

# 열 전도율별 열 유입량

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# 열전도율에 따른 산업의 활용

- ① 열전도율이 높은 재료를 써야 유리한 산업  
열에너지 전달이 중요한 산업  
EX) 증기 터빈
  
- ② 열전도율이 낮은 재료가 필요한 산업  
단열효과를 이용할 수 있는 산업  
EX) 소형 전자기기

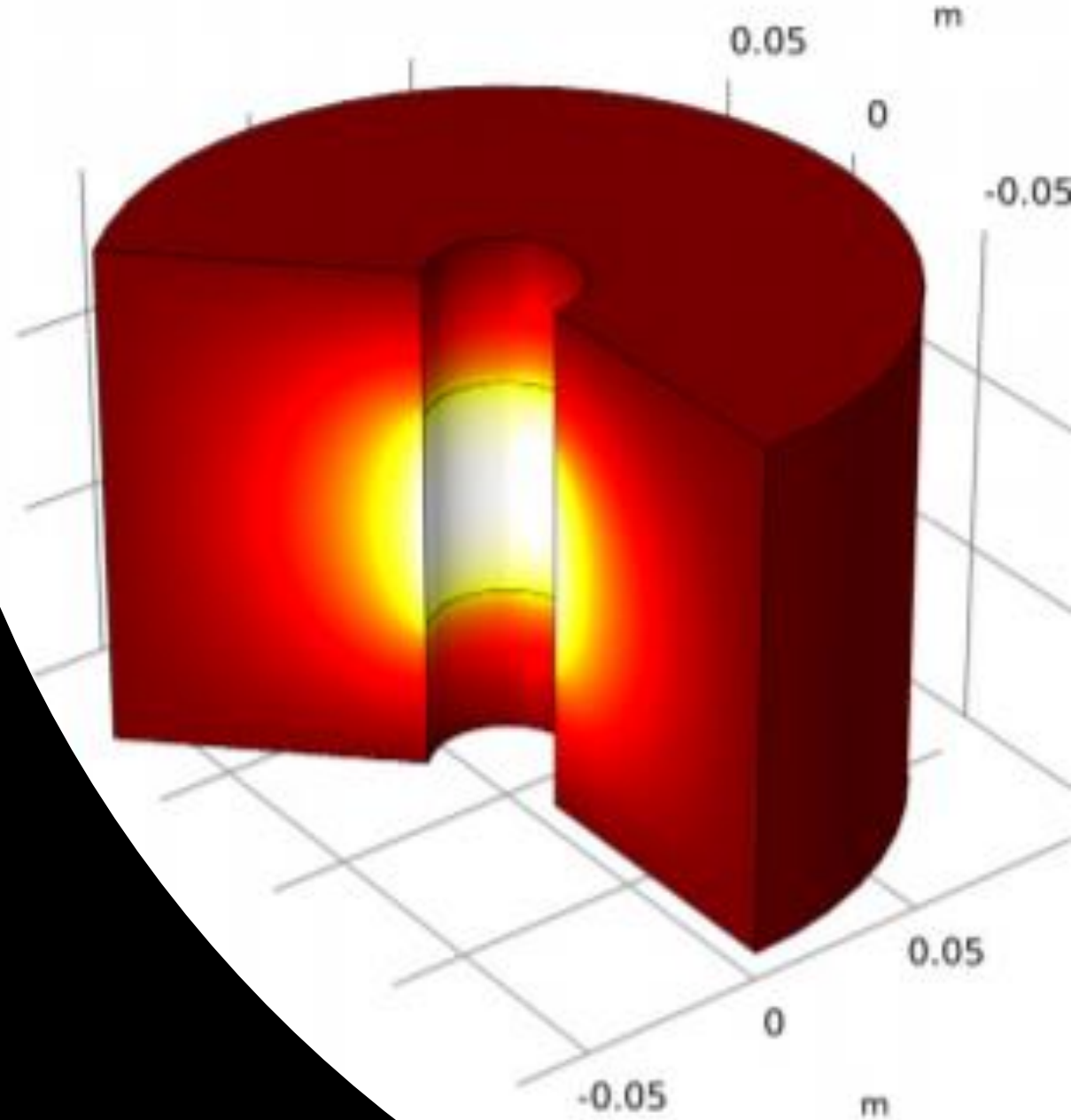
# 열전도체별 열전도율

- 모델링
- 실린더

2D-Axisymmetric

선택한 재료의 열전도체

- 구리(copper)
- 주철(cast iron)
- 공기(Air)



# 열 전도율 이론

- 열전도란?
  - 두 물체가 접촉해서 분자의 운동이 전달되어 열이 이동하는 현상
- 열 전도율 공식
- $\rho c_p u \cdot \nabla T + \nabla \cdot q = Q + Q_{ted}$
- $q = -k \nabla T$ 
  - 정상상태에서 체적열원을 0으로 설정한 방정식
  - 규정된 열 유속
  - 절연 / 대칭
  - 규정된 온도

# 모델링 순서

Model Wizard -> 2D-axisymmetric

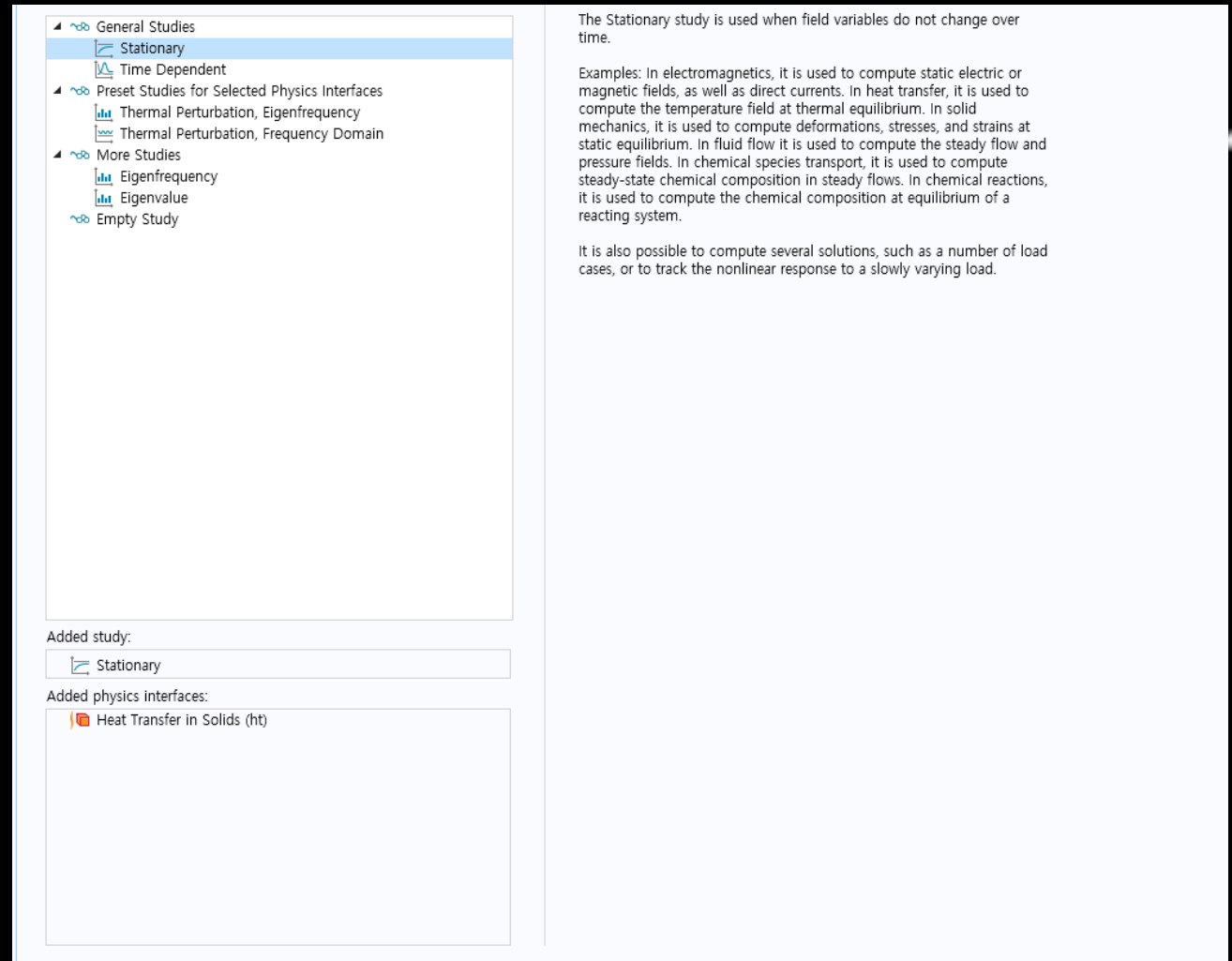
->Heat Tranfer

-> Heat Transsfer in Solids(ht)

-> Add

-> Study -> General Studies

-> Stationary -> Done



The screenshot shows the Model Wizard interface. The 'General Studies' category is expanded, and the 'Stationary' study type is selected. Below the list, the 'Added study:' field contains 'Stationary'. The 'Added physics interfaces:' field contains 'Heat Transfer in Solids (ht)'. The right-hand pane provides a description of the Stationary study and its applications.

The Stationary study is used when field variables do not change over time.

Examples: In electromagnetics, it is used to compute static electric or magnetic fields, as well as direct currents. In heat transfer, it is used to compute the temperature field at thermal equilibrium. In solid mechanics, it is used to compute deformations, stresses, and strains at static equilibrium. In fluid flow it is used to compute the steady flow and pressure fields. In chemical species transport, it is used to compute steady-state chemical composition in steady flows. In chemical reactions, it is used to compute the chemical composition at equilibrium of a reacting system.

It is also possible to compute several solutions, such as a number of load cases, or to track the nonlinear response to a slowly varying load.

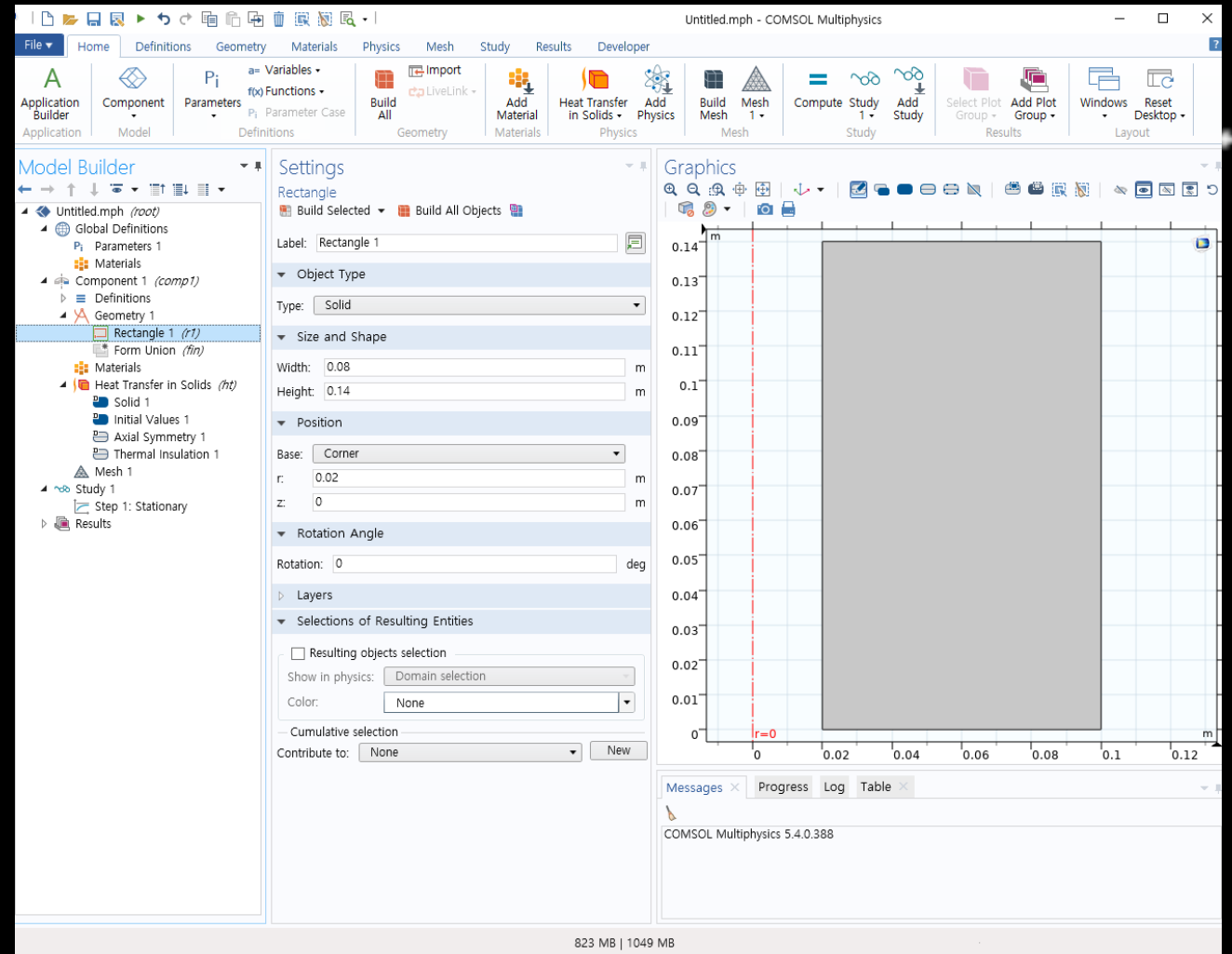
# 모델링 순서

Rectangle 1 생성

-> Width : 0.08, Height : 0.14

-> position r : 0.02

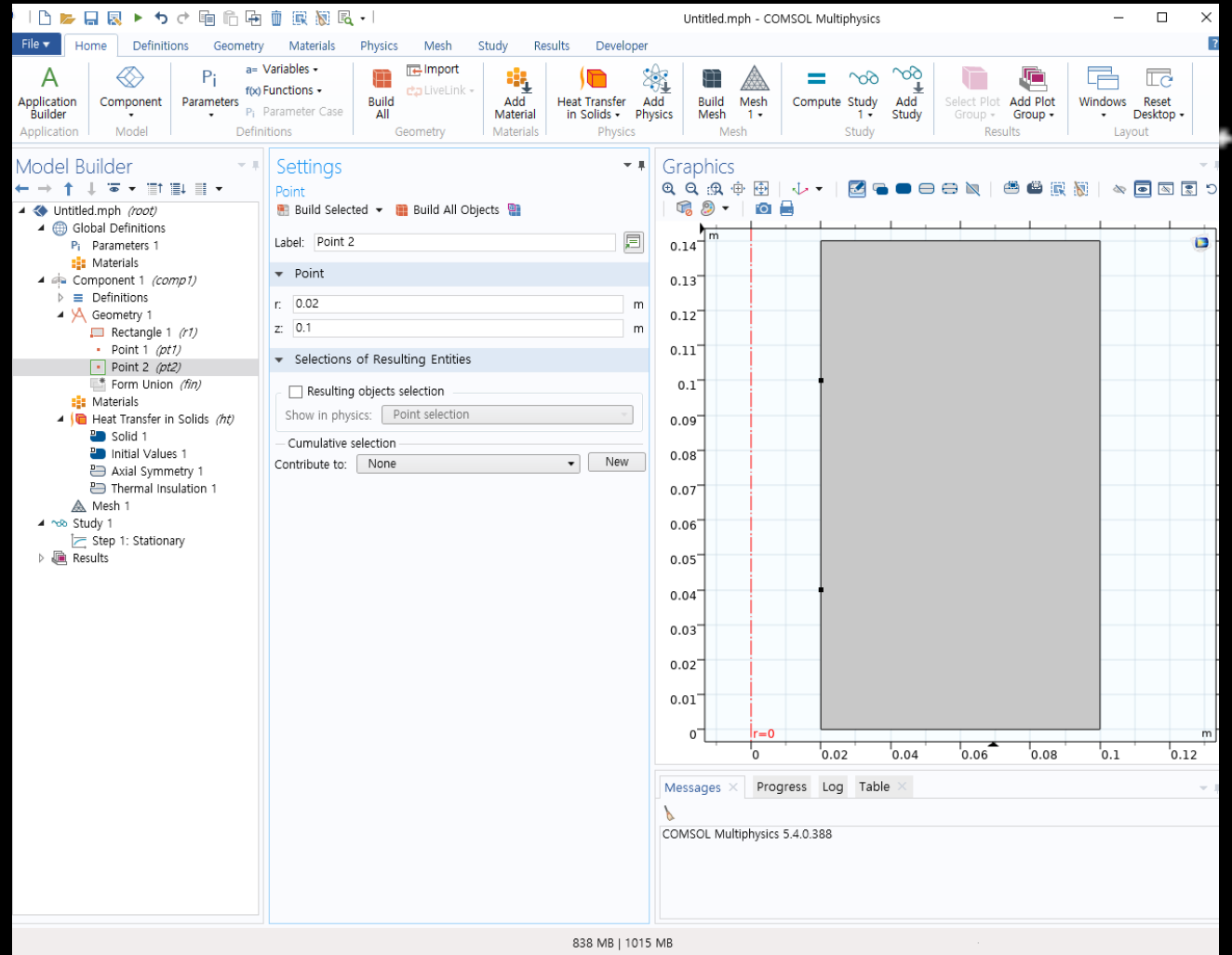
-> Build Selected



# 모델링 순서

Point 1 :  $r = 0.02\text{m}$ ,  $z = 0.4\text{m}$

Point 2 :  $r = 0.02\text{m}$ ,  $z = 0.1\text{m}$









# 모델링 순서

Materials 우클릭

-> Add Material from Library 클릭

-> Built-in 클릭

-> 원하는 재료 선택

-> 도형 클릭

The screenshot displays the COMSOL Multiphysics software interface. The main window shows a rectangular domain in the Graphics area, with a mesh applied. The Material Builder pane on the left shows the hierarchy of the model, with the material 'Copper (mat2)' selected. The Settings pane in the center shows the material properties for Copper, including density, thermal conductivity, and Young's modulus. The Add Material pane on the right shows the 'Built-in' material library, with 'Copper' selected. The Messages pane at the bottom shows the results of the meshing process.

Material Properties Table:

Property	Variable	Value	Unit
Heat capacity at constant pressure	Cp	385 J/(kg·K)	J/(kg·K)
Density	rho	8960 kg/m³	kg/m³
Thermal conductivity	k_iso	400 W/m·K	W/(m·K)
Relative permeability	mu_r	1	1
Electrical conductivity	sigma	5.998e7 S/m	S/m
Coefficient of thermal expansion	alpha	17e-6 1/K	1/K
Relative permittivity	epsilon	1	1
Young's modulus	E	110e9 Pa	Pa
Poisson's ratio	nu	0.35	1
Reference resistivity	rho0	1.72e-8 Ω·m	Ω·m
Resistivity temperature coefficient	alpha	0.0039 1/K	1/K

Messages:

- [Dec 4, 2019 2:37 PM] Finalized geometry has 1 domain, 6 boundaries, and 6 vertices.
- [Dec 4, 2019 2:49 PM] Complete mesh consists of 360 domain elements and 50 boundary elements.
- [Dec 4, 2019 2:49 PM] Number of degrees of freedom solved for: 771 (plus 106 internal DOFs).
- [Dec 4, 2019 2:49 PM] Solution time (Study 1): 5 s.
- [Dec 4, 2019 2:52 PM] Number of degrees of freedom solved for: 771 (plus 106 internal DOFs).

# 모델링 순서

Mesh 생성

-> Study -> Compute

The screenshot displays the COMSOL Multiphysics software interface for a simulation titled "Untitled.mph - COMSOL Multiphysics". The main window shows a 3D plot of a temperature distribution on a cylindrical object, with a color scale ranging from 275 K (red) to 295 K (yellow). The plot is titled "Surface: Temperature (K)".

The interface includes several panels:

- Model Builder:** Shows the hierarchical structure of the model, including "Global Definitions", "Component 1 (comp1)", "Geometry 1", "Materials", "Mesh 1", "Study 1", and "Results".
- Settings:** Displays the configuration for the "3D Plot Group" and "Plot". The "Data set" is set to "Revolution 2D". The "View" is set to "Automatic". The "Color Legend" is checked, and the "Position" is set to "Right".
- Graphics:** Shows the 3D plot of the temperature distribution on the cylindrical object.
- Add Material:** Provides a list of materials, including "Air", "Acrylic plastic", "Alumina", "Aluminum 3003-H14", "Aluminum 6063-T83", "Aluminum", "American red oak", "Beryllium copper UN", "Brick", "Cast iron", "Concrete", "Copper", "FR4 (Circuit Board)", "Glass (quartz)", "Granite", "High-strength alloy s iron", "Magnesium AZ31B", "Mica", "Molybdenum", "Nimonic alloy 90", "Nylon", "Polysilicon", "Lead Zirconate Titan", "Silica glass", and "Silicon".
- Messages:** Shows the progress and log of the simulation, including the number of degrees of freedom solved for (771 plus 106 internal DOFs) and the solution time (2 s).

The status bar at the bottom indicates a memory usage of 1.69 GB | 1.97 GB.

# 모델링 순서

Results값 확대

-> Data Sets 우클릭

-> Cut Point 2D 생성

-> R : 0.04, Z : 0.04 생성

The screenshot displays the COMSOL Multiphysics software interface. The top menu bar includes File, Home, Definitions, Geometry, Materials, Physics, Mesh, Study, Results, and Developer. The main workspace is divided into several panels:

- Model Builder:** Shows the hierarchical structure of the model. Key elements include: Global Definitions, Parameters 1, Common Model Inputs, Materials, Component 1 (comp1) with sub-elements like Definitions, Geometry 1 (containing Rectangle 1 (r1), Point 1 (pt1), Point 2 (pt2), and Form Union (fin)), Materials (containing Copper (mat2)), Heat Transfer in Solids (ht) with Solid 1, Initial Values 1, Axial Symmetry 1, Thermal Insulation 1, and Temperature 1, Mesh 1, Study 1 with Step 1: Stationary, Solver Configurations, and Solution 1 (sol1), and Results (containing Data Sets, Views, and Derived Values).
- Settings:** The 'Cut Point 2D' settings are shown. The 'Data' section is set to 'Study 1/Solution 1 (sol1)'. The 'Point Data' section shows 'Entry method' set to 'Coordinates', with 'R' and 'Z' both set to 0.04 m. There is an option for 'Snap to closest boundary' which is currently unchecked.
- Graphics:** A 2D plot showing a square domain with a red dot at the center, representing the cut point. The axes are labeled 'm' and range from 0 to 0.1.
- Add Material:** A panel on the right showing a list of materials under 'Built-in', including Air, Acrylic plastic, Alumina, Aluminum, etc.

At the bottom of the window, the status bar indicates '1.69 GB | 1.98 GB'.

# 모델링 순서

Derived Values 우클릭

-> Point Evaluation 생성

-> Data Set을

Cut Point 2D로 바꾼뒤 Evaluate

-> Temperature 해석

The screenshot displays the COMSOL Multiphysics software interface. The main window is titled "Untitled.mph - COMSOL Multiphysics". The interface is divided into several panels:

- Model Builder:** Shows the hierarchical structure of the model. The "Point Evaluation 1" node is selected under the "Derived Values" section.
- Settings:** The "Point Evaluation" settings are displayed. The "Label" is "Point Evaluation 1". The "Data" section shows "Data set: Cut Point 2D 1". The "Expressions" section is empty. The "Data Series Operation" is set to "None".
- Graphics:** A 2D plot of the temperature field is shown. The plot area is a square with axes ranging from 0 to 0.14 m. The temperature is represented by a color gradient from blue (low) to red (high).
- Add Material:** A list of materials is shown on the right side of the interface, including "Air", "Acrylic plastic", "Alumina", "Aluminum 3003-H14", "Aluminum 6063-T83", "Aluminum", "American red oak", "Beryllium copper UN", "Brick", "Cast iron", "Concrete", "Copper", "FR4 (Circuit Board)", "Glass (quartz)", "Granite", "High-strength alloy s", "Iron", "Magnesium AZ31B", "Mica", "Molybdenum", "Nimonic alloy 90", "Nylon", "Polysilicon", "Lead Zirconate Titane", "Silica glass", and "Silicon".

At the bottom of the interface, the "Messages" and "Progress" panels are visible. The "Messages" panel shows the following text:

Temperature (K), Point: (0.04, 0.04)
280.92

The status bar at the bottom indicates "1.7 GB | 1.98 GB".

# 결과 & 비교

- 구리(copper)

$$c_p = 385 \left[ \frac{J}{kg * K} \right], \rho = 8960 \left[ \frac{kg}{m^3} \right], k = 400 \left[ \frac{W}{m * K} \right]$$

- 이론값

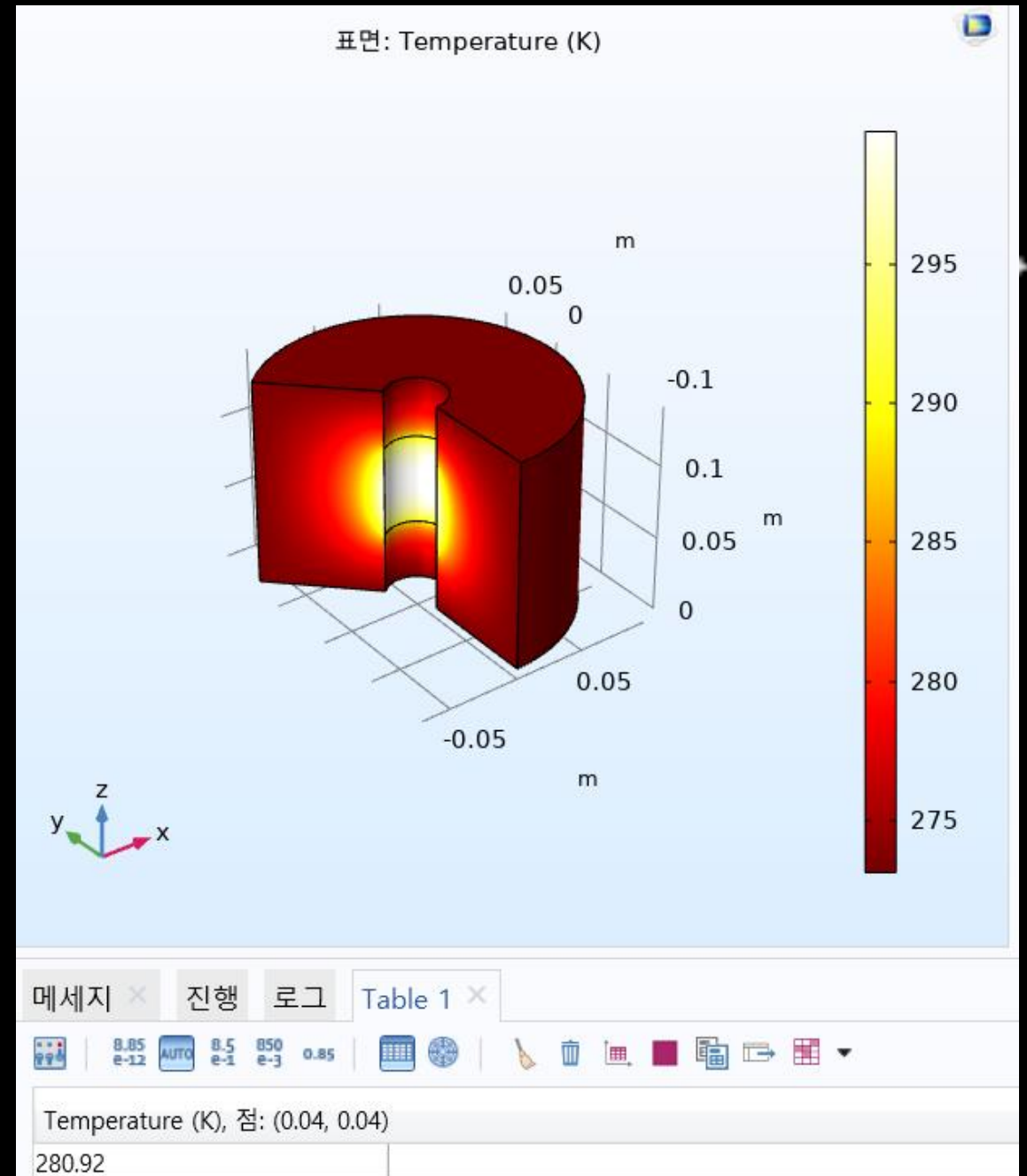
- 270.45(K)

- 실험값

- 280.92(K)

- 오차율

- 3.87%



# 결과 & 비교

- 주철(cast iron)

$$c_p = 420 \left[ \frac{J}{kg * K} \right], \rho = 7000 \left[ \frac{kg}{m^3} \right], k = 50 \left[ \frac{W}{m * K} \right]$$

- 이론값

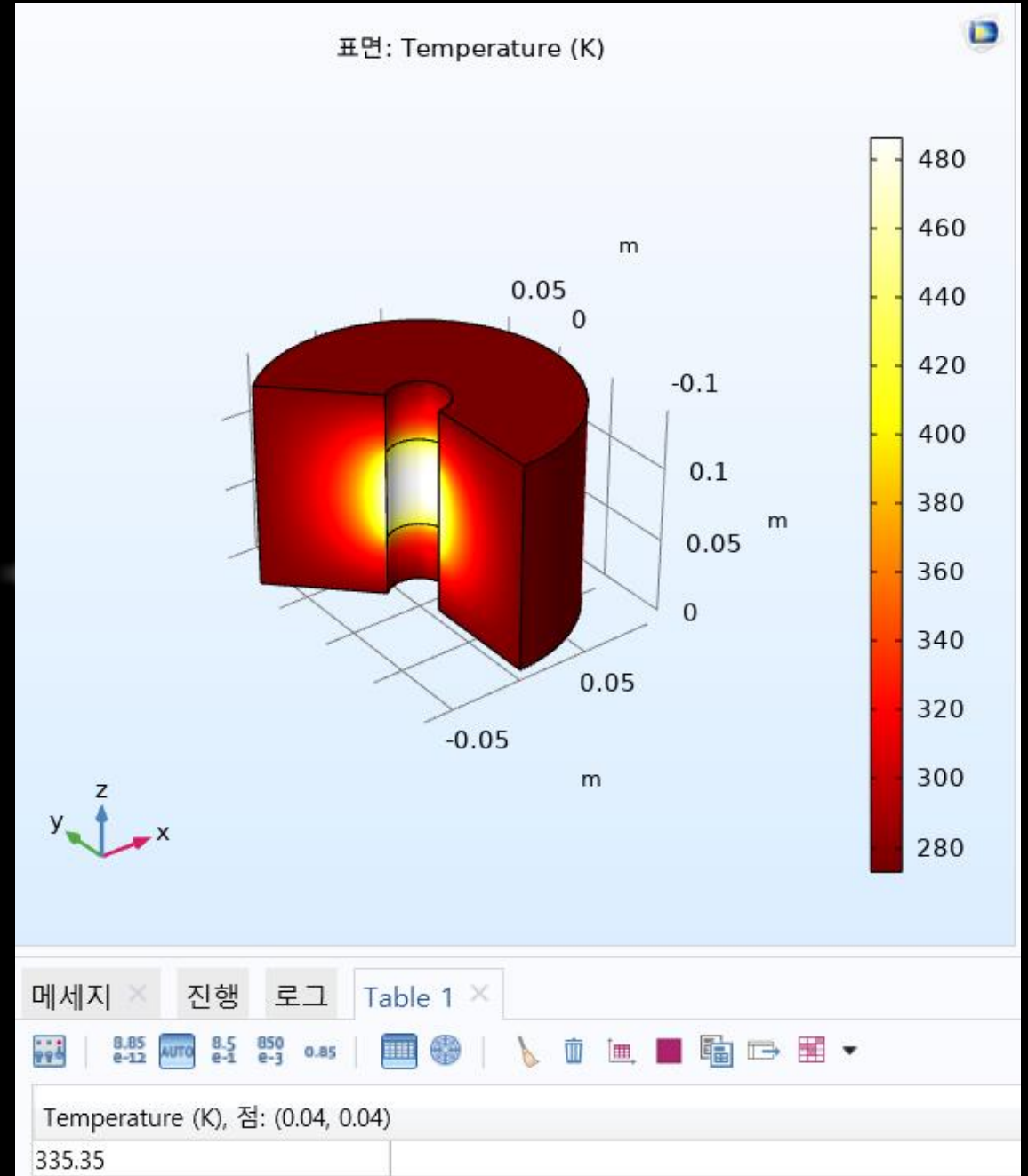
- 321.67(K)

- 실험값

- 335.35(K)

- 오차율

- 4.25%



# 결과 & 비교

- 알루미늄(Aluminum)

$$c_p = 900 \left[ \frac{J}{kg * K} \right], \rho = 2700 \left[ \frac{kg}{m^3} \right], k = 238 \left[ \frac{W}{m * K} \right]$$

- 이론값

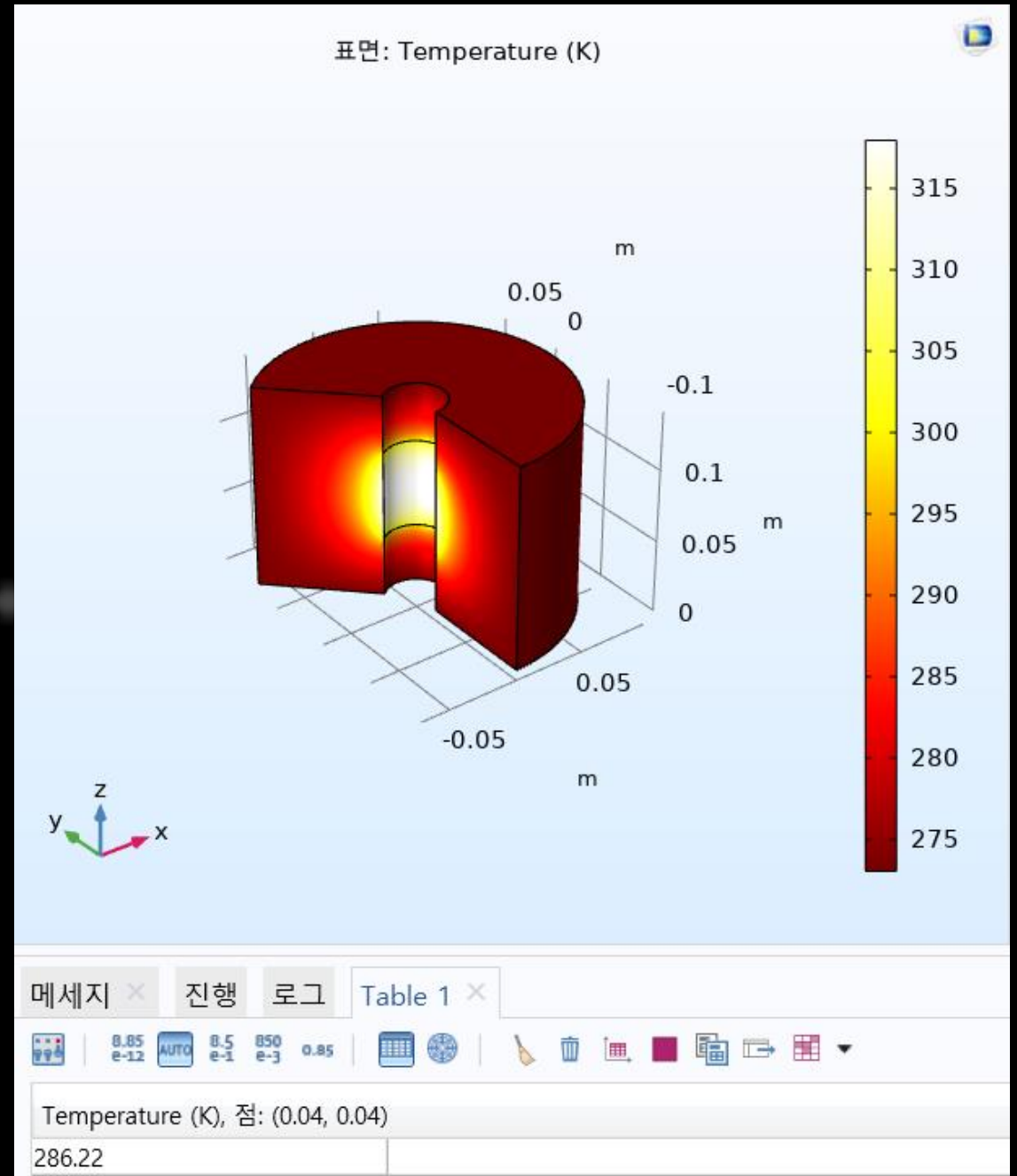
  - 280.32(K)

- 실험값

  - 286.22(K)

- 오차율

  - 2.10%





# 결론

- ① 구리, 주철, 알루미늄을 비교한 결과 구리가 가장 열 전도율이 낮음
- ② 열전도도가 가장 적은 물질은 구리라고 할 수 있다.
- ③ COMSOL 검사결과를 활용하여 각 산업체에서 재료에 따른 열 전도율에 따라 산업에 알맞게 재료를 사용할 수 있다.