Simulations and Measurements of the Thermal Behavior of an Electrochemical Cell

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Long Range Goal:

Reproduce, Control, Understand and Exploit
Lattice Enabled Nuclear Reactions

Short Range Goal:

Reproduce, Control, Understand and Exploit
LENR Experiments

Methodology:

Quantitative assessment of the energetics of experiments
by use of both measurements and simulations
and comparisons between the two.

1 + 1 = 3

Experiments:

Can give reality, but we measure temperatures only in the center of the cell.

Simulations:

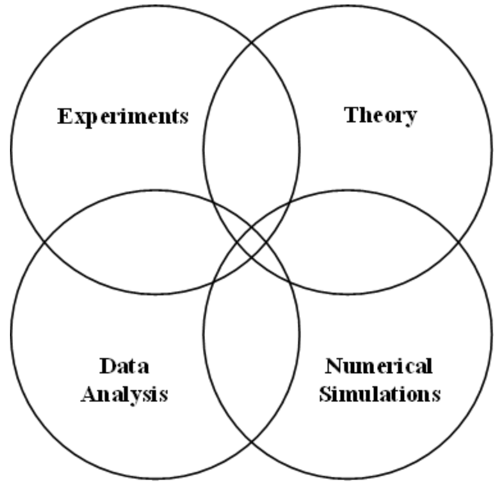
Can be wrong due to many reasons, including
inadequate equations, wrong parameters, poor algorithms, inadequate codes, etc.
However, simulations give temperatures at all points in space and time.
And, simulations give the dynamics of energy production and redistribution.

Significant Issue:

Calibration and Validation of the Simulations.
Calibration by comparison of simulations with measurements ,
and subsequent adjustment of the simulations, is valuable,
but it removes the desirable independence.
Validation is done by comparison of
other simulation results with other measurements,
independent of the calibrations.

The above can be very similar to the training of neural networks
for Deep Learning analyses of large data sets.

Outline



Simulations of LENR Experiments.

Experimental Arrangement

Experimental Results

Simulation Tools

Geometrical Design

Materials and Properties

Mesh Type and Size

Electric Fields and Currents

Electric Field and Current Density Results

Heat Production and Redistribution

Temperature Distribution Results

Parametric Variations

Comparison of Simulations & Measurements

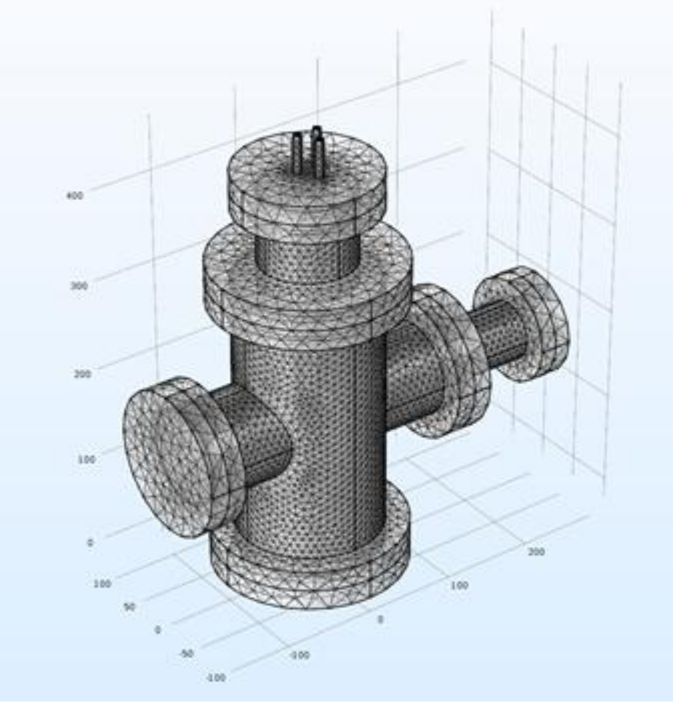
Conclusion

Simulations of LENR Experiments

Despite the value of simulations of experiments, they are rare in our field.

There are various software packages that can be used for multi-physics simulations of LENR experiments.

Simulations are challenging due to the complex software and the need for many input parameters.

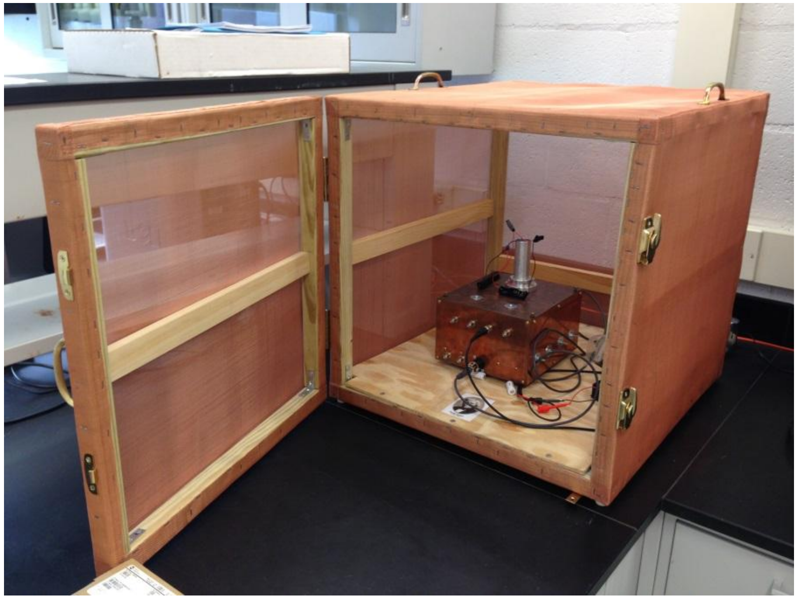


Meshing of the experimental chamber at Tohoku University.

GWU LENR Energy and Spectroscopy Laboratory

General View of 20 by 14 foot laboratory

Filtered Hood and BioLogic SP-300 System (Blue Box)



Faraday Cage for RF and Noise Spectroscopy

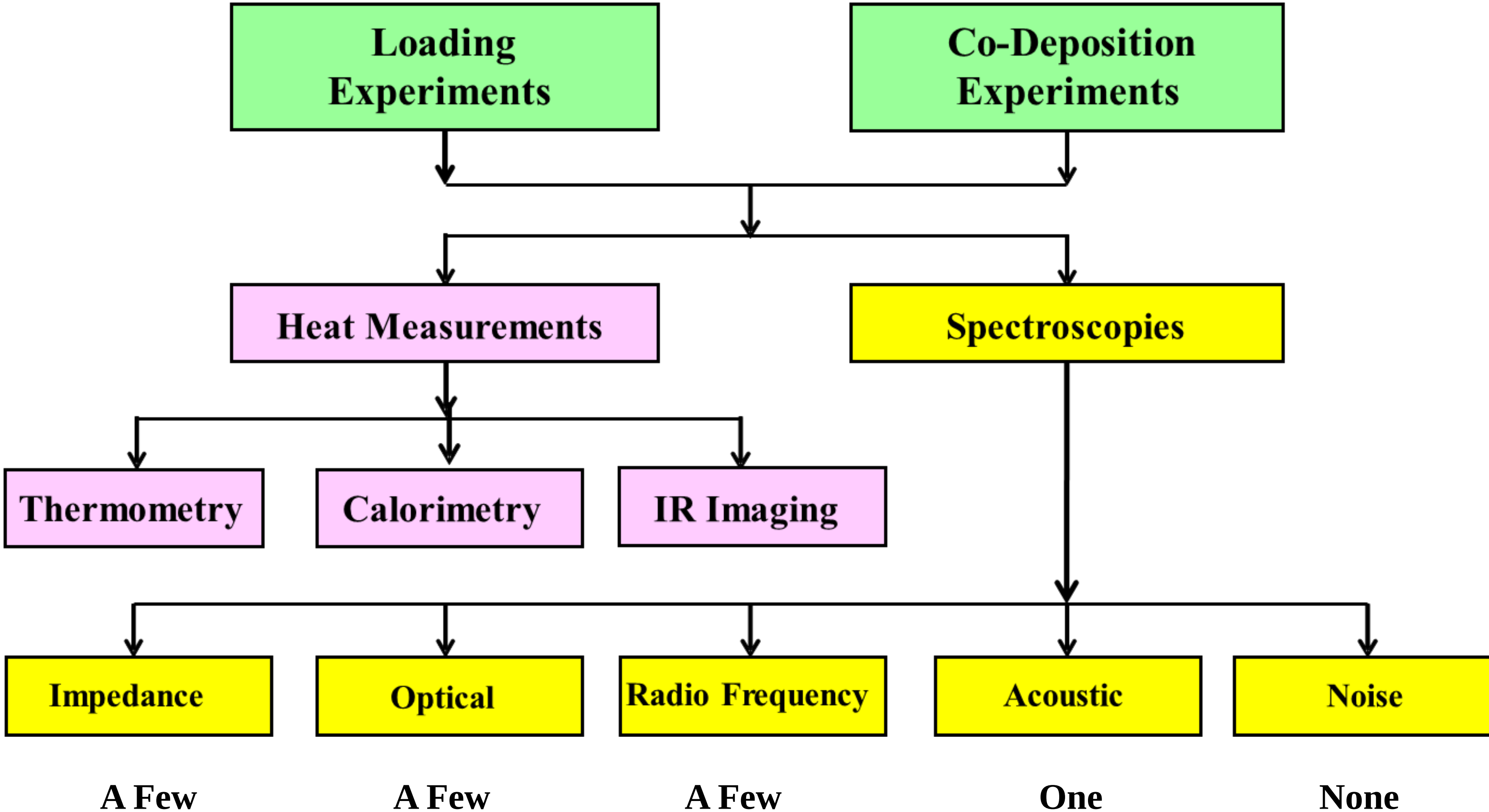
Light-Tight Box for Optical Emission Experiments

GWU Strategy for Experimental Replication

	Electrochemical Loading	Gas Loading
D and Pd	Original Method: Scientific Research	Some Early Work: Continuing Research
H and Ni	Some Early Work: **Current GWU Program**	Early Method: Being Commercialized

Received relatively little attention after early 1990s.
Materials are less expensive than Pd-based experiments.
Many diagnostic tools available for electrochemical experiments.

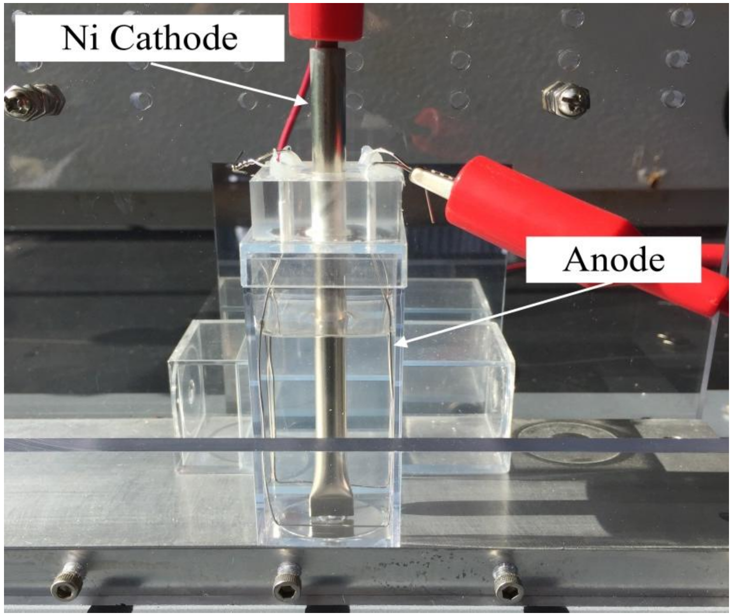
Experiments and Tools in the GWU LENR Laboratory



Currently, we are using thermometry, and
will switch to calorimetry, if our data indicate that we have achieved heat production.

While the eventual goal is to understand LENR,
the first target is to understand our experiments quantitatively.

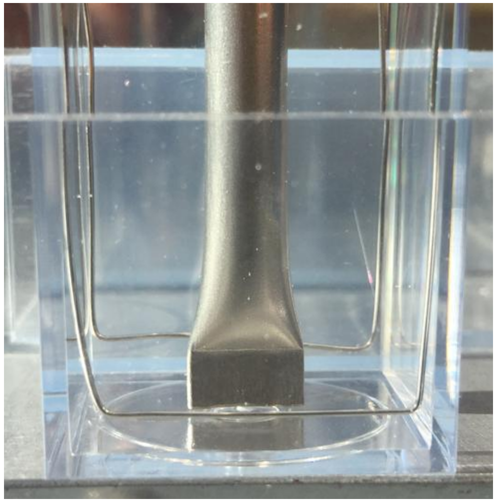
Experimental Arrangement



Cathode is a 99.5% pure nickel **tube**
6.5 mm OD with a wall thickness of 0.5 mm
bought from Goodfellow in the UK.

Anode is a 0.51 mm diameter Pt wire
located in all four corners of the cell.

Cell is Poly(methyl methacrylate) container
26 mm square and 62 mm high (inside)
with 35 ml of electrolyte from TAP Plastics.



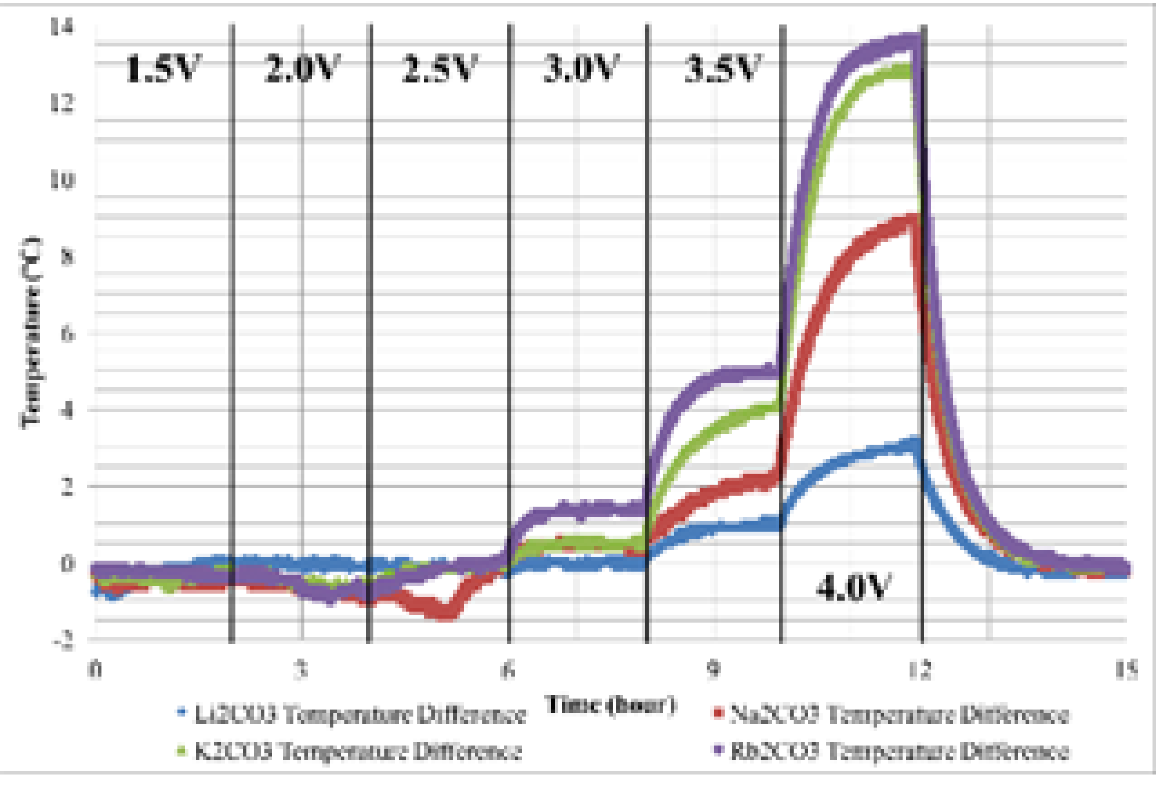
Electrolytes are all carbonates, as in the 1991-3 papers.

Electrolyte	Molarity	Early Papers
Li_2CO_3	0.08 M limited by solubility	Not used
Na_2CO_3	0.5 M	No Excess heat
K_2CO_3	0.5 M	Excess Heat
Rb_2CO_3	0.5 M	Excess Heat

Voltages of 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0. V
are applied to the cells

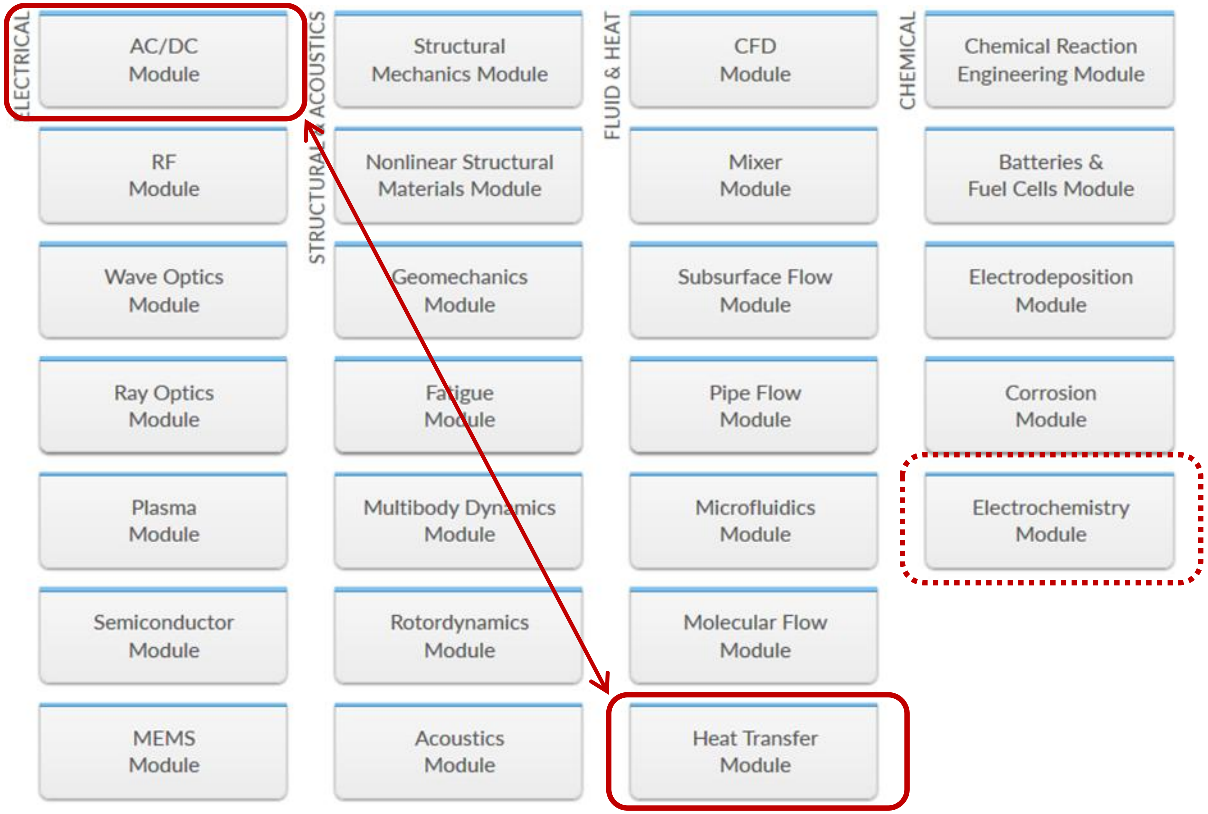
Experimental Resistive Heating Results

Temperature in Center of Cathode minus the air temperature



Only higher voltages give clear temperature differences.
Heavier ions give more resistive heating.
K_2CO_3 and Rb_2CO_3 give similar results.
Time constants are on the order of half an hour
Maximum temperature rises are 14 ^oC

COMSOL Simulation Tools: Multi-Physics and Self-Consistent

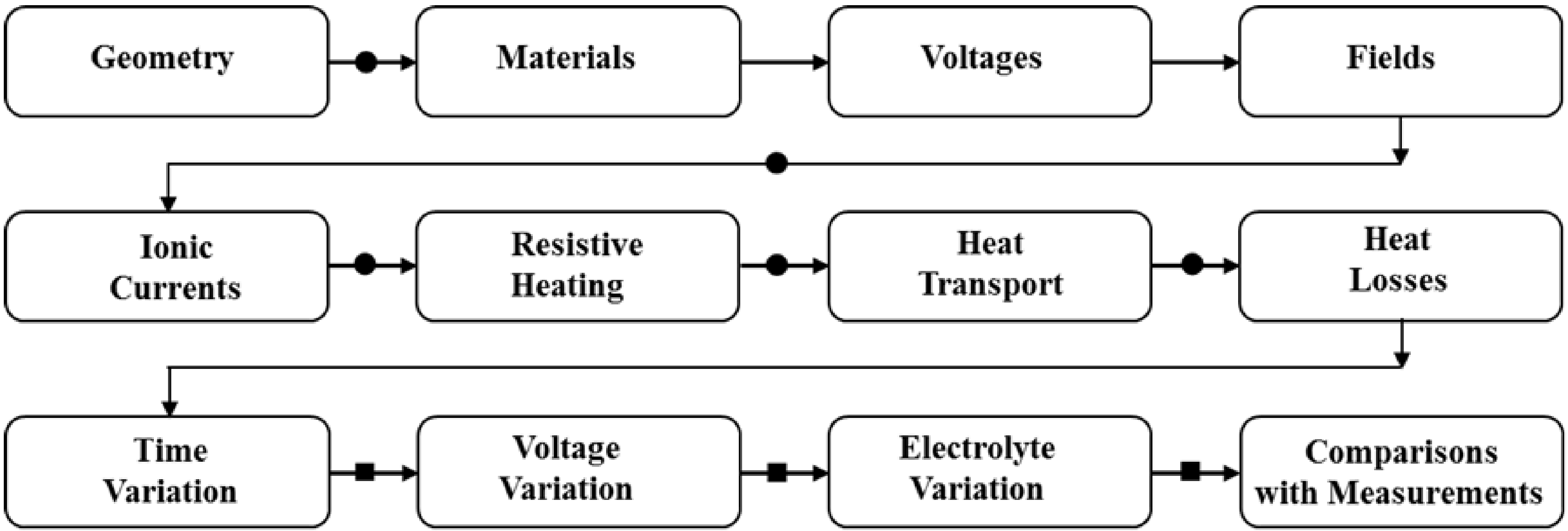


https://www.comsol.com/

Steps in Doing and Using Simulations

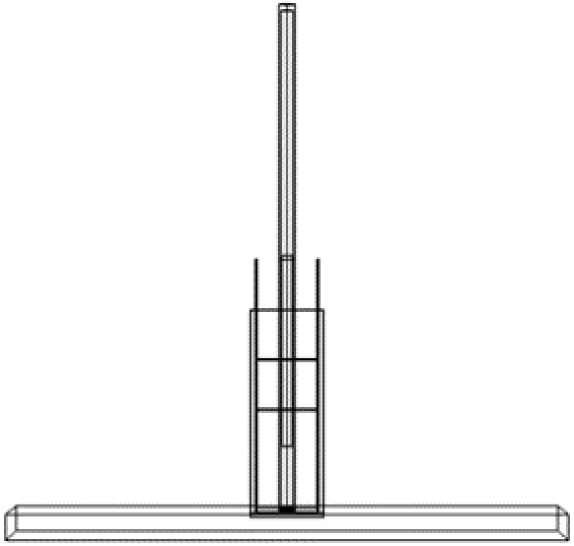
Flow diagram and outputs of the COMSOL simulation,

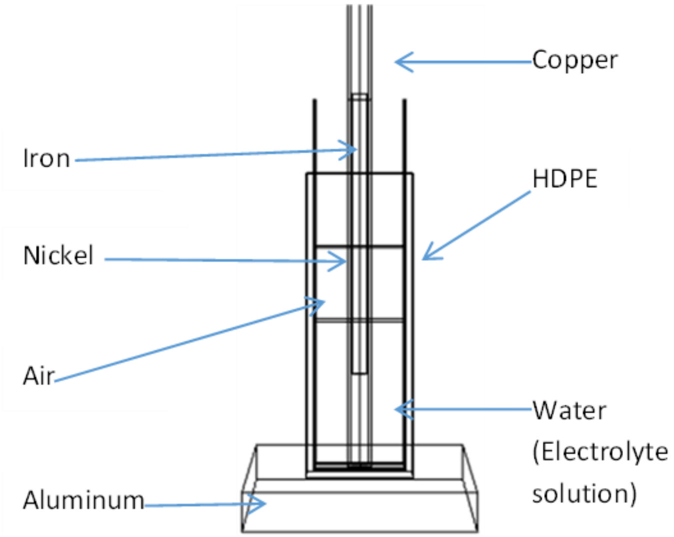
where circles indicate graphical images and squares indicate plots.



Goal is to simulate electrostatic fields, electrical currents, power dissipation and thermal redistribution in Space and Time

Geometrical Design, Materials and Properties

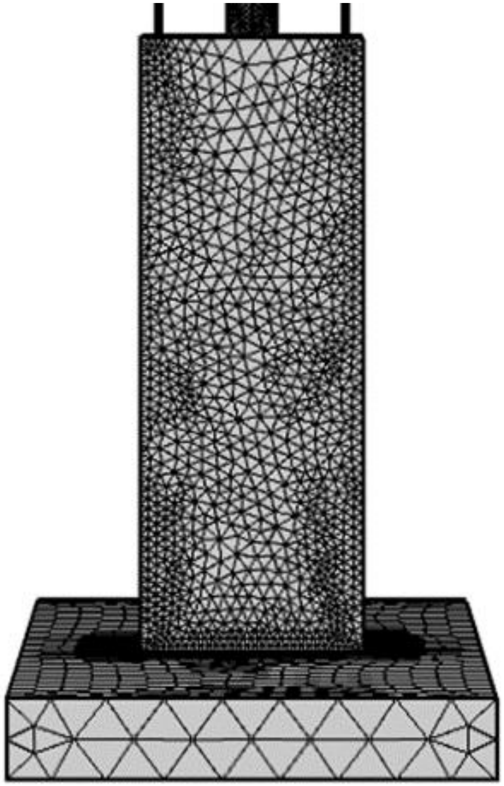


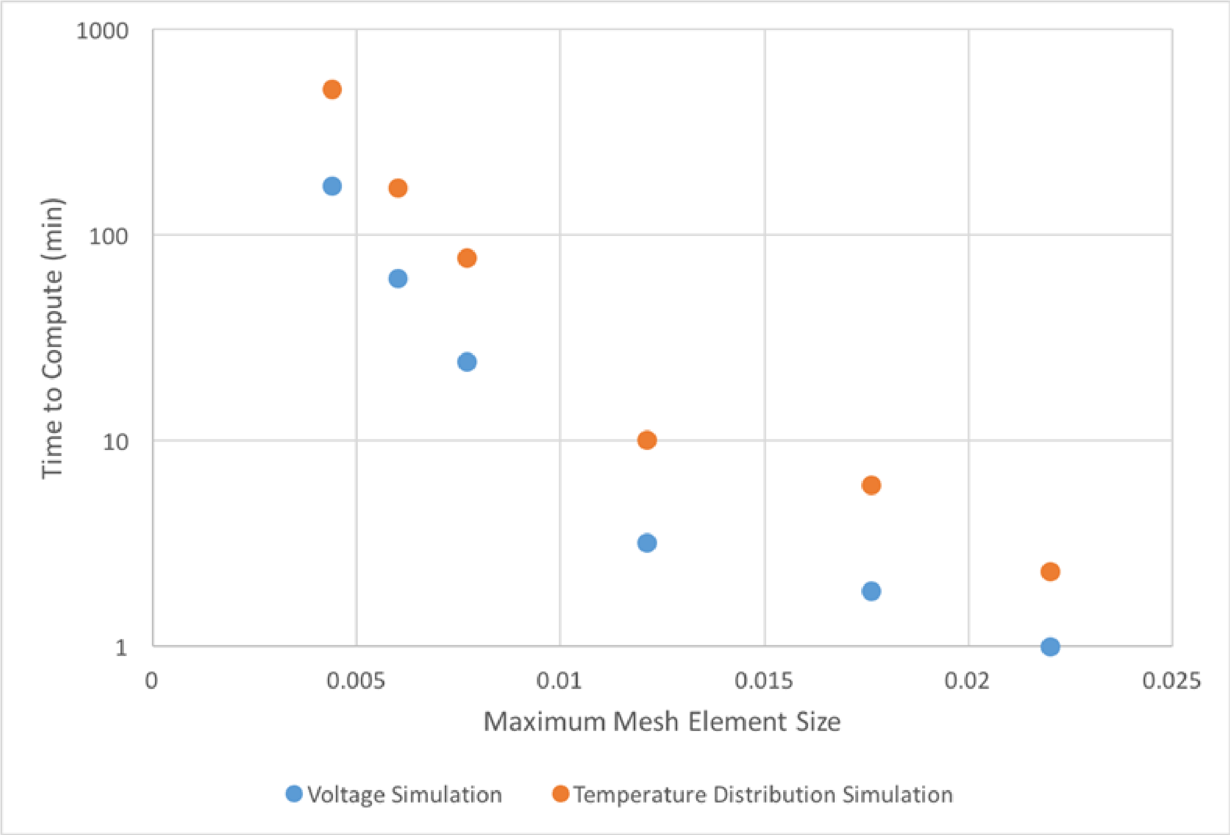


	Heat Capacity [J/(kg*K)]	Density [kg/m^3]	Thermal Conductivity [W/(mK)]
Nickel	445	8900	90.7
Platinum	133	21450	71.6
Aluminum	900	2700	238
HD Polyethylene	2400	0.96	0.49
Iron	440	7870	76.2
Copper	384	8960	401

	Ratio of Specific Heats	Electrical Conductivity [S/m]	Relative Permittivit y
Li_2CO_3	1.0	0.86	75
Na_2CO_3	1.0	4.7	75
K_2CO_3	1.0	7.37	75
Rb_2CO_3	1.0	7.61	75

Mesh Type, Size and Run Times

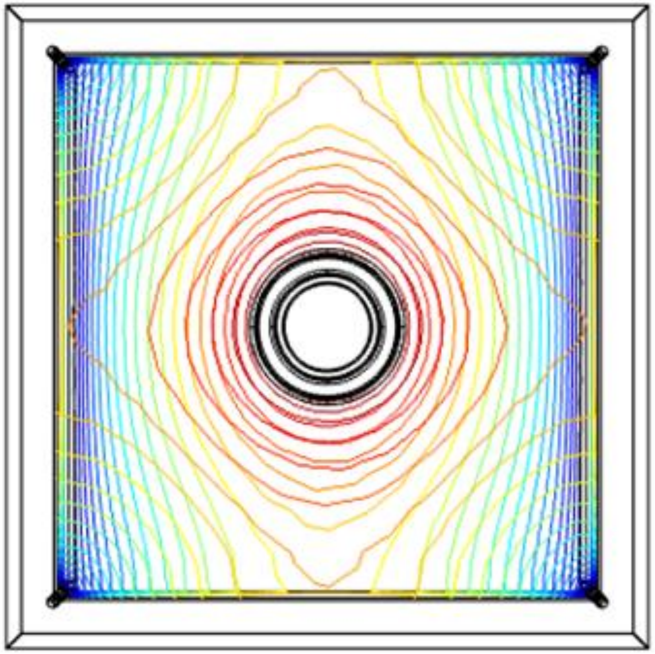




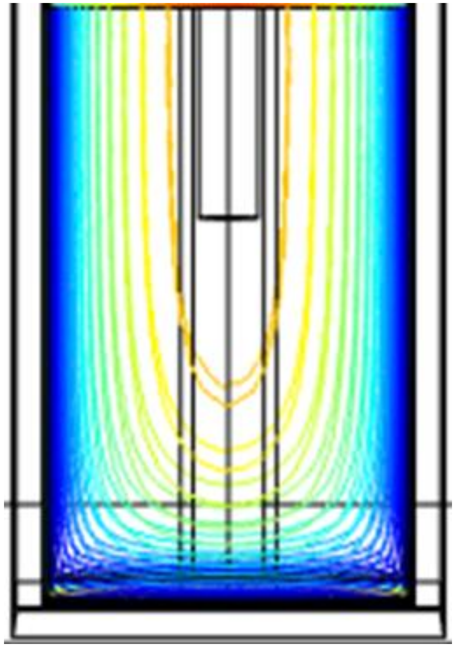
Even for large meshes, time is needed to achieve iterative self consistency

Voltage Distributions

Contour maps of voltage distribution for Na_2CO_3 with 2.5 V applied

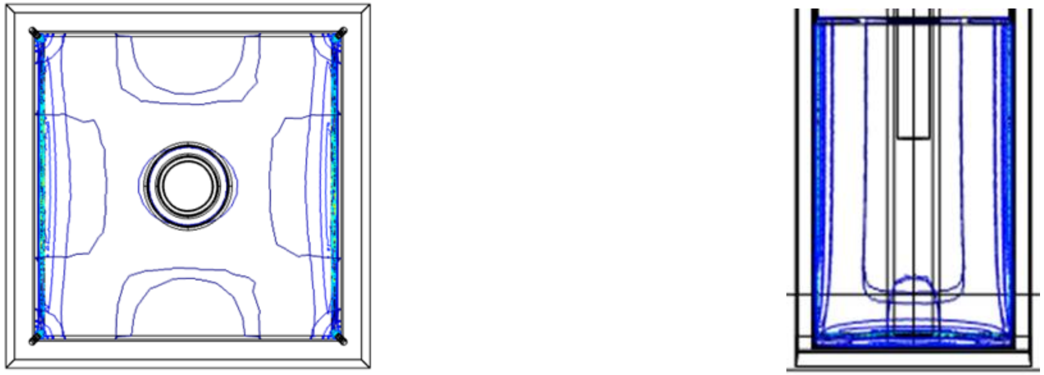


The distribution of voltages
near the cathode is nicely circular

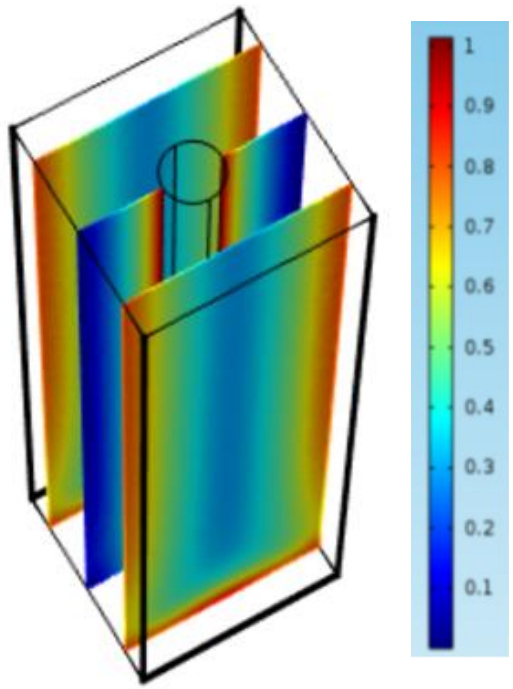


The distribution of voltages
is non-uniform near the bottom of the cathode

Electric Field and Current Density Results



Top and Side views of the electric field contours for Na_2CO_3 with 2.5V applied



Current density showing the convergence of current onto the central Ni Cathode

Heat Production and Redistribution

Heat generated resistively in the electrolyte is distributed by conduction, convection and radiation.

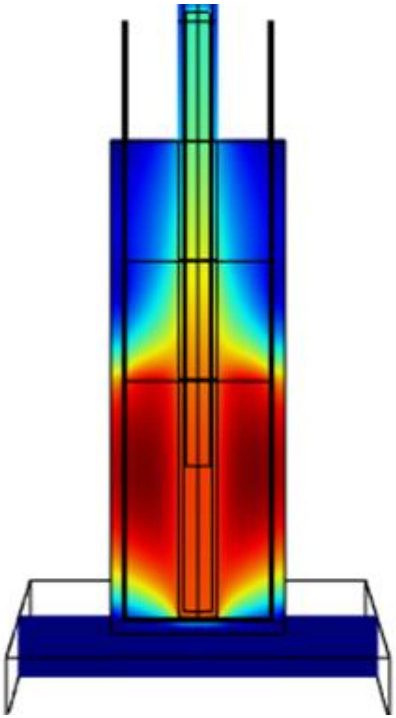
It is possible to simulate the temperature at any point in the cell and its surroundings at any time due to the resistive heating.

The ultimate distribution of the input electrical energy can be computed.

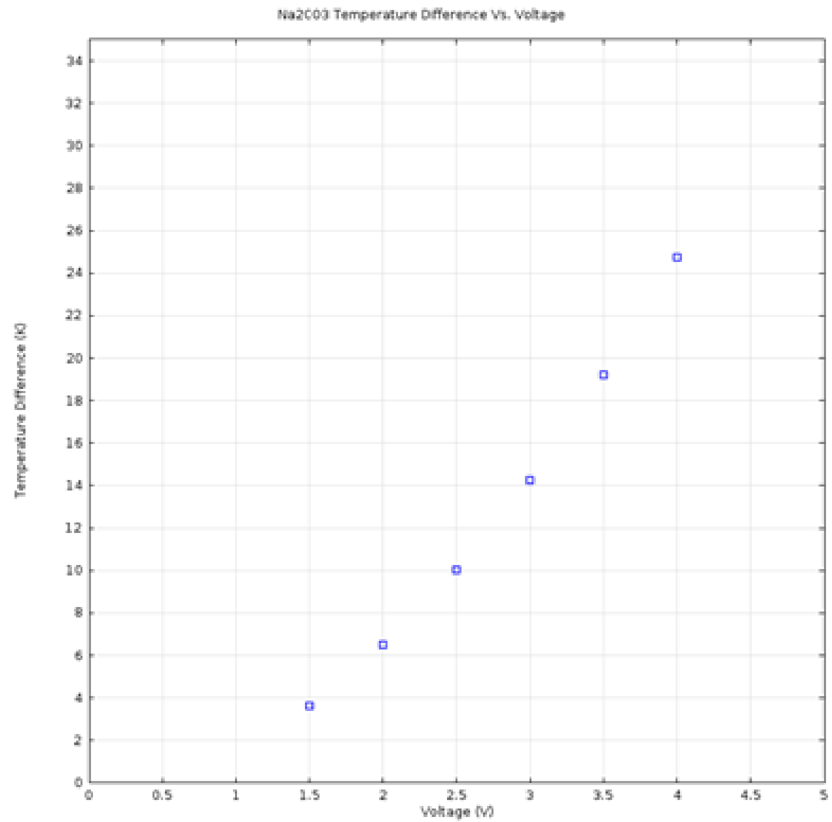
It is possible to simulate the occurrence of LENR on or in the cathode.

The addition of LENR power on top of the resistive heating will alter the computed temperature distributions and histories.

Temperature Distribution Results

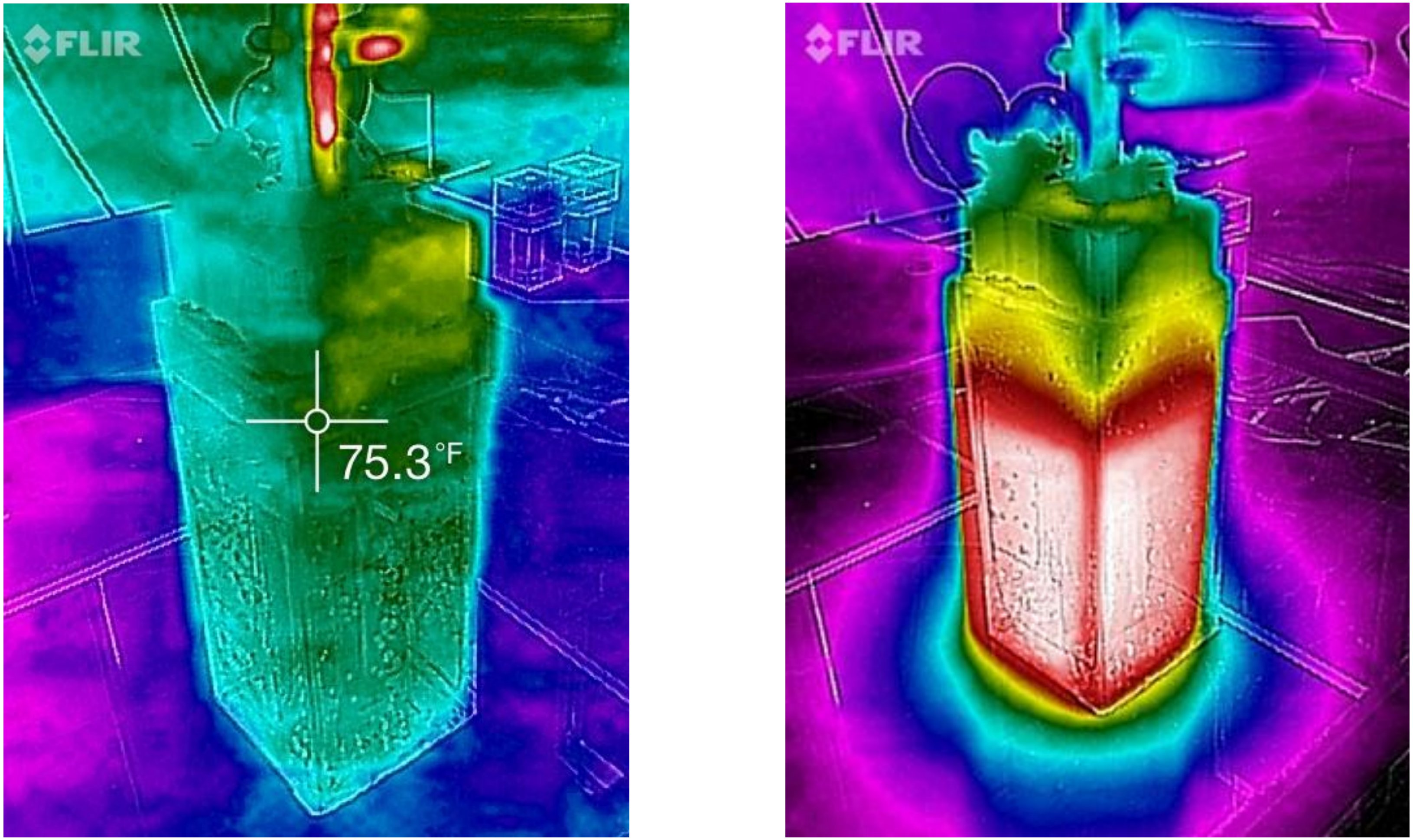


Steady State heat distribution for Na_2CO_3 with 1.5V applied



Temperature difference for a point on the thermocouple compared to a point off the apparatus for different voltages

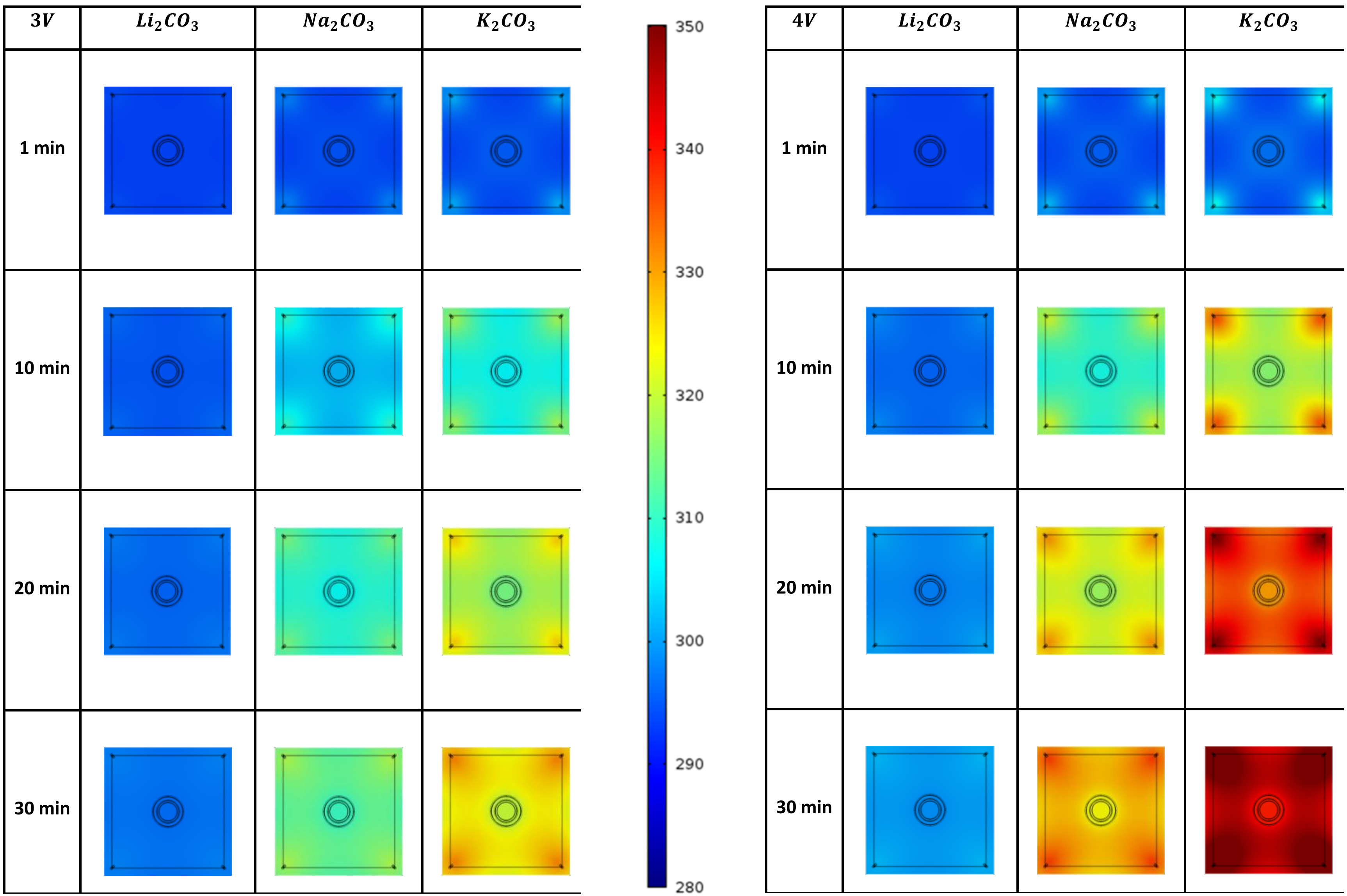
Thermal Imaging of Cell Exterior



Thermal Images of a Cell
Taken with a FLIR One Infrared Camera

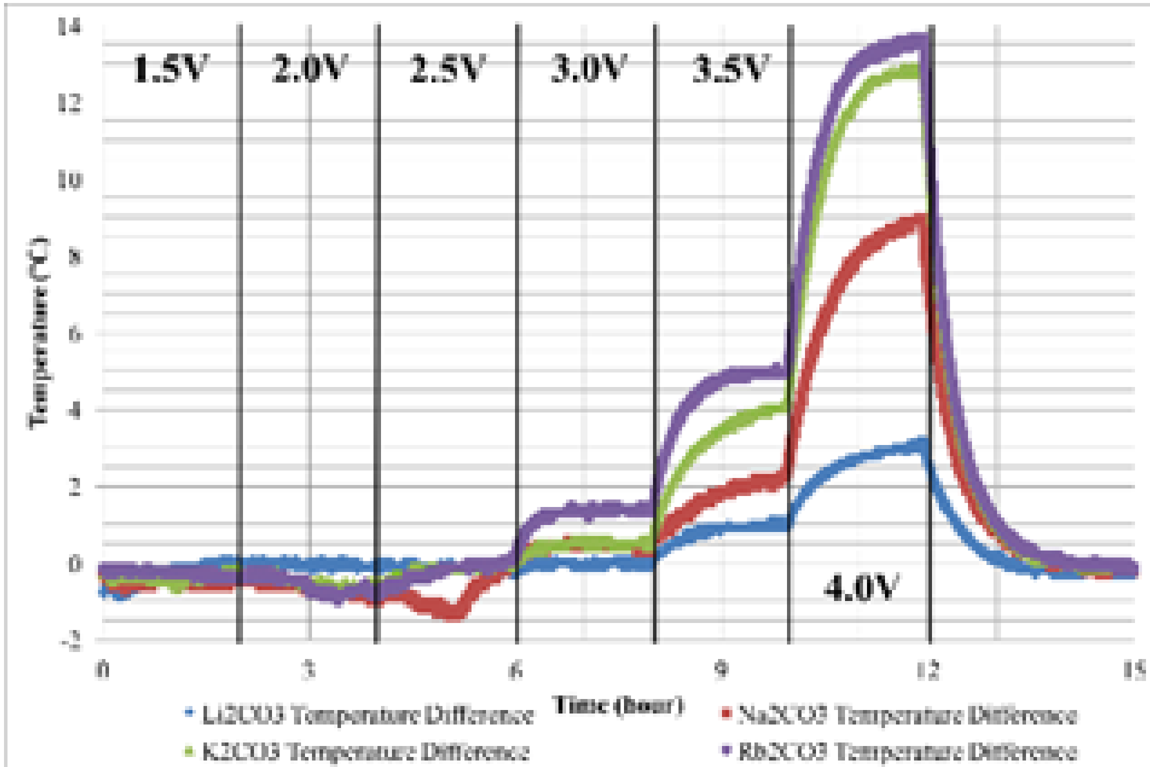
Cross Sections of the Cell:

Variable Time, Electrolyte and Voltage



Experimental Resistive Heating Results

Temperature in Center of Cathode minus the air temperature



Only higher voltages give clear temperature differences.
Heavier ions give more resistive heating.
K_2CO_3 and Rb_2CO_3 give similar results.
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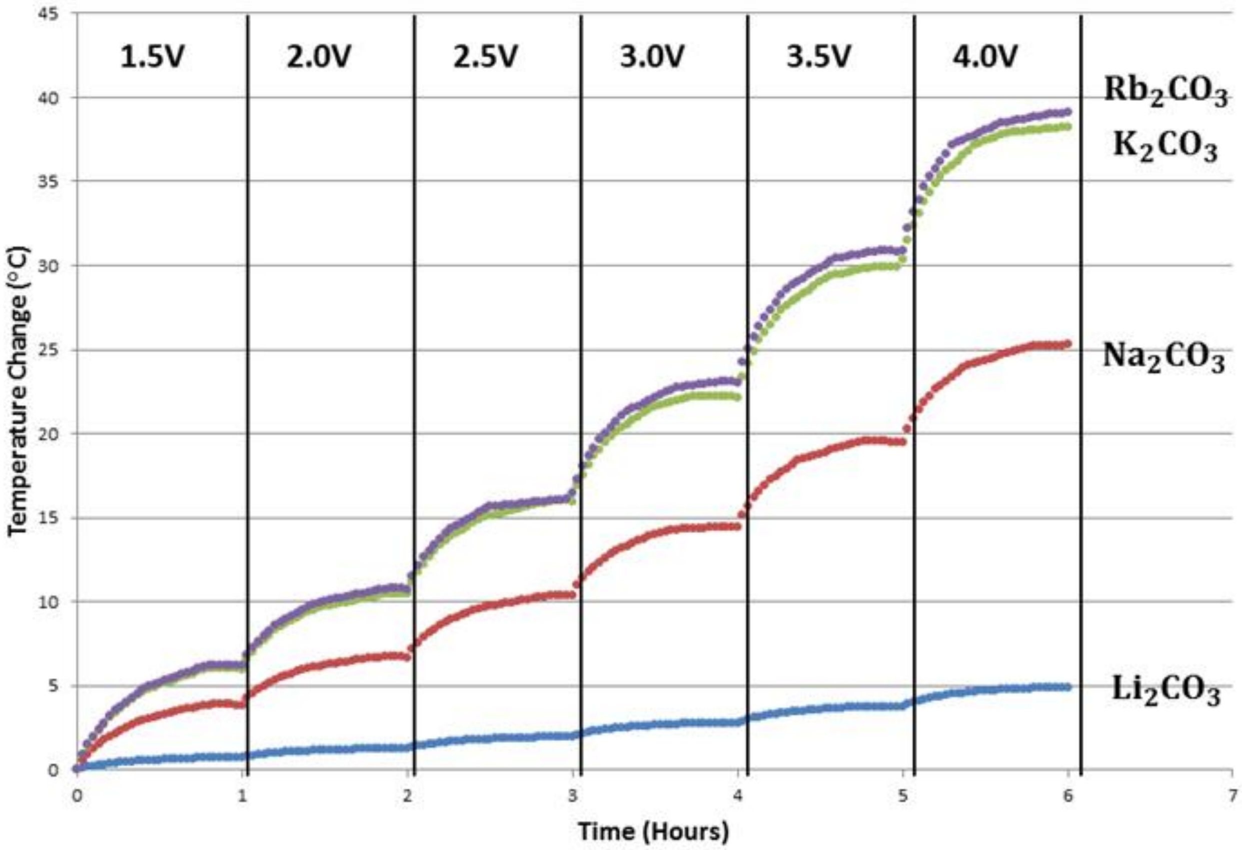
Maximum temperature rises are 14 ^oC

Computed Parametric Variations



Clear temperature differences can be seen for all cases.

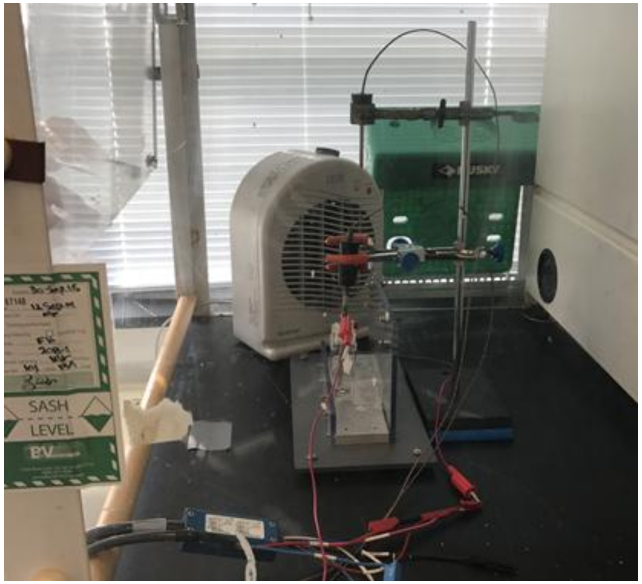
Heavier ions give more resistive heating.

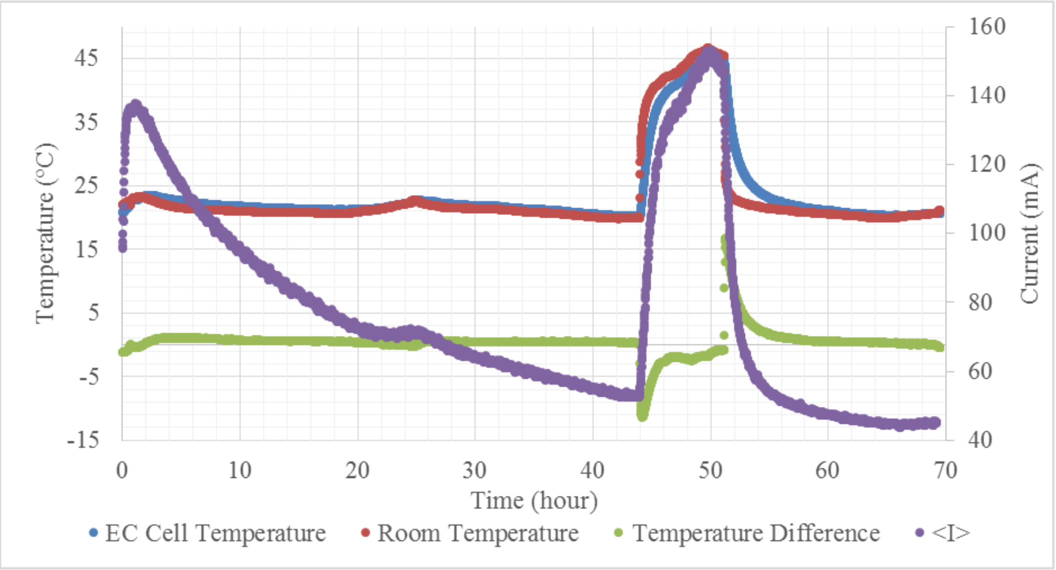
K_2CO_3 and Rb_2CO_3 give similar results.

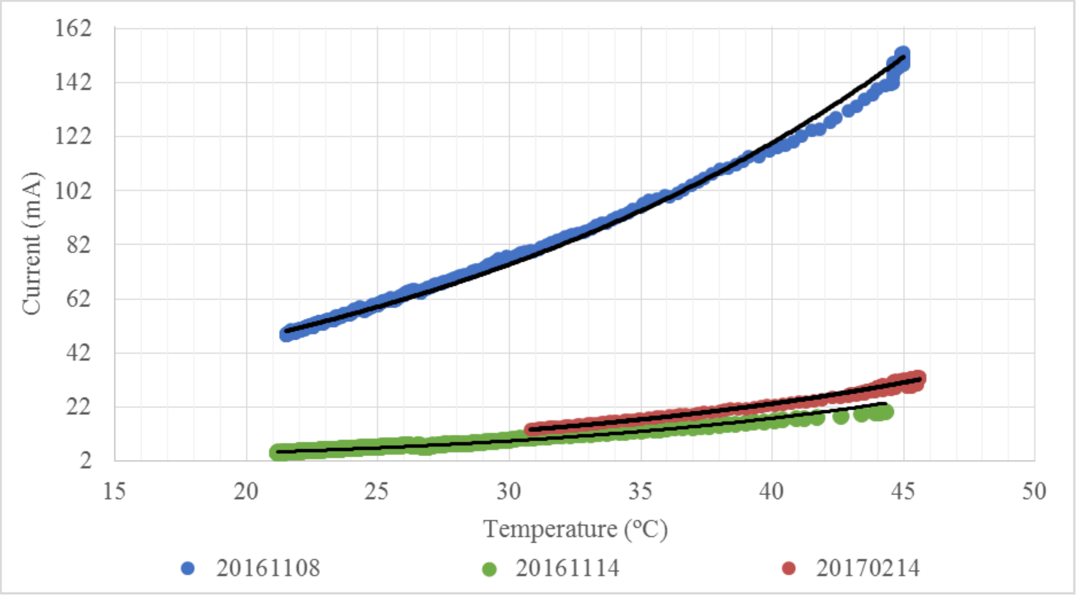
Time constants are on the order of half an hour

Maximum temperature rises are 38 ^oC.

Temperature Dependence of Conductivity







Conclusion

We learned to use COMSOL and partially modeled our experiments.

The temperature variation of conductivity is now being incorporated.

Next, we will get and use the Electrochemistry Module. so that we can account for the energy going into electrolysis in full simulations.

We are now simulating loading of deuterons into Palladium from the 0.5M LiOD electrolyte in anticipation of experiment with Pd tubes.