Carbon composite bipolar plates and light weight PEMFC stacks

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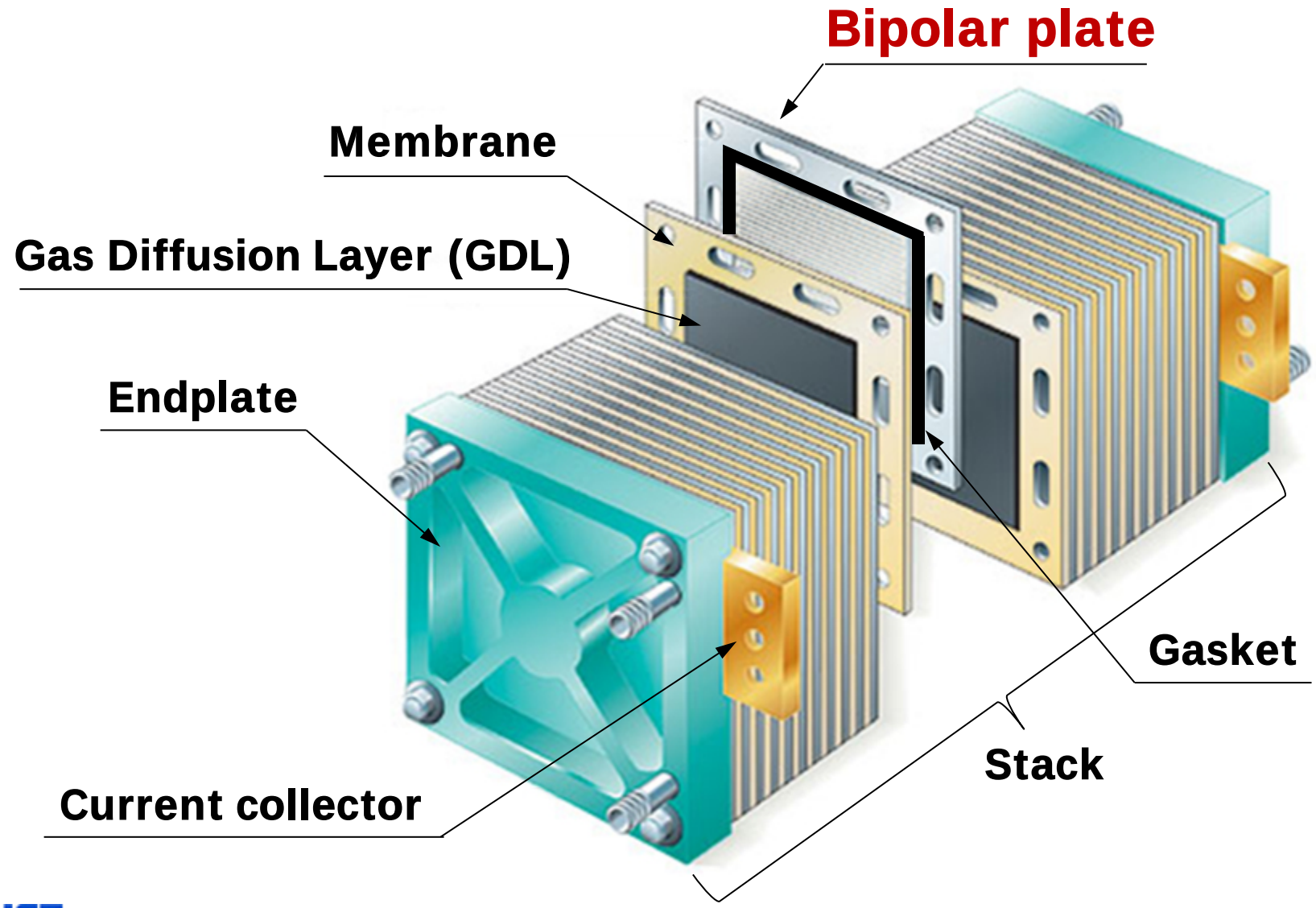
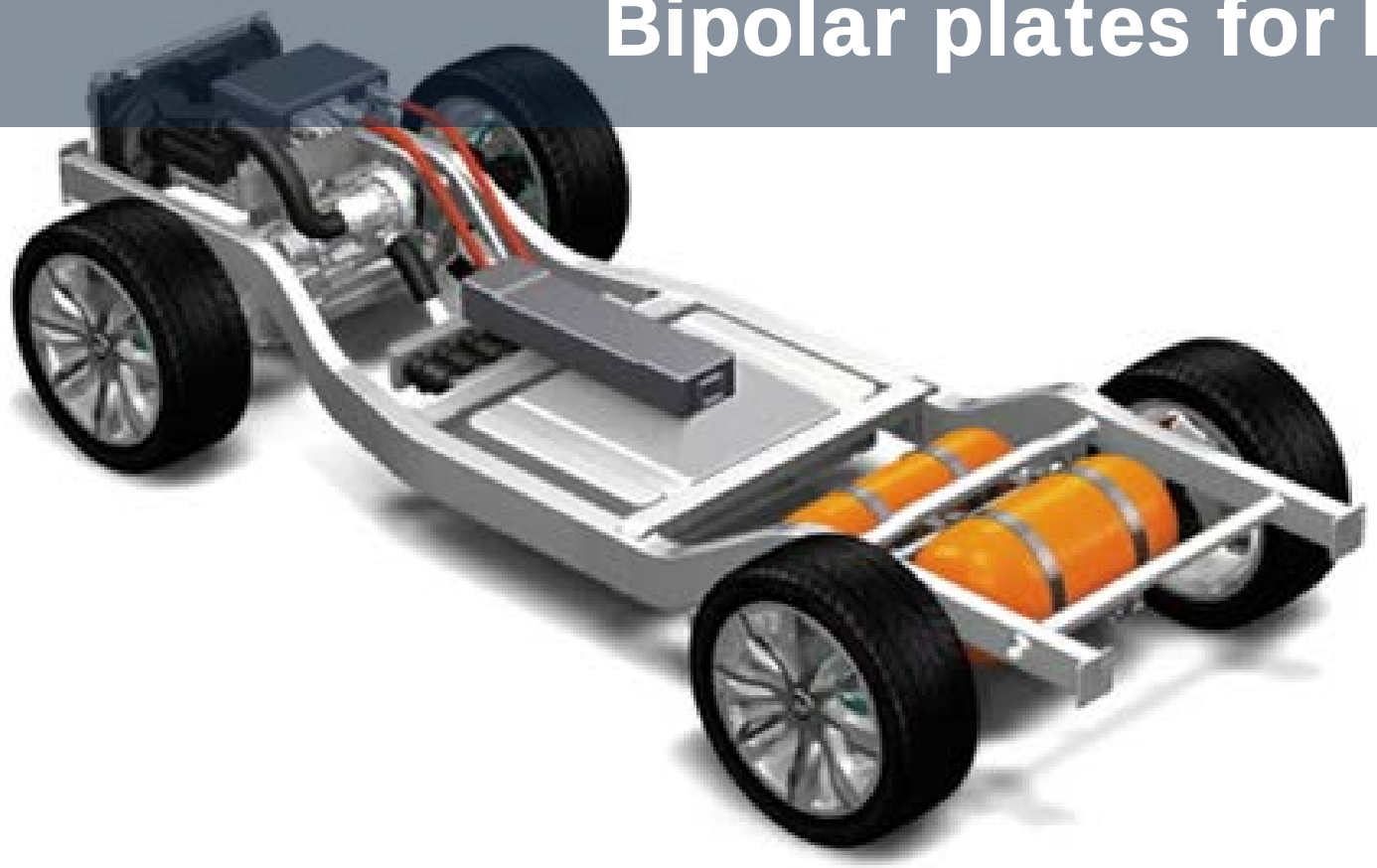
Contents

PEMFC (Polymer Electrolyte Membrane Fuel Cell)

Schematic of stack for PEMFC



Bipolar plates for PEM fuel cell



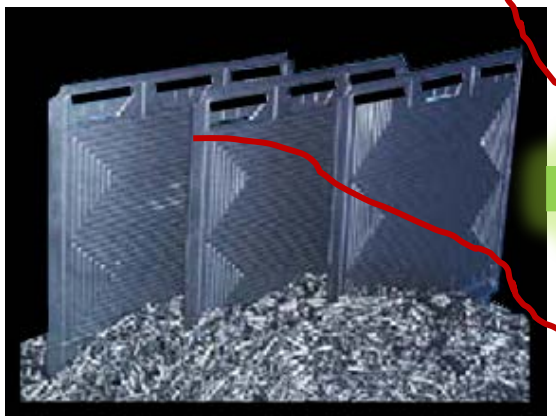
Bipolar plates

Requirements of bipolar plate

- Low electrical resistance
- High chemical resistance
- Thin thickness
- High mechanical properties
- Productivity

Bipolar plates

Graphite



- High electrical conductivity
- Brittle material
- High cost (machining)
- High gas permeability

Metal (stainless steel)

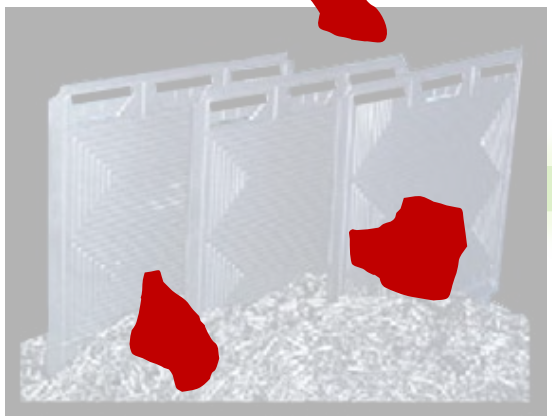
- High electrical conductivity
- Corrosion problem
- High cost (coating)
- High contact resistance

?

- High electrical conductance
- Chemical stability
- Low cost
- Flexibility

Bipolar plates

Graphi



- High electrical conductivity
- Brittle material
- High cost (machi)
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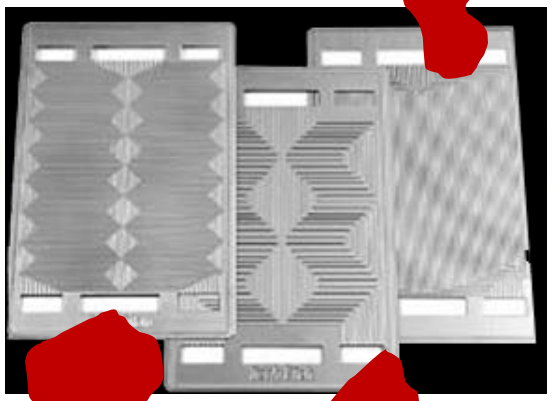
Metal (stainless steel)



- High electrical conductivity
- Corrosion problem
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- High contact resistance

- High electrical conductivity
- Chemical stability
- Low cost
- Flexibility

Bipolar plates

Graphite

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- Brittle material
- High cost (machining)
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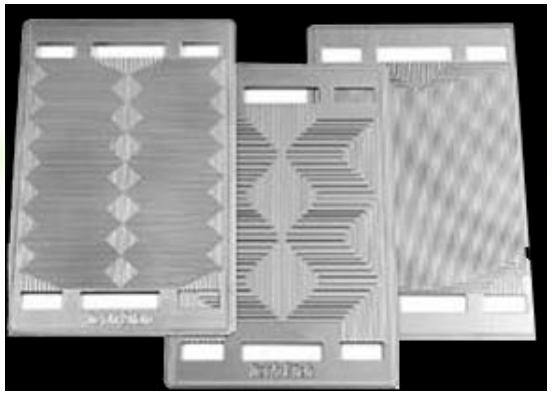
Metal (stainless steel)



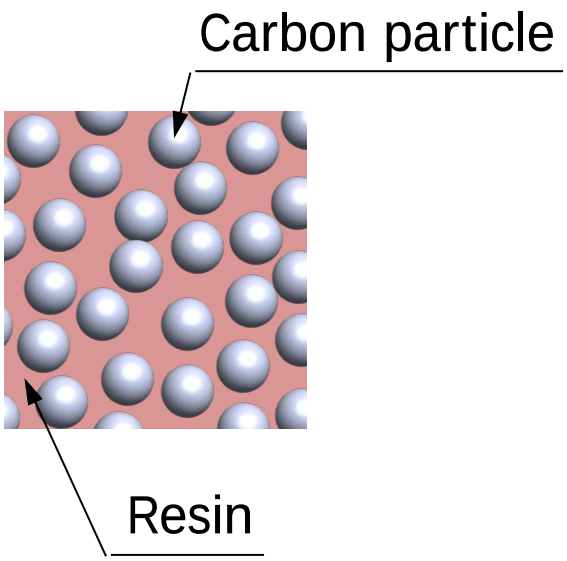
- High electrical conductivity
- Corrosion problem
- High cost (coating)
- High contact resistance

- High electrical conductivity
- Chemical stability
- Low cost
- Flexibility

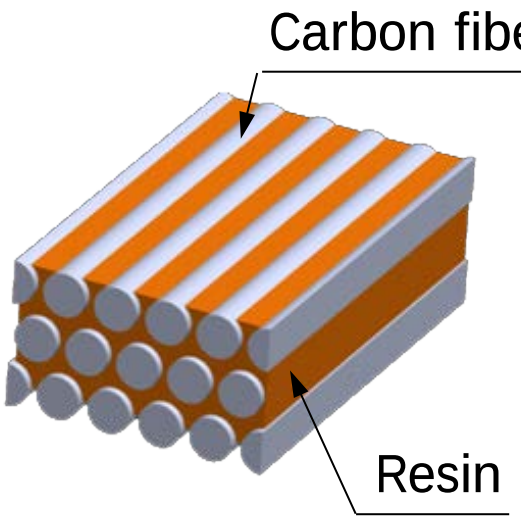
Continuous carbon fiber/epoxy Composite

Bipolar plates

Conventional material



Continuous carbon fiber/epoxy composite



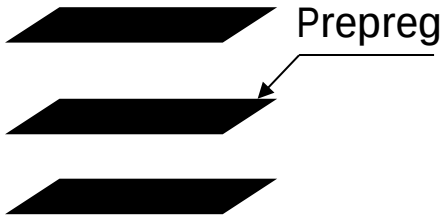
High volume fraction of conducting material

High stiffness and high strength

Uniform quality

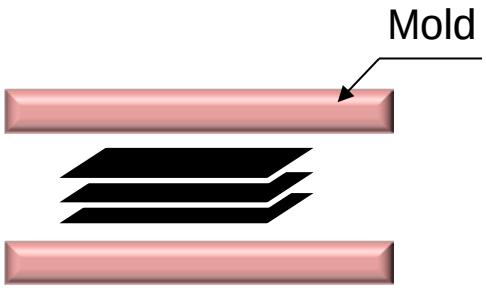
Bipolar plates

How to fabricate ?



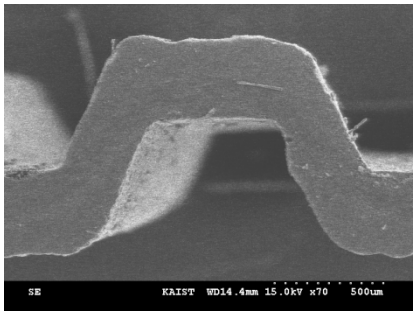
Unidirectional carbon fiber + epoxy resin: prepreg

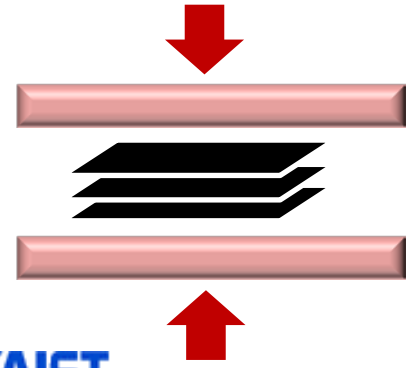
Stacking sequence: variable



Mold: compressive mold

with grooves (flow channel)





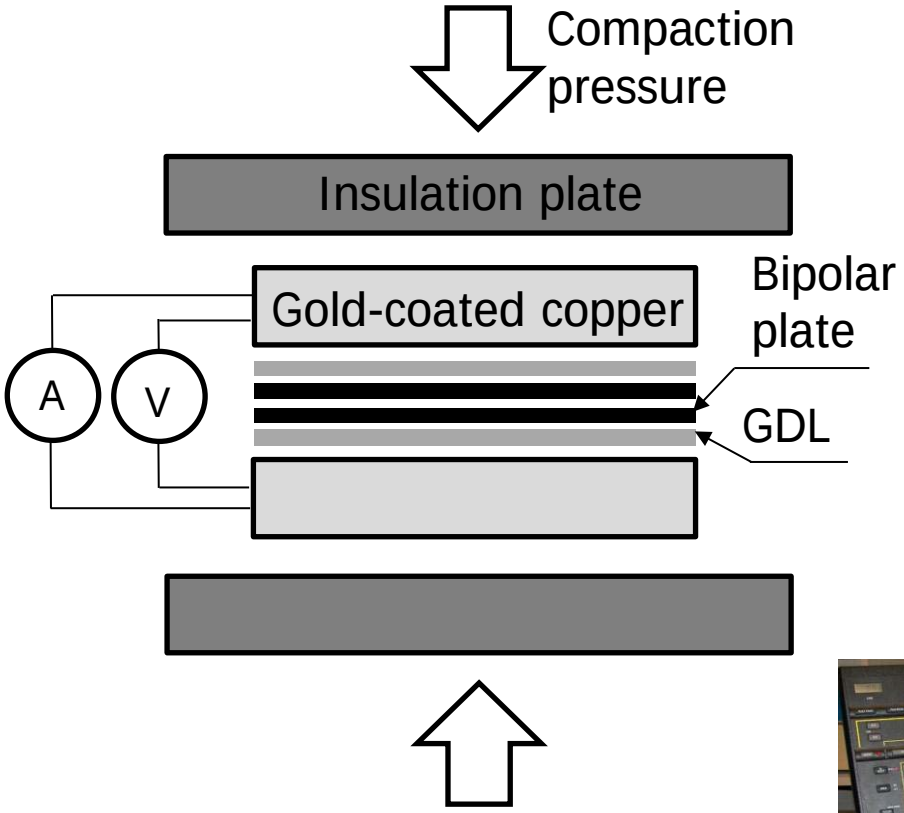
Press: hot press

Curing condition: 120°C for 5 min → 160°C for 20 min

20 MPa

Total electrical resistance

Measuring total resistance of the composite specimens



Total resistance [Ω]

$V = ir \quad (i = I/A, \; r = RA)$

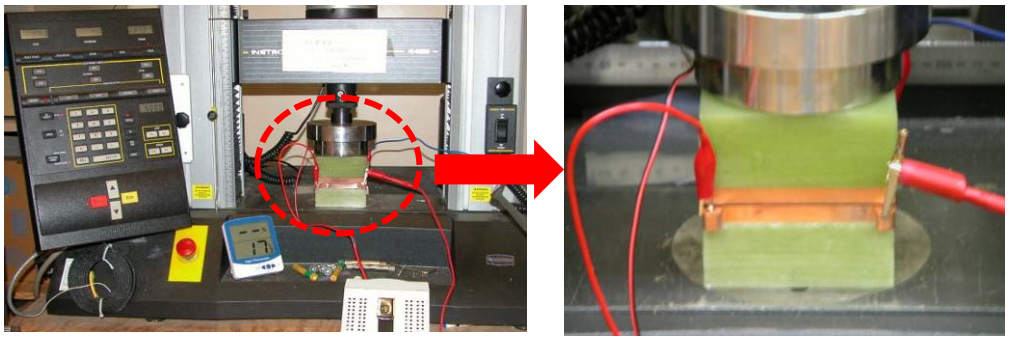
R_c : resistance of specimen

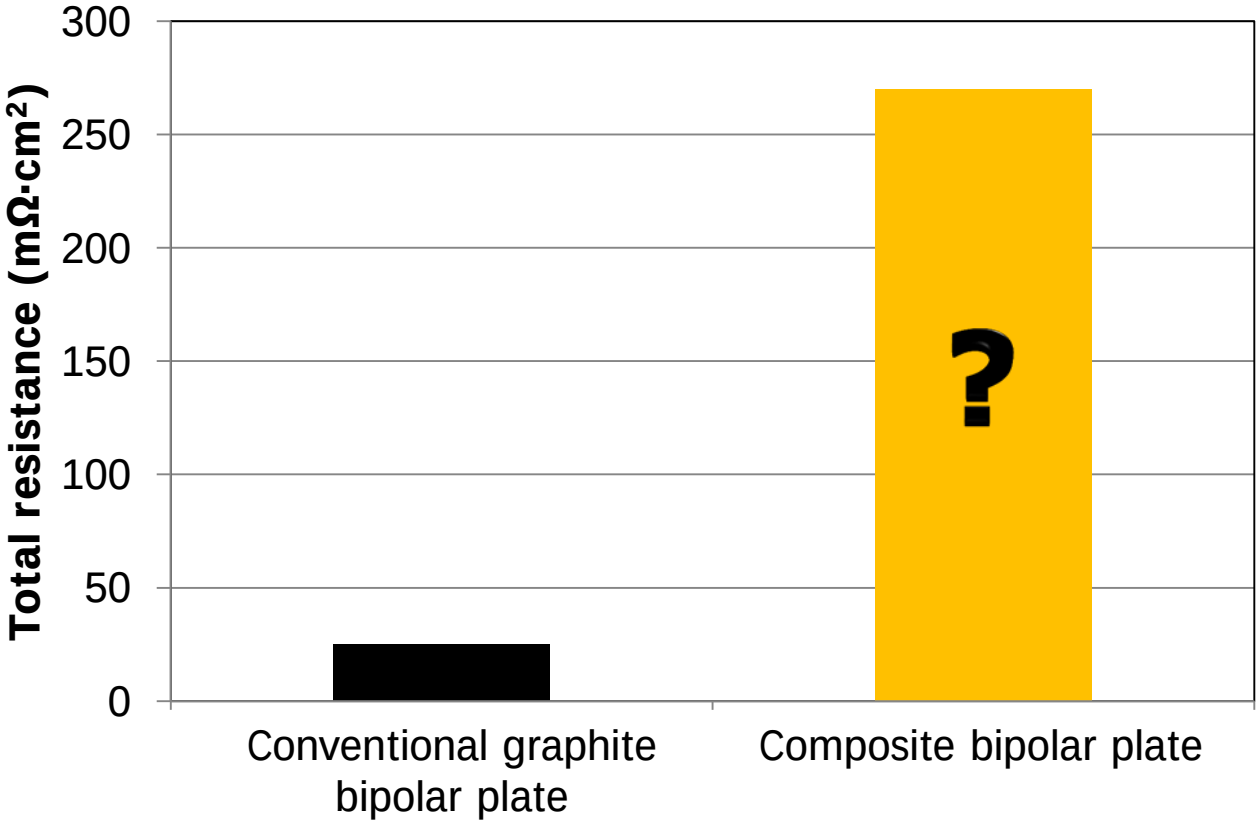
$R_{d/c}$: contact resistance between specimen & gas diffusion layer

R_d : resistance of gas diffusion layer

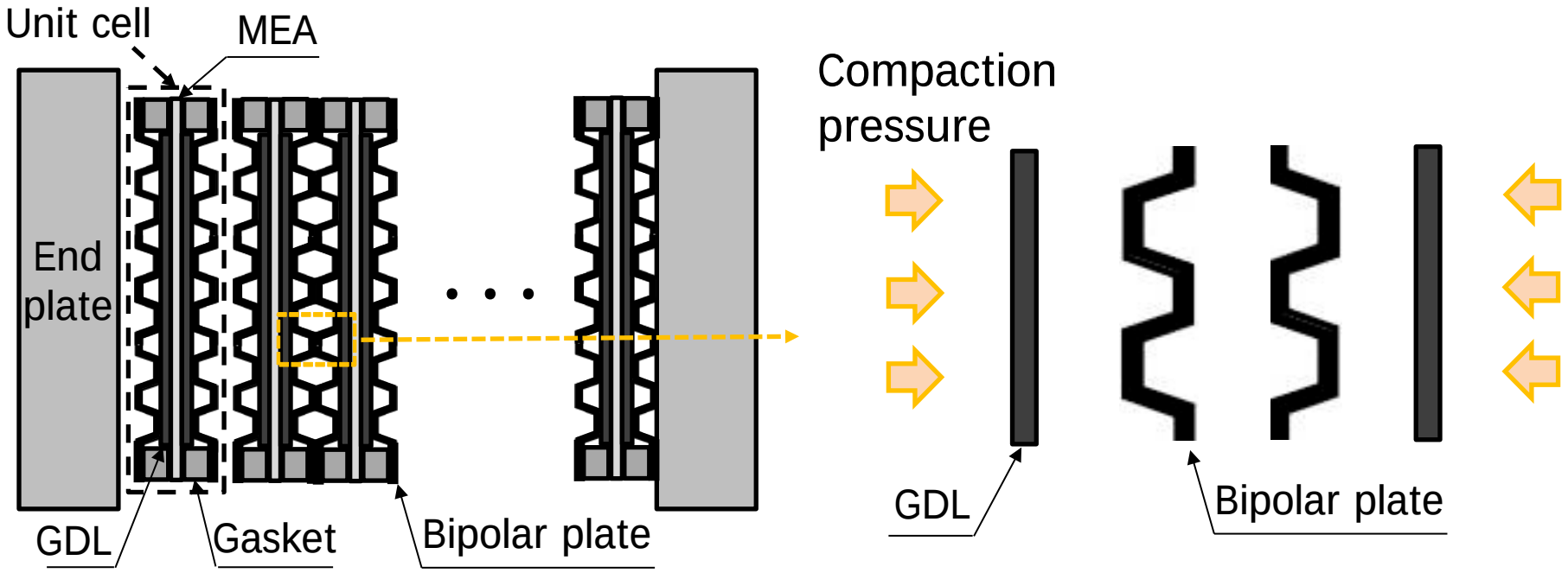
$R_{d/Cu}$: contact resistance between gas diffusion layer & copper plate

R_{total} : $2R_{d/Cu} + 2R_d + 2R_{d/c} + R_c$

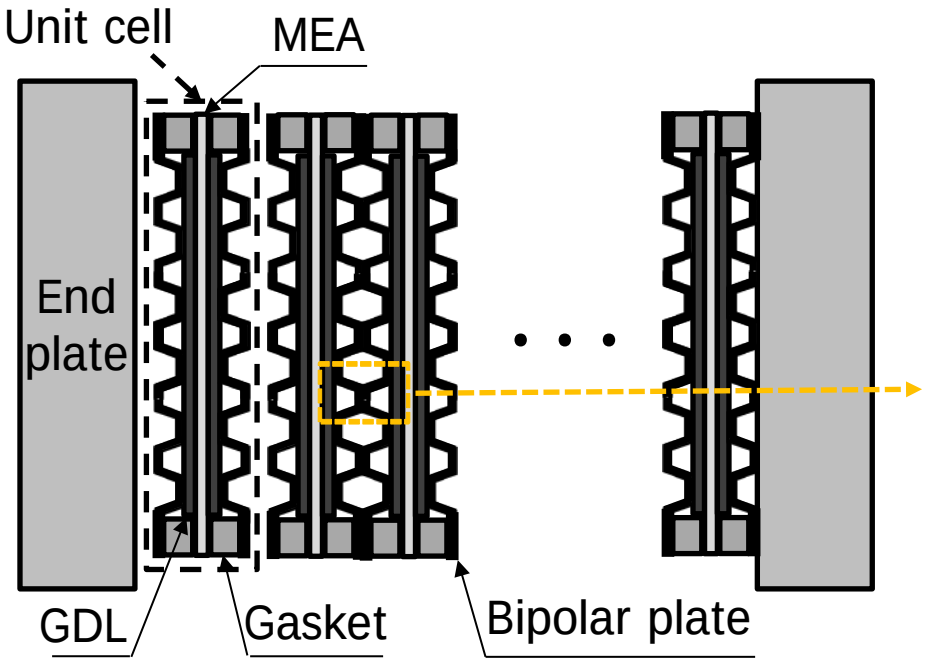


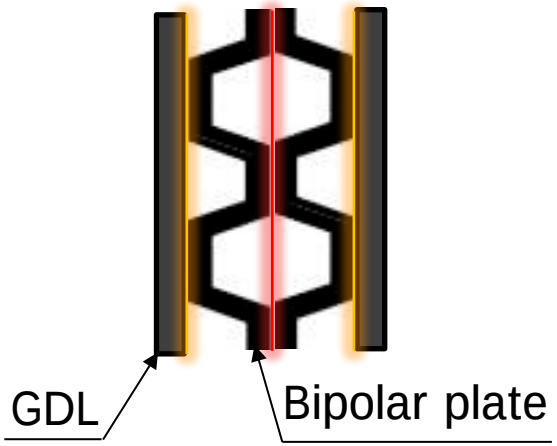

300
250
200
150
100
50
0
Total resistance (mΩ·cm²)
?
Conventional graphite bipolar plate
Composite bipolar plate

Bipolar plates



Bipolar plates

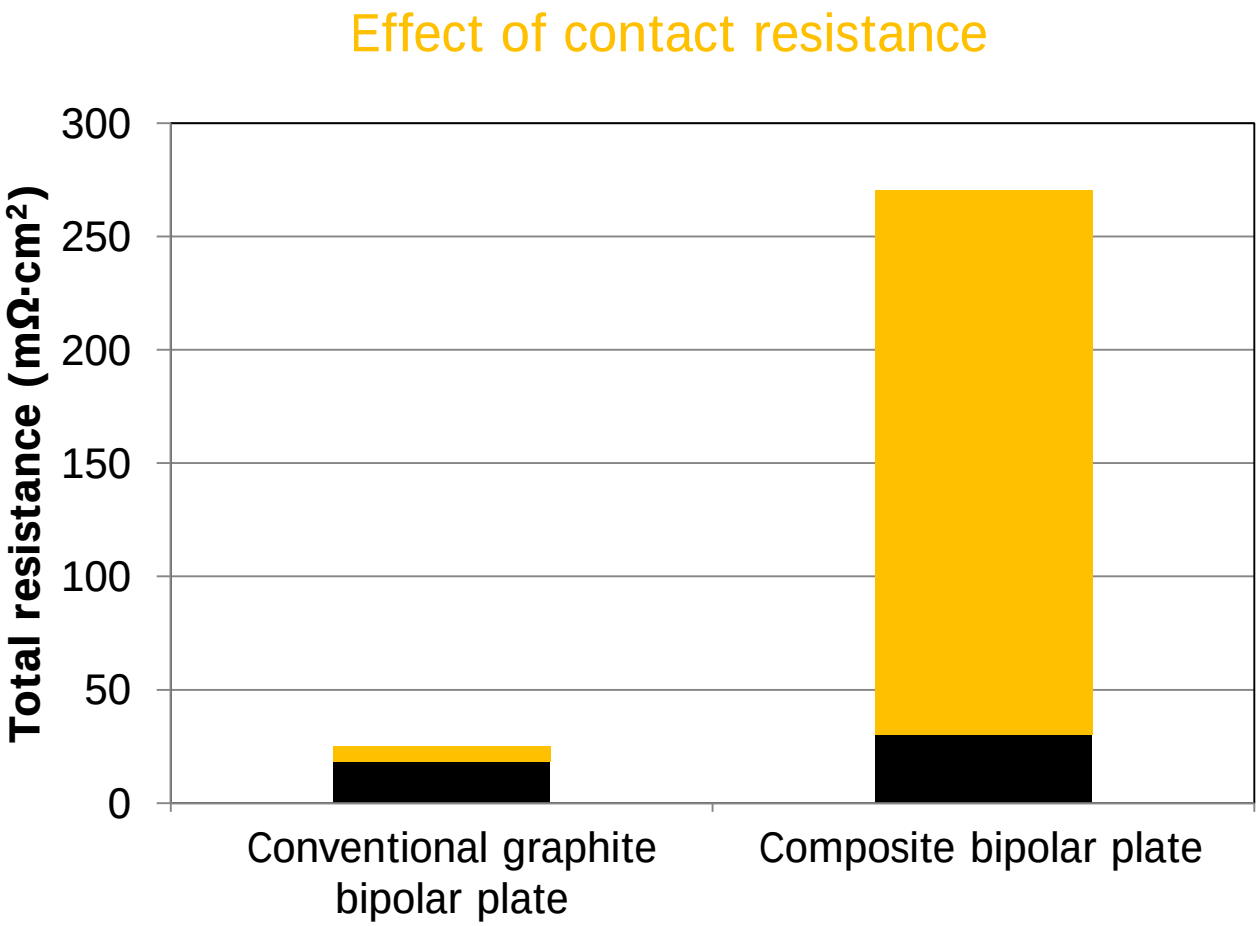




Interfacial contact resistance between bipolar plates

Interfacial contact resistance between bipolar plate and GDL

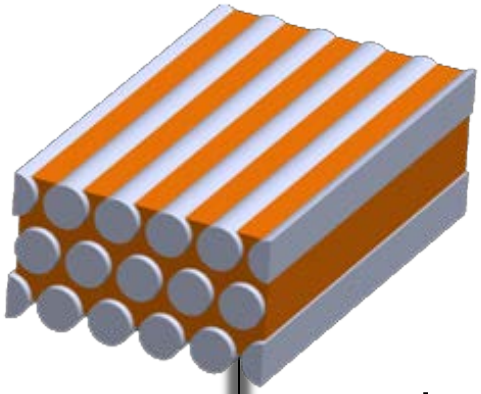
Bipolar plates



How to reduce the contact resistance ?

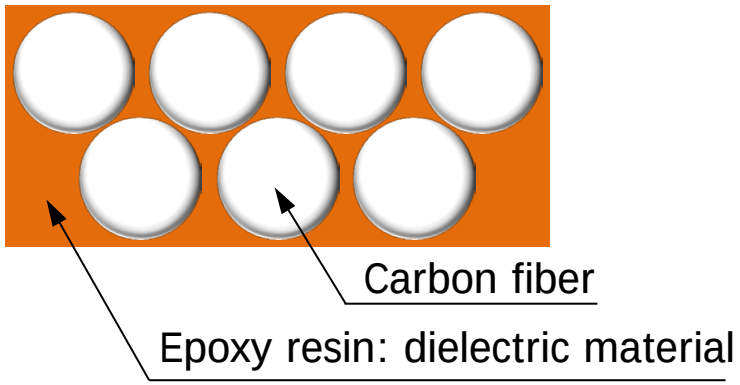
Bipolar plates

Composite = carbon fiber + resin = conducting material + dielectric material

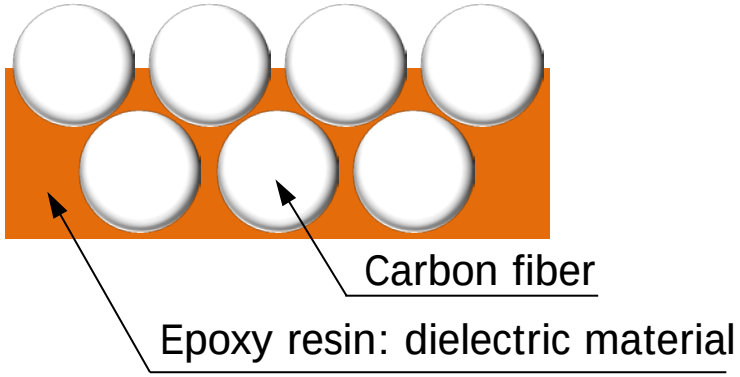


High contact resistance:

surface resin-rich area



Low contact resistance



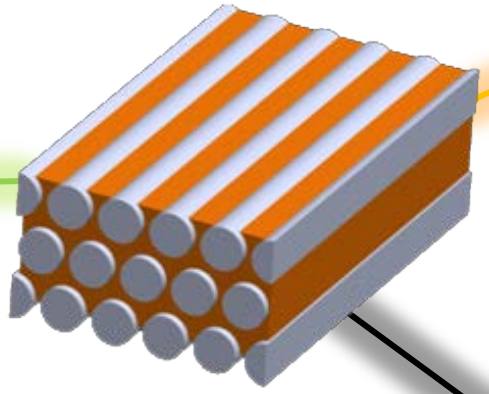
Bipolar plates

How to remove the surface resin ?

Advanced surface modification technique

Microwave-carbon surface modification

SCI paper #2, #3



Plasma treatment

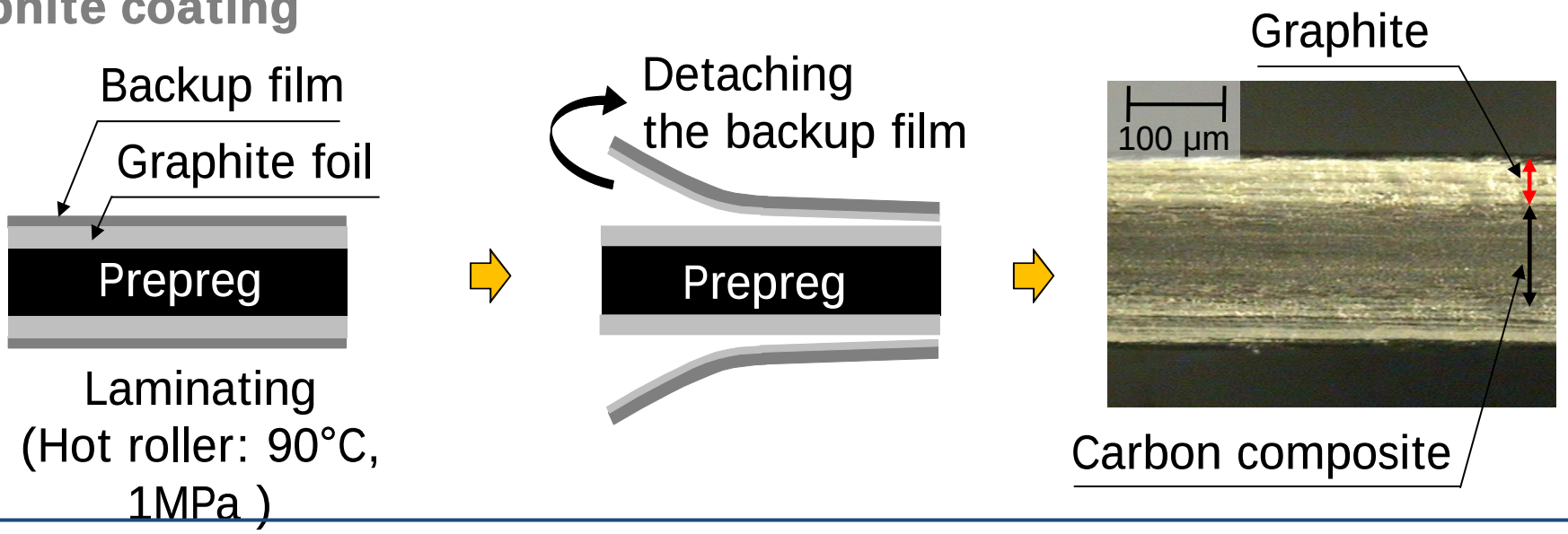
SCI paper #1

Graphite coating

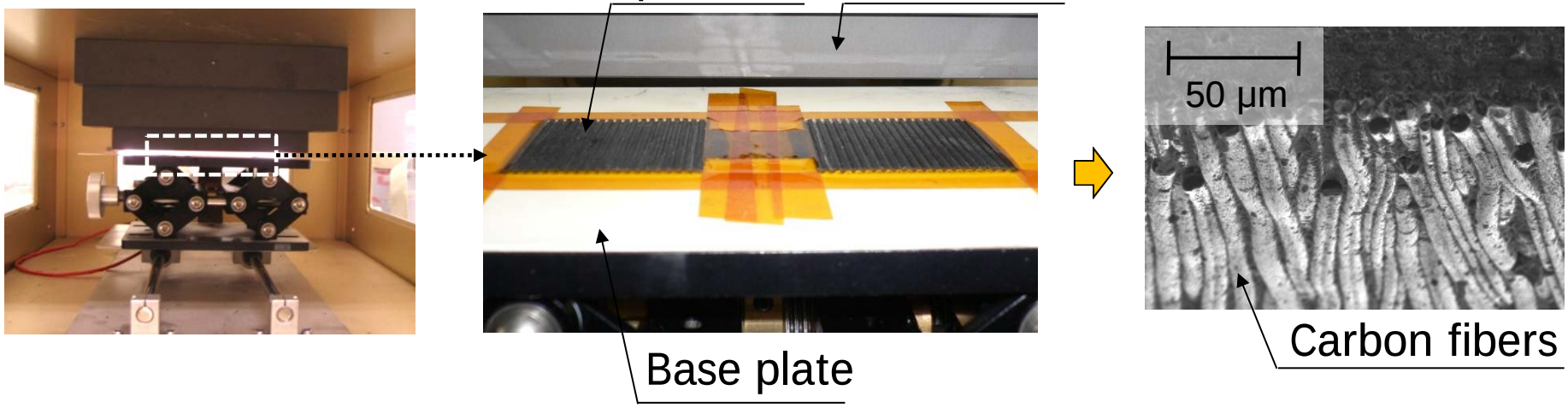
SCI paper #4

Surface treatment of hybrid bipolar plate

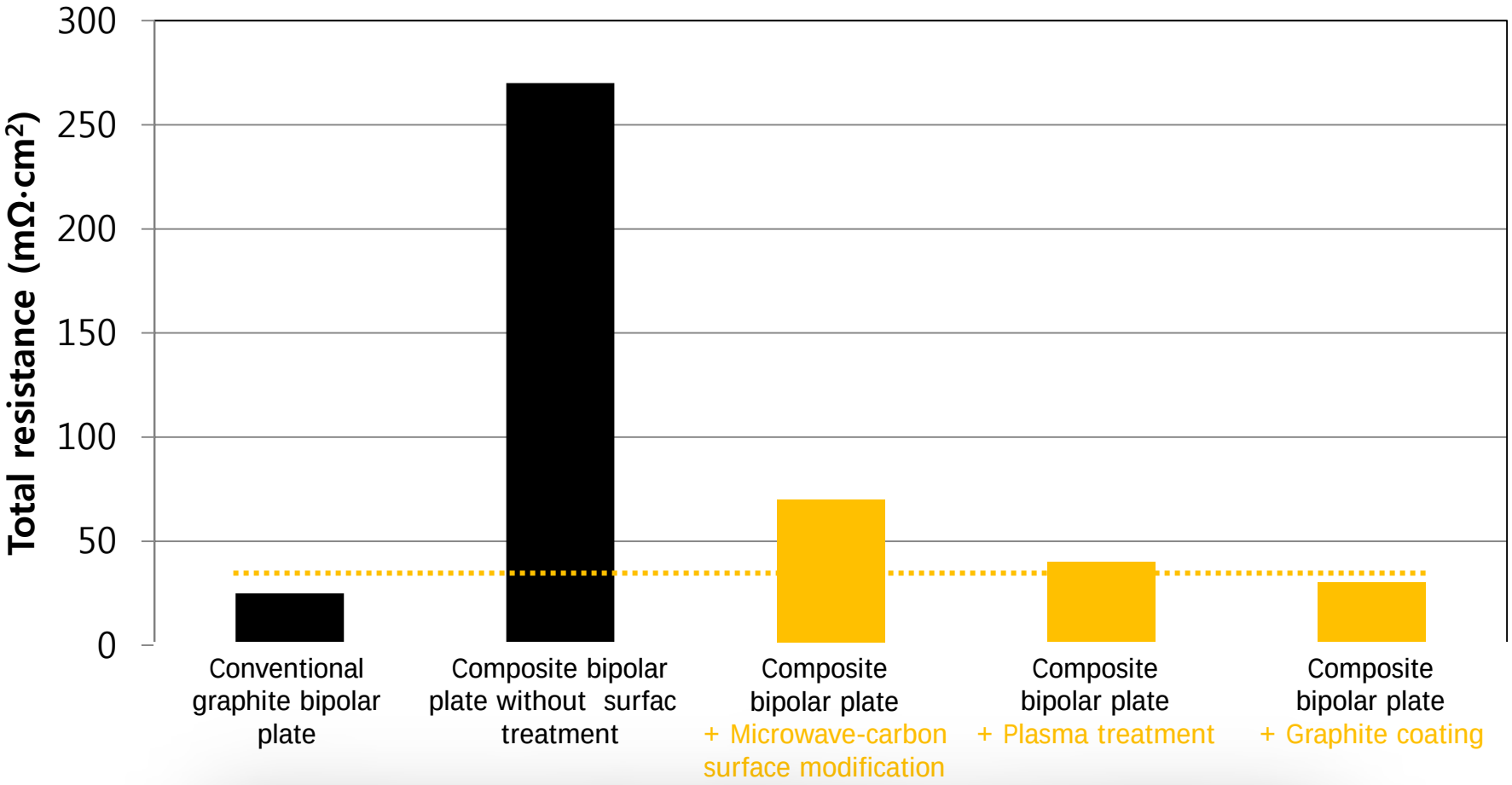
Graphite coating



Plasma surface treatment (150W, 5min)

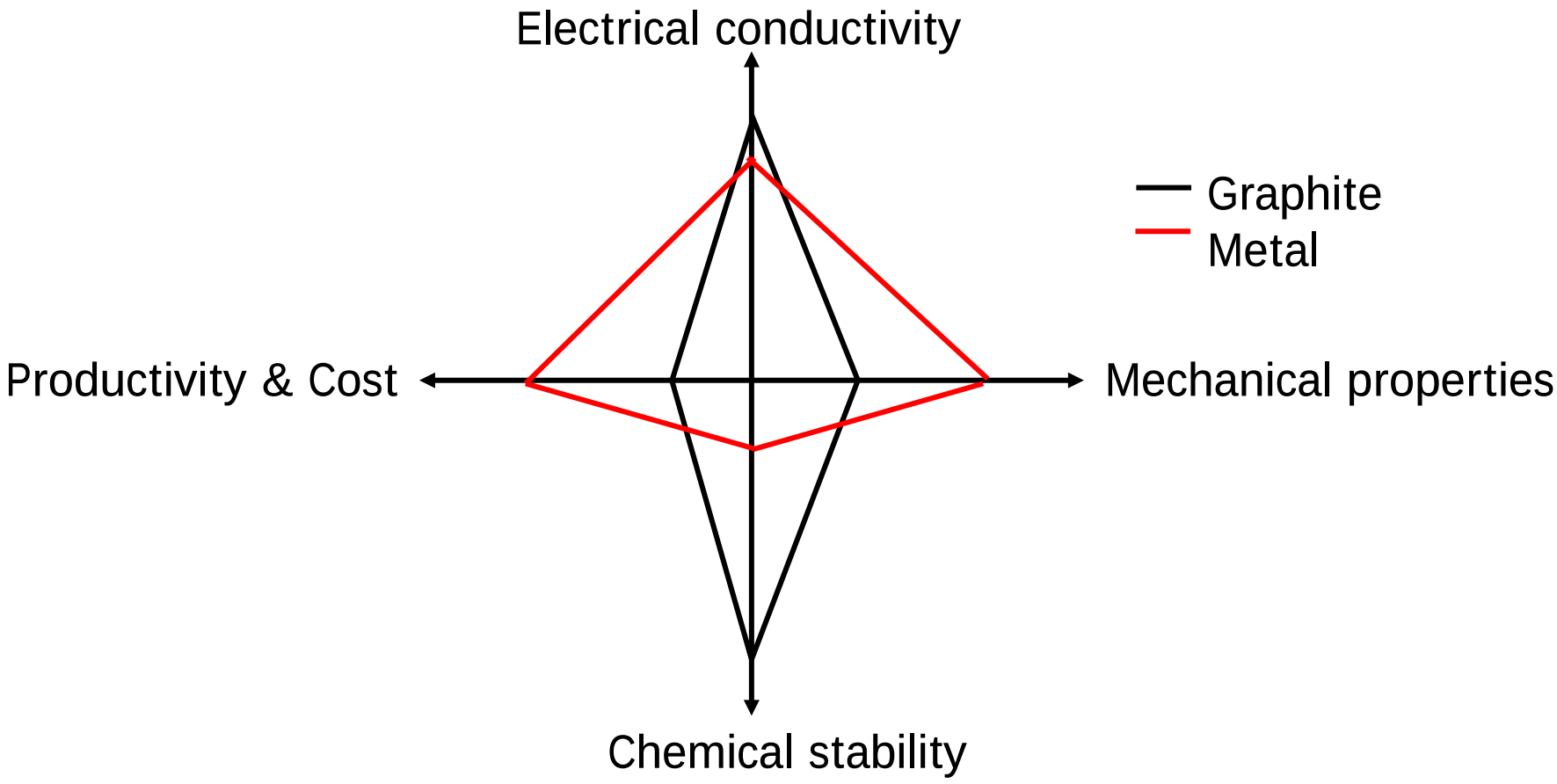


Bipolar plates



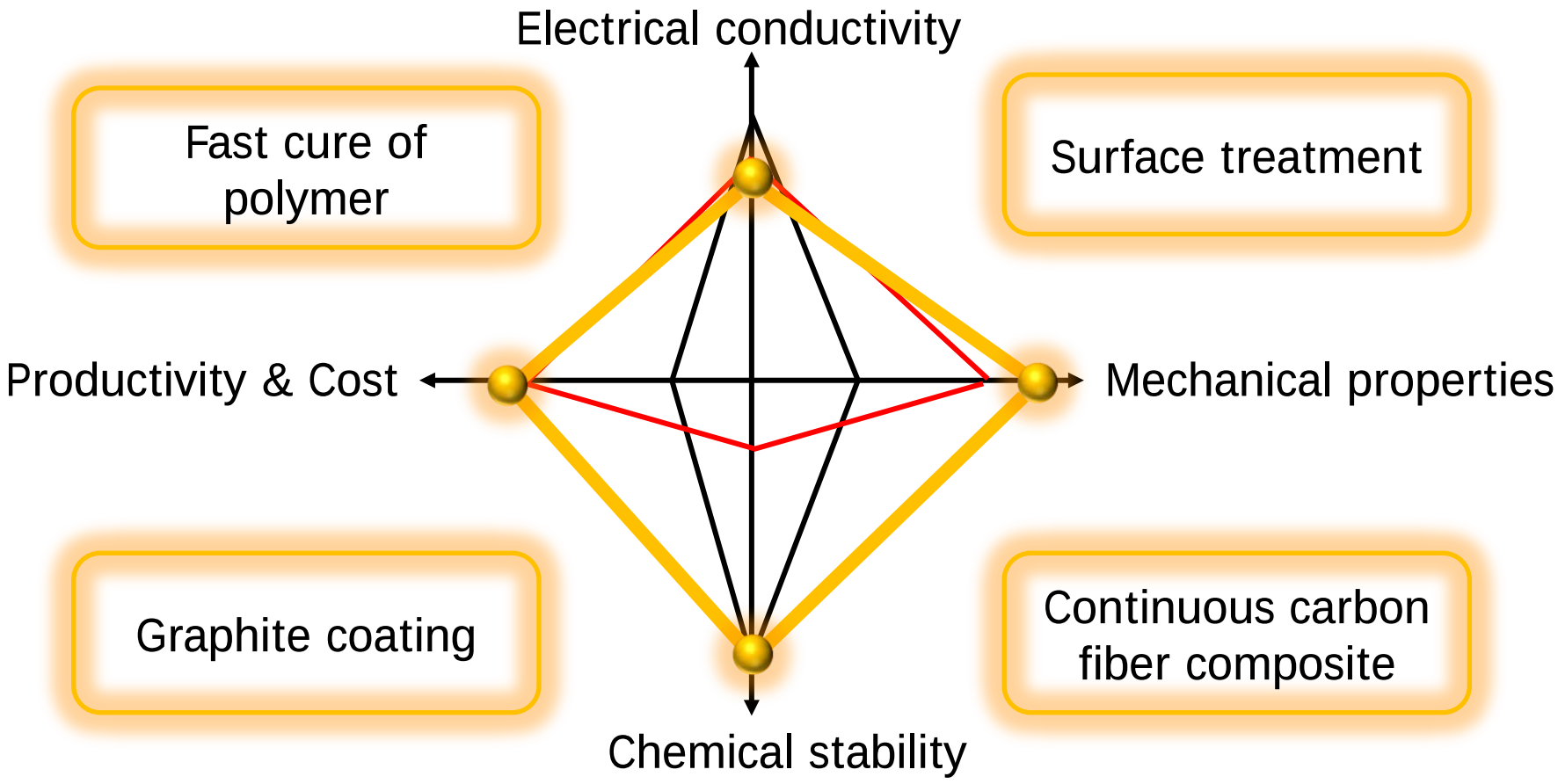
Improvement in progress

Bipolar plates

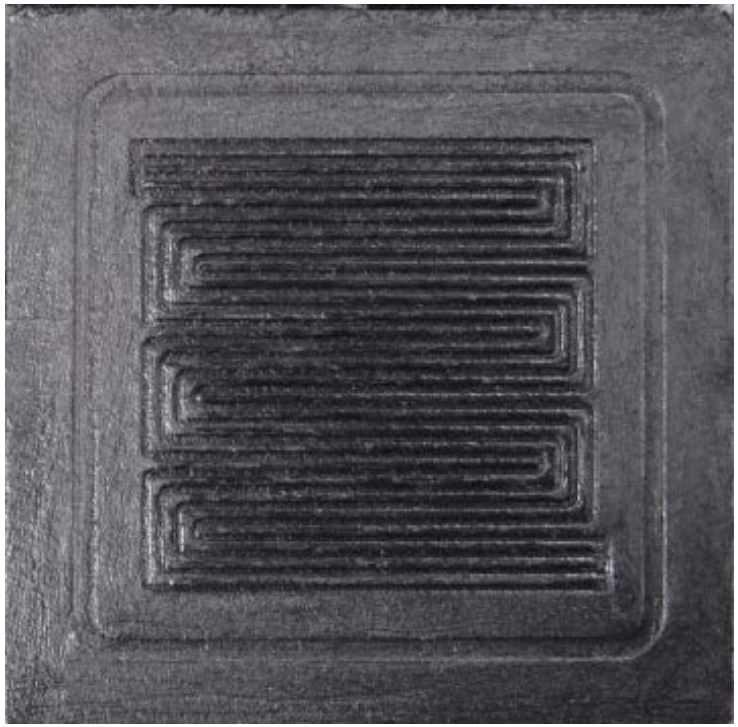


Bipolar plates

Composite bipolar plate



Bipolar plates



0.1 mm thickness

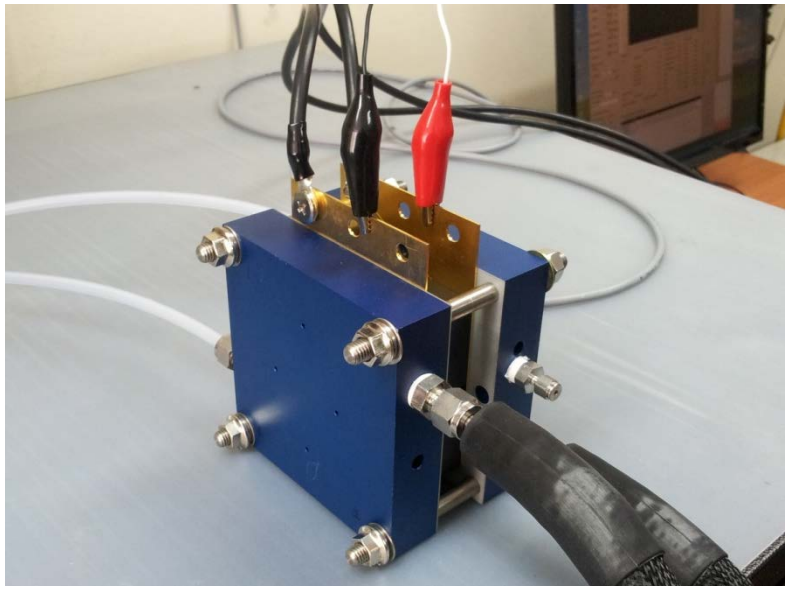
Graphite coated surface

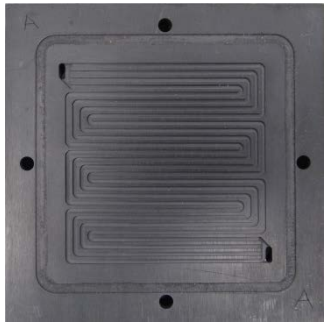
Surface modification technique

Light weight

Applications

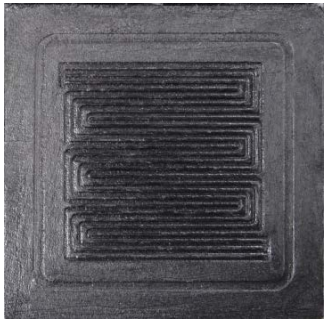
Unit cell test





<Graphite>

<Composite $[0_3/90_3]_s$>



<Graphite coated>

Capacity = 150 W, 32 A

Relative humidity = 100% at 80°C

Cell temperature = 60°C

H_2/Air stoichiometry = 1/3

3 Layer MEA

Active area: 5x5 cm

Membrane thickness: 50 μm

Catalyst: 70% Pt/C

Catalyst Loading: 0.5 mg Pt/cm^2

GDL

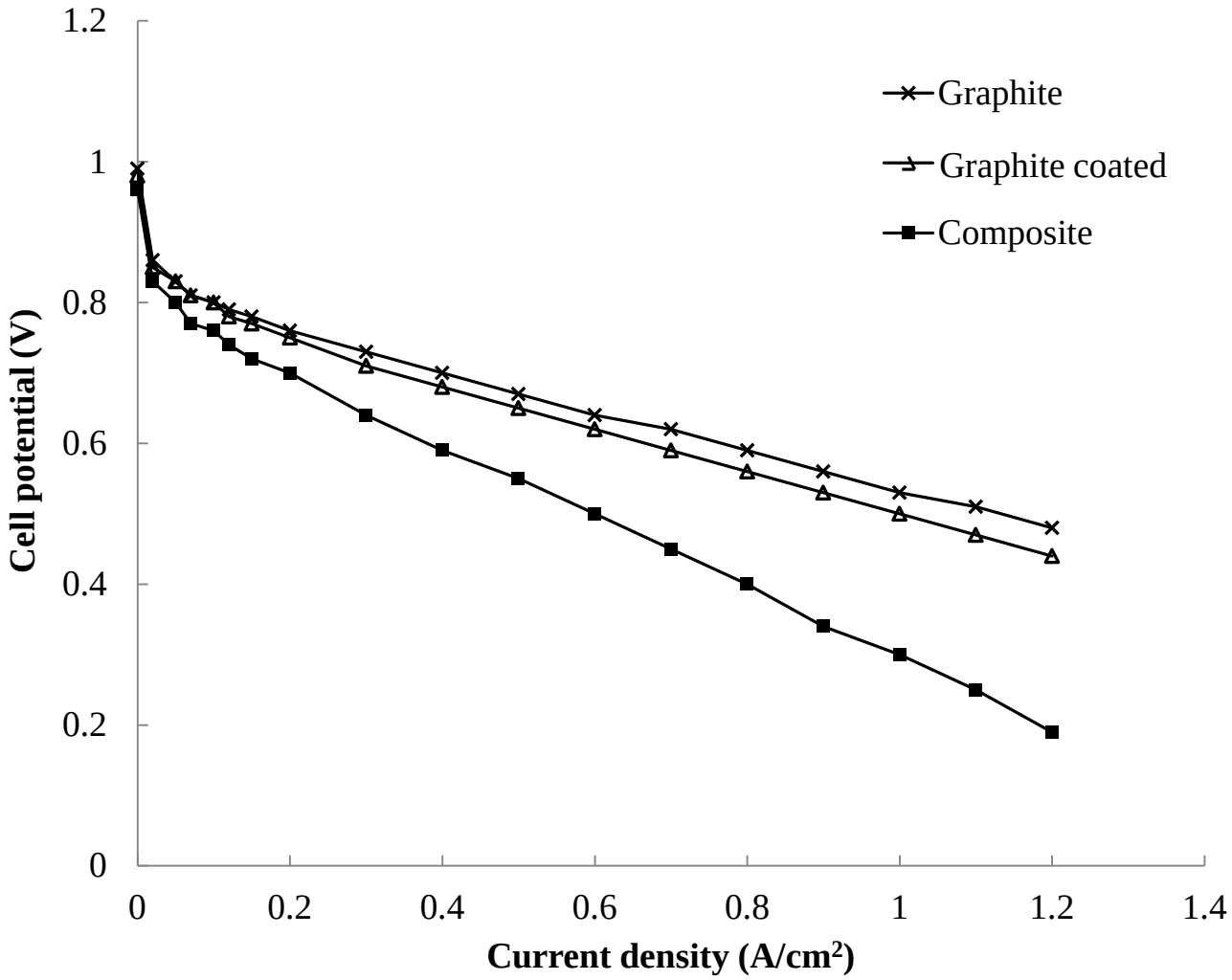
10 BC (SGL Group)

Thickness: 0.4 mm

Unit cell performance assessments

Performed after 2 hours of activation time

Unit cell test



$V_{cell} = E_r - \Delta V_{act} - \Delta V_{con} - \Delta V_{ohm}$

V_{cell} = Cell potential

E_r = Open circuit voltage

ΔV_{act} = Activation polarization losses

ΔV_{con} = Concentration polarization losses

ΔV_{ohm} = Ohmic losses

- Developed bipolar plates show much improved cell performance

200 W light weight PEM fuel cell stack

PEMFC stack

Design target	
Stack weight	**0.7 kg**
System weight	**2.0 kg**
Number of cells	32
Size	115 × 112 × 95 mm
Performance	**28.8 V @ 7.2 A**
Endurance	2 hour

- **Ultra light carbon composite bipolar plates**

  70 g / bipolar plate

- **Composite frame with sandwich construction endplates**

  Weight reduction : 700 g → 200 g

Thank you