C8 Revealing temperature fields of thermal models basing on multichannel measurement and simulation

SUPPLEMENTARY INFORMATION

Experimenter: Zweig, Wong 20980066
Participant: Runbing Mo 20980131
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Contents

1 Materials and instruments

Table S1: **Materials and instruments**

Name	Total	Model and parameters
$CompactDAQ$	1	$NI\ CDAQ\ NI-9171$
Thermocouple acquisition module	1	NI 9211
Resistance	4	$100.000\Omega, 81.588\Omega, 42.902\Omega, 19.846\Omega$
$COMSOL$	1	6.0

2 Exp.1 Resistor model

2.1 Main parameters

The resistance value and currents provided are summarized in Tab. S2. The values of properties of different materials adapted in the simulation experiment are summarized in Tab. S3.

$C_p(J/kg \cdot K)$: Specific heat capacity at constant pressure; $\rho(kg/m^3)$: Density; $k(W/m \cdot K)$: Thermal conductivity.

Table S2: **Resistors and currents**

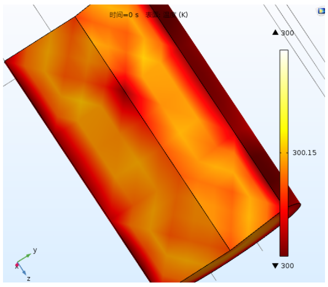
Item	parameters
R_1	100.000Ω
R_2	81.588Ω
R_3	42.902Ω
R_4	19.846Ω
I_1	$0.020A$
I_2	$0.025A$
I_3	$0.030A$
I_4	$0.035A$
I_5	$0.040A$

Table S3: **Material properties**

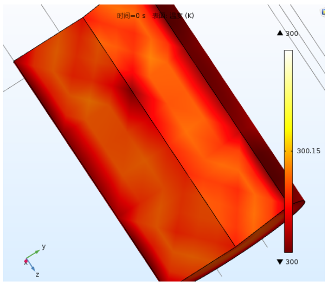
Material	$C_p(J/kg \cdot K)$	$\rho(kg/m^3)$	$k(W/m \cdot K)$
Copper(Heater)	385	8700	400
Silicon(Core)	700	2329	130
Sponge(Insulator)	1	1700	0.09

2.2 Supplementary data and figure

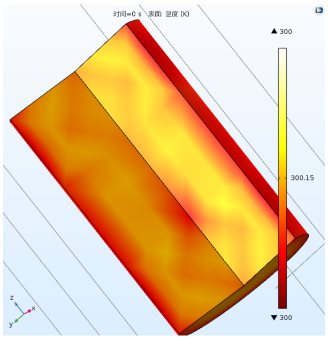
1. Fig. S1: Temperature field distribution of the ideal resistor model.
2. Fig. S2: Temperature field distribution of the complex resistor model.



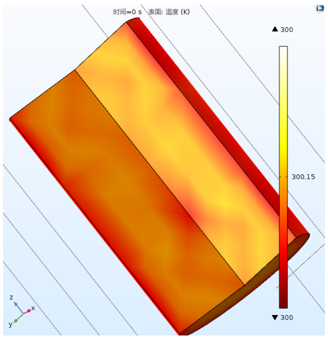
(a) $I = 0.020A$



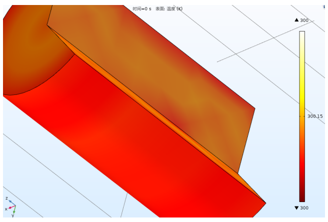
(b) $I = 0.025A$



(c) $I = 0.030A$



(d) $I = 0.035A$



(e) $I = 0.040A$

Figure S1: **Temperature field distribution of the ideal resistor model.**

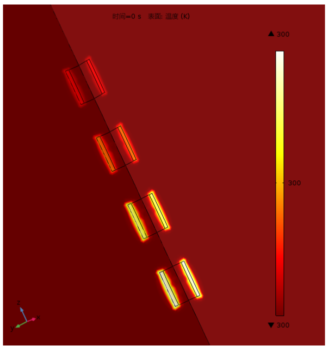
2.3 Question

2.3.1 What are Dirichlet condition, Neumann condition and Robin condition? Which of them can COMSOL deal with?

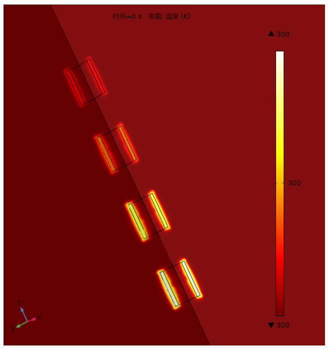
1. Dirichlet condition: The temperature of the boundary is fixed ($u_{|s} = u_0(r,t)$).
2. Neumann condition: The temperature of the boundary is determined by the heat flux ($\frac{\partial u}{\partial n}_{|s} = \frac{q(r,t)}{k}$).
3. Robin condition: The temperature of the boundary is determined by Newton's cooling law ($(\frac{\partial u}{\partial n} + hu)_{|s} = hu_0(r,t)$).
4. COMSOL is capable of dealing with all three types of conditions.

2.3.2 Improve the performance of the model

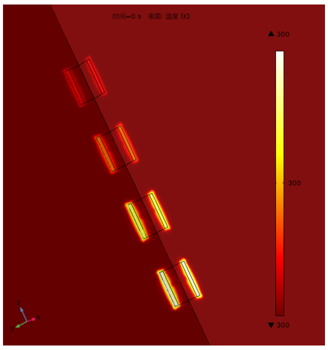
1. Refine the structure of the model: For instance, the model of the resistor can be further refined by adding the electrodes and the insulating layer and so on.



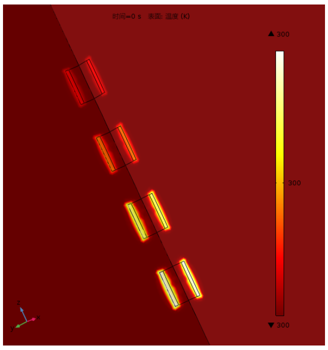
(a) $I = 0.020A$



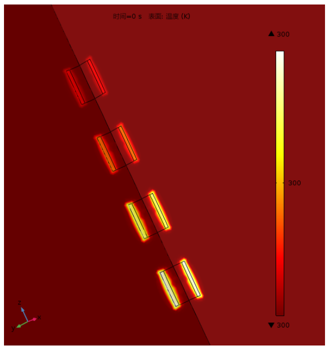
(b) $I = 0.025A$



(c) $I = 0.030A$



(d) $I = 0.035A$



(e) $I = 0.040A$

Figure S2: **Temperature field distribution of the complex resistor model.**

2. Ascertain the accurate values of the properties of materials: Accurate values of the properties of materials should be carefully measured in real-world experiments rather than using empirical values.

3. Increase the complexity of computation: A finer mesh and greater number of sampling points, if available, may increase the accuracy of the model.

3 Exp.2 Plate model

3.1 Main parameters

Parameters including the resistance value of the heater($r/Omega$), the heating voltage(U/V), default Area correction factor(A), and the heat exchange coefficient(H) are shown in Tab. S4. Values of properties of different materials adapted in the simulation experiment are summarized in Tab. S5. $C_p(J/kg \cdot K)$: Specific heat capacity at constant pressure; $\rho(kg/m^3)$: Density; $k(W/m \cdot K)$: Thermal conductivity.

3.2 Supplementary data and figure

1. Fig. S3: Temperature field distribution of the four models.

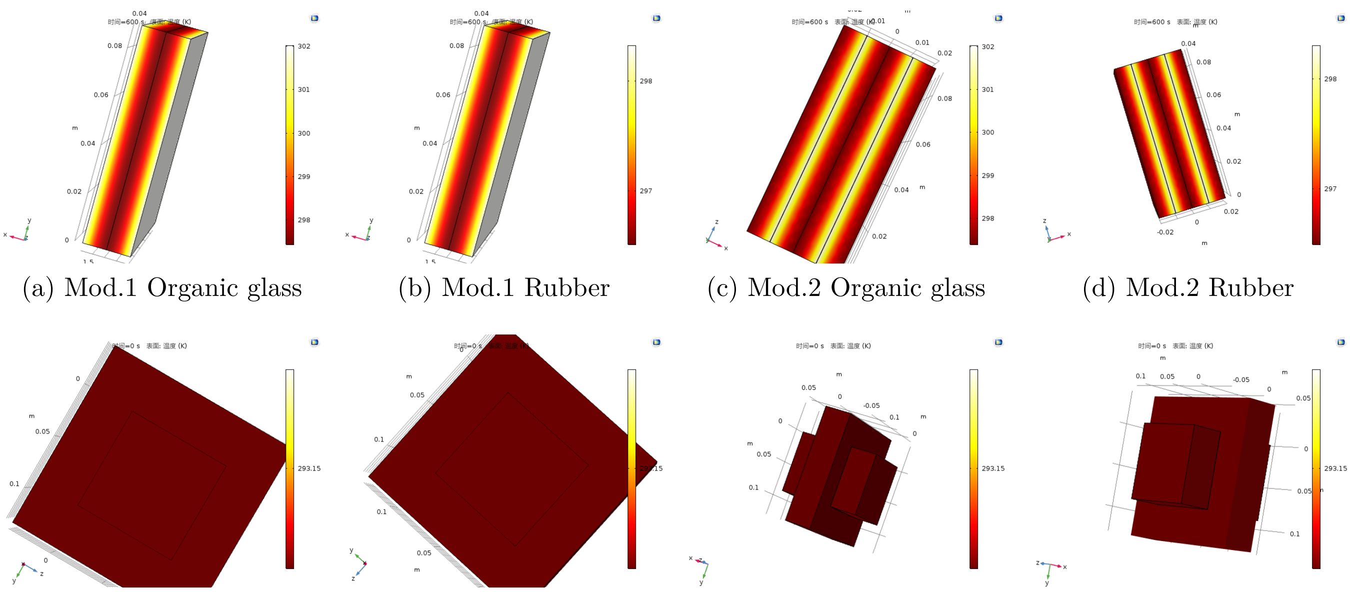
2. Fig. S4: Change the area correction factor A for Model 1.

Table S4: **Parameters**

Item	parameters
Heating voltage U	$17.0V$
Resistance R	$110/Omega$
Area correction factor$A$	0.85
Heat exchange coefficient$H$	50

Table S5: **Material properties**

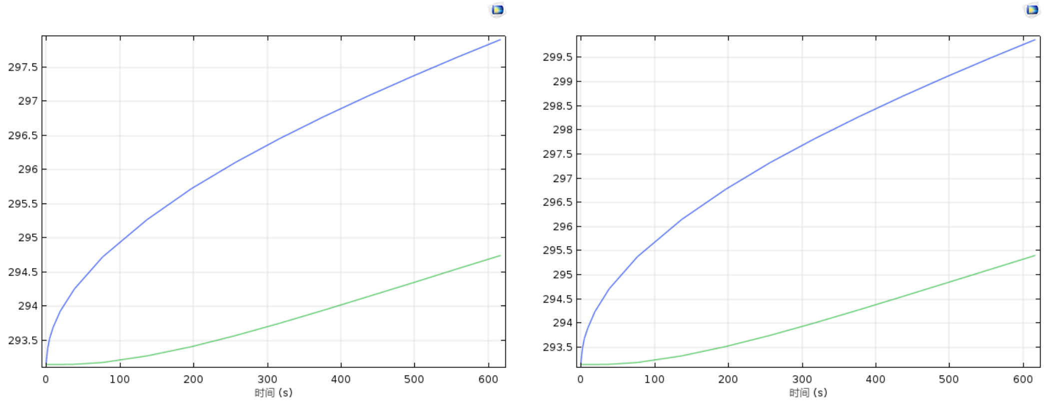
Material	$C_p(J/kg \cdot K)$	$\rho(kg/m^3)$	$k(W/m \cdot K)$
Organic glass(Sample)	1333	1196	0.168
Rubber(Sample)	1700	1374	0.426
Aluminum(Heater)	972.5	2676.8	67.09
Film(Heater)	1058	1533	33.97
Frame(Insulator)	920	1900	0.90
Sponge(Insulator)	400	4200	0.046



(a) Mod.1 Organic glass (b) Mod.1 Rubber (c) Mod.2 Organic glass (d) Mod.2 Rubber

(e) Mod.3 Organic glass (f) Mod.3 Rubber (g) Mod.4 Organic glass (h) Mod.4 Rubber

Figure S3: **Temperature field distribution of the ideal resistor model.**



(a) Mod.1 $A = 0.60$ (b) Mod.1 $A = 0.85$

Figure S4: **Change the area correction factor A for Model 1**

3.3 Question

3.3.1 Why to set the area correction factor $\boldsymbol{A}$?

The area correction factor is used to correct the area of the heater to eliminate the edge effect. In the four-sample model, the heat flux $\boldsymbol{q}$ can be expressed as:

$$\boldsymbol{q} = \frac{U^2}{2Fr} \tag{1}$$

where $F = AS$ is the heating area after correction of the edge effect, A is the area correction factor, and S is the actual area of the heater.

$\boldsymbol{A}$ sometimes need to be adjusted empirically as illustrated in Fig. S4. We found that if the area correction factor is set to 0.6, the results are more approximate to the results of real-world experiment.

4 Data and code availability

Data and code are available at `https://github.com/Jeg-Vet/SYSU-PHY-EXP/tree/main/`