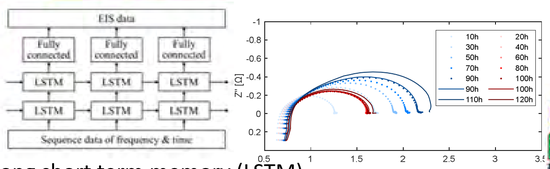
Microstructure Characterization

Quantitative characterization of electrode microstructures using focused ion beam scanning electron microscope (FIB-SEM)



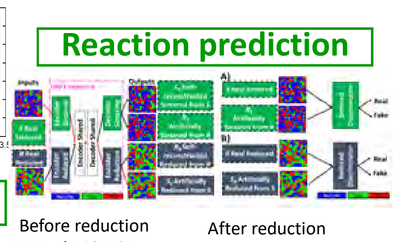
Resin infiltration-less FIB-SEM measurement

Degradation prediction



Long short term memory (LSTM)

Reaction prediction

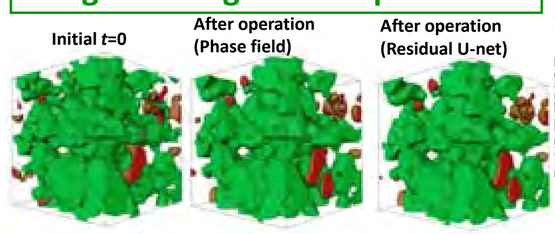


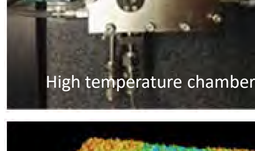
Before reduction Real NiO-YSZ
After reduction UNIT Ni-YSZ
After reduction Real Ni-YSZ

Unsupervised image-to-image translation (UNIT) prediction of NiO→Ni reduction.

3D synthetic microstructure generation by CGAN

Long-time degradation prediction





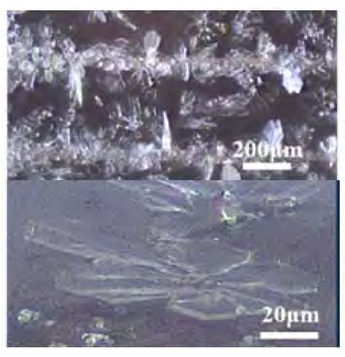
Operando observation of patterned Ni-GDC electrodes under real operation.

R&D on Heat Pumps & Heat Engines

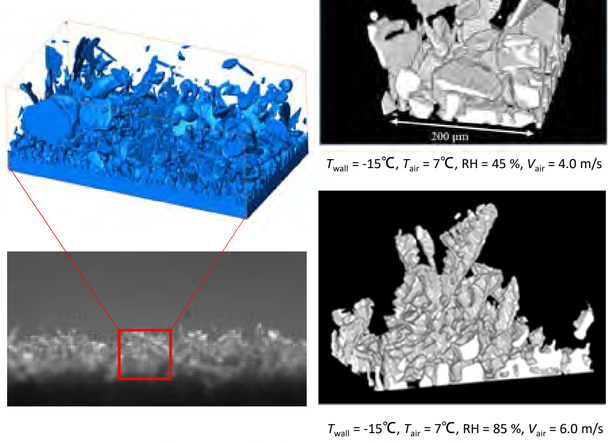
Efficient utilization of thermal energy is becoming even more important in the energy demand side. In order to reduce exergy loss, heat cycles which operate at small temperature difference, and component technologies such as efficient heat exchangers and gas-liquid separators are developed under collaboration with industry partners.

- Novel steam/refrigerant cycles (2 phase expansion/compression, Lorenz cycle)
- 3D measurement of frost microstructure
- Heat exchangers and gas-liquid separators, etc.

Vibration-free two phase expander



Planar frost growing on AgI pattern

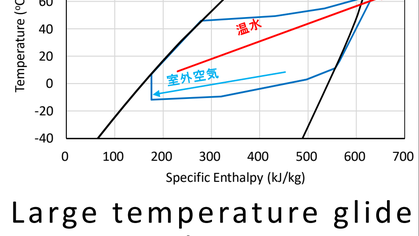


T_{wall} = -15℃, T_{air} = 7℃, RH = 45 %, V_{air} = 4.0 m/s

T_{wall} = -15℃, T_{air} = 7℃, RH = 85 %, V_{air} = 6.0 m/s

Reconstruction of frost 3D microstructure

High performance anti-scale V-fins



Large temperature glide Lorenz heat pump

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