Admittance Spectroscopy as a TE Characterization Tool
Evan Witkoske, Luna Lu, and Mark Lundstrom, Purdue University

Motivation
The use of Admittance Spectroscopy as a characterization tool applied to thermoelectric materials has the potential to become a quick and simple method for extracting the relevant thermoelectric properties at a given temperature, i.e., figure of merit (ZT), Seebeck coefficient, electrical resistivity, and thermal conductivity.

The analysis, focused on the complex plane, provides the required equivalent circuit elements to interpret the impedance/admittance measurements, without the need of having to measure temperature differences.

Admittance Spectroscopy Equipment
- Gannry Device (Bio Clean room in Birck)
  - Gannry Reference 600 (BE1000/Electrothermal Impedance)
  - ldc=0, lac=10mA, 1MHz to 5kHz
  - Poor accuracy at high frequency.
- Keysight Device (Lyles Building)
  - Using a Keysight E4990A
  - ldc=0, lac=10mA, 20Hz to 120kHz
  - Calibrated setup inside Vacuum chamber. Can vary the pressure down to 1mTor. Temperature can vary from room temp to 700K.

With this initial test circuit giving accurate results, let’s move on to our TE devices.

Calibration (Test Circuit) (Birck Bio Clean Room)
With lower frequency to resolve further. Need lower frequency to resolve further.

Assumed Parameters:
- Seeback coefficient: 1250 (V/K)
- Thermal conductivity: 1.5 (W/mK)
- Electrical Conductivity: 6.46 x 10^5 (S/m)
- Material Density: 3.77 (g/cc)
- Specific Heat: 1.13 (J/Kg)
- Area: 1.23 x 10^-4 (m^2)
- Length: 6.2 (cm)
- Number of Legs: 252

We see a large discrepancy in Cañadas’ results and ours. Let’s compare our experimental results with Cañadas’ simulation results.

Real resistance of 2.11 is smaller than Cañadas’ 4.2, and the simulated value of 2.26 Ohms.

Swarm Fitting Considerations

Assumed Parameters:
- Seeback coefficient: 1250 (V/K)
- Thermal conductivity: 1.5 (W/mK)
- Electrical Conductivity: 6.46 x 10^5 (S/m)
- Material Density: 3.77 (g/cc)
- Specific Heat: 1.13 (J/Kg)
- Area: 1.23 x 10^-4 (m^2)
- Length: 6.2 (cm)
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We see the Gannry device is better suited for this larger TE device.

Experiment (Lyles Civil Engineering)
- Keysight Device (Lyles Building)
  - Keysight device only can go down to 20kHz. For larger TE modules, it is necessary to go down to 1kHz to attain the appropriate plots.
  - However, high frequency accuracy is very good. This device would lend itself very well for small samples.

Theory and fitting
- Swarm fitting is dependent upon precision and accuracy of experiment.
- Need to tackle what the best swarm fitting plots would be for accuracy, as well as error analysis techniques.

- Moving forward?
  - Shift towards a method of measuring smaller devices (In collaboration with Prof. Luna Lu’s Lab.)
  - A better understanding of the parameter space and error analysis of particle swarm fitting is required. How many multiple solutions are there?

Discussion