휴대형 전자기기 및 이동 전원용 Small Fuel Cell 기술

장 혁

(삼성종합기술원)

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산업은 물론 사회의 각 분야에 있어서 21 세기가 요구하는 기술분야는 기계, 화학, 재료, 전자등의 기간기술을 포함하여 정보화기술, 환경친화기술, 생명공학기술등 범위가 방대할 뿐 아니라 그 기대수준이 매우 높고, 개발 속도는 더욱 가속화 되고 있다. 여러가지 Social Needs 중 전기화학 기술이 담당 해야 할 기술 분야로는 무한청정 대체에너지 개발 과 휴대형 정보통신 단말기의 고기능화를 지원할 수 있는 이동 전원의 개발등일 것이고, Fuel Cell 은 이러한 분야의 일부를 해결할 수 있는 미래 주요 기술중의 하나이다.

본 발표에서는 상온작동, 고용량 및 고출력이 가능하여, 이차전지의 한계를 극복하는 차세대 휴대형 전자기기용 전원과 소형 이동전원은 물론 주택용 전원 및 무공해 자동차등 응용분야가 다양한 PEMFC (Proton Exchange Membrane Fuel Cell) 와 DFMC (Direct Methanol Fuel Cell) 기술을 소개하고자 한다. 특히 이에 필요한 요소 기술인 고출력밀도 촉매전극 및 MEA (Membrane & Electrode Assembly) 기술, 수소이온 전도막 기술, 그리고 Cell Pack 혹은 Stack 기술의 원리 및 최근 개발 동향에 대하여 언급하였다.

또한, 당 팀에서 개발한 Small Fuel Cell 기술 중 고효율 MEA 재료 및 공정 (0.3 W/cm^2, Dry H_2/Air, 상온, 상압 ; 0.1 W/cm^2, 2M Methanol/Air, 80C, 상압), Nafion 대체 수소이온 전도막 재료 (0.1 S/cm), 그리고 소형 PEMFC Stack (40 W, 100 W, 200 W) 과 DMFC Cell Pack (600 mW) 기술을 소개하고, 선진기술 혹은 목표수준과 비교하여 앞으로 연구력을 집중해야 할 분야들을 소개함으로써 국내의 Small Fuel Cell 관련 기술의 발전 및 실용화를 도모하고자 한다.

Technology Review

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휴대형 전자기기 및 이동 전원용
Small Fuel Cell 기술

삼성종합기술원

장 혁

Battery Symposium, Dec.1. 2000

Social Needs

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■ 전기화학기술이 담당 해야 할 21세기의 Social Needs

✓무한 청정 대체에너지

✓휴대형 정보통신 단말기의 고기능화를 지원할 수 있는

고출력밀도, 고에너지밀도, 초소형화 및 충전시간 단축을 실현한 전원장치

■ Battery vs. Fuel Cell

Rechargeable Battery의 한계		Fuel Cell로 해결
제한된 사용시간	New Concept →	사용시간 연장 (Theo. 5 X)
긴 충전시간		충전 불필요 (1분 이내 Refill)
공해유발 발전소의 유지 필요		소형화 및 고출력 가능
		무한 청정에너지

Research Objectives

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- 21세기 무공해 대체 에너지기술 확보
- Battery의 한계 (충전시간, 사용시간)를 극복하는 차세대 이동전원으로써 상온 작동, 고용량, 고출력 *Portable Fuel Cell*의 연구 개발

↑

- 고출력 MEA (Membrane & Electrode Assembly) 개발
- 저가격 Proton Exchange Membrane 재료 개발
- PEMFC, DMFC Cell Pack / Stack 개발 및 실용화를 위한 요소기술 확보

Technology Principle

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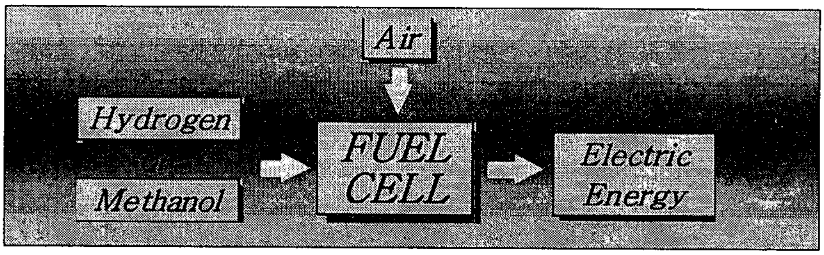
Fuel Cell Concept



Electrochemical Reactions

$H_2 \Rightarrow 2H^+ + 2e^-$

$O_2 + 2H^+ + 2e^- \Rightarrow H_2O$

$H_2 + 1/2O_2 \Rightarrow H_2O$ (E = 1.23V)

$CH_3OH + H_2O \Rightarrow CO_2 + 6H^+ + 6e^-$

$3/2O_2 + 6H^+ + 6e^- \Rightarrow 3H_2O$

$CH_3OH + 3/2O_2 \Rightarrow 2H_2O + CO_2$ (E = 1.21V)

Technology Principle

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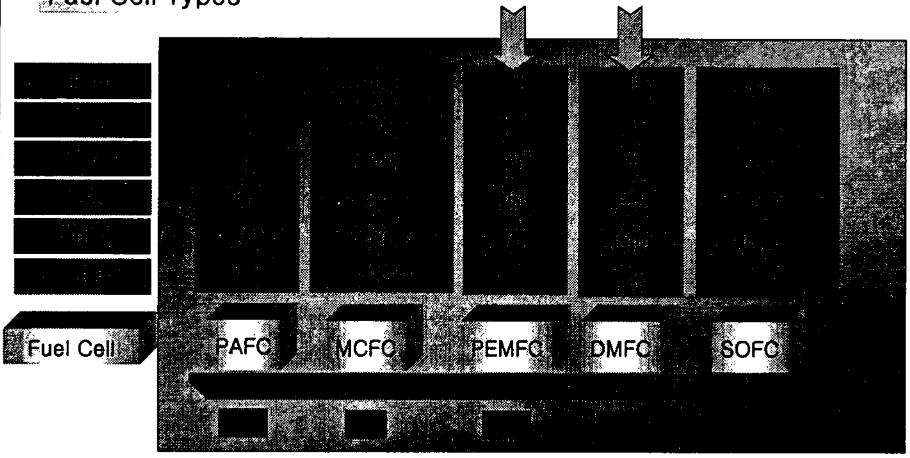
Fuel Cell Types



Technology Principle

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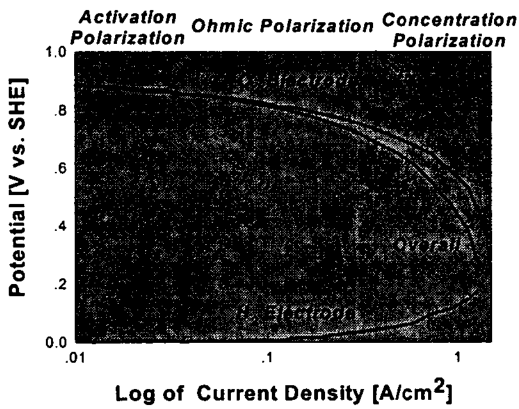
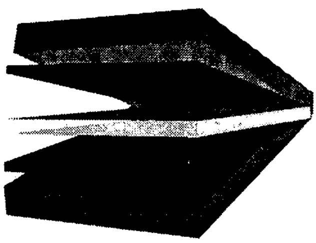
Polarization





MEA

Applications (PEM & DMFC)

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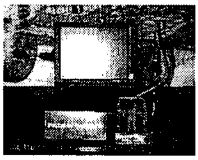
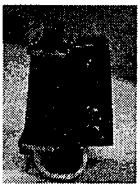
- Portable Electronic Devices (Note PC, Cellular Phone, PDA, Portable Power)
- Stationary Stand-alone Power (House Utilities)
- Fuel Cell Vehicle (ZEV or LEV)

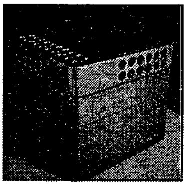


Ref. Samsung

Ref. Samsung



Ref. www.daisanalytic.com



Ref. www.ballard.com

Ref. www.daimlerchrysler.de

Technology Trend

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Core Technology	Technical Issues
MEA	· Catalyst Electrode Process · High Power Density MEA · Self Humidified (Water Management Electrode) · Air Breathing Diffusion Layer · CO Tolerant Catalyst · Catalyst Coating (Catalyzed Membrane)
Membrane	· High Proton Conductivity / Conductance · Chemical / Mechanical Stability · Low Cost · Low Methanol Cross-over
Cell Pack	· Thin & Light Bipolar Plate · Cell Pack Design · Ambient Temp./Ambient Pressrue Operation

Technology Trend

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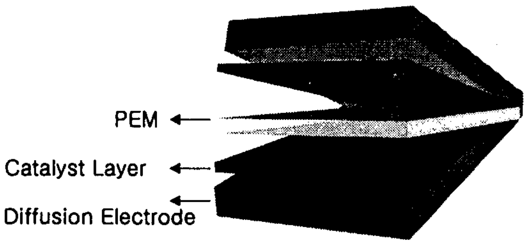
고출력 밀도 MEA Process



- Catalyst Electrode
  - ✓Spray Coating
  - ✓Decal Process
  - ✓Tape Casting...
- Catalyzed Membrane
  - ✓Spray Coating
  - ✓Vapor Deposition
- MEA Bonding

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Technology Trend

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MEA Microstructure

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Technology Trend

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Why Pt

- H_2 dissociation ΔG_{298} = 412 kJ/mol
- O_2 dissociation ΔG_{298} = 468 kJ/mol
- H + O_2 or H_2 + O activation 40 kJ/mol
- 2Pt + H_2 --> 2 Pt-H zero activation
- 2Pt + O_2 --> 2 Pt-O zero activation
- 1/2 O2 + H_2 --> H_2O ΔG_{298} = -232 kJ/mol

Why Ru

- activate water or form surface oxides at lower potential
- CO absorption bond is less strong on Pt-Ru
- Pt-Ru ensemble
  oxidative methanol dehydrogenation on Pt by oxygen-like species on Ru
- OH_{ads} species on Pt-Ru pair sites

Technology Trend

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Proton Exchange Membrane

- Strong functional radicals : high rapid exchange capacity
- Water dissociation of the polar sulfonic acid groups
  ⇒ releases protons from SO_3^- groups
  ⇒ hydrated
  ⇒ protons move

- Ionic conductivity : ~0.1s/cm
- Gore-Select : 12㎛, 80 s/cm at 25C, 0.1 s/cm
- Nafion 117 : 200㎛, <10 s/cm at 25C, 0.15 s/cm

Technology Trend

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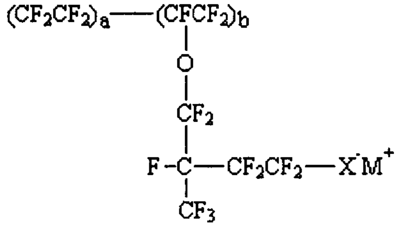
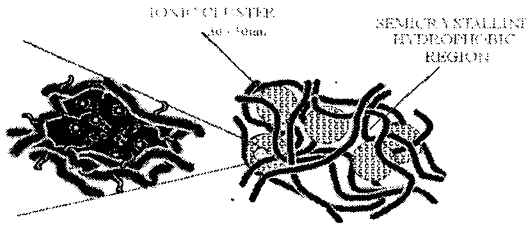
Nafion





Technology Trend

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Stack or Cell Pack

- **JPL / USC / Giner** ***DMFC***
  25W ~ 200W for charger & cell phone (Composite membrane, PSSA/PVDF)
- **H-Power** ***PEMFC***
  50W ~ 200W for message sign, military, telecommunication
- **LANL / Motorola** ***PEM / DMFC***
  1W with dc/dc converter for cell phone
- **Fraunhofer Inst.** ***PEM / DMFC***
  250mW ~ 30W for Note PC with dc/dc converter (Micromachined bipolar plate)
- **MSI** ***DMFC***
  Nuclepore membrane with Pd layer for cell phone (300Wh/kg)
- **SAIT** ***PEM / DMFC***
  1W ~ 200W for portable electronic devices

Technology Trend

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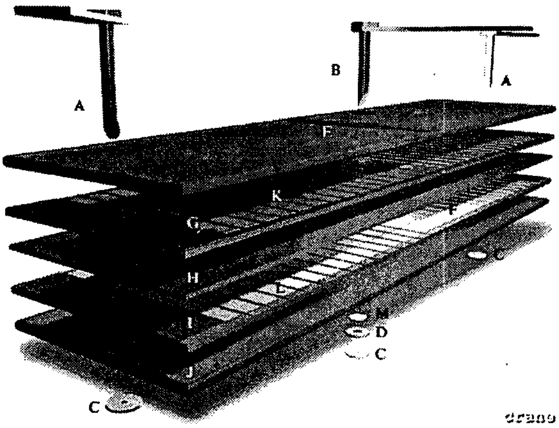
Micro Fuel Cell ™



A. Air Electrode Contact Rivet
B. Fuel Needle
C. Rivet Fold Out
D. Upper Gasket Ring
E. Lower Gasket Ring
F. Through Contacts
G. First Set of Fuel Cells
H. Fuel Manifold
I. Second Set of Fuel Cells
J. Air Manifold
K. Air Electrodes
L. Fuel Electrodes
M. Contact Washer

Technical Achievements at SAIT

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MEA

- Humid H_2/O_2 1Bar : 0.6 W/cm^2
- Dry H_2/Air 1Bar : 0.3 W/cm^2
- 2M MeOH/Air 1Bar : 0.1 W/cm^2
- PFSI Electrode & Catalyzed Membrane Process
- Water Management Electrode

Membrane

- Partially Fluorinated Membrane (Sulfonated PTFS)
- Composite Membrane

Stack / Cell Pack

- Light Weight / Thin Bipolar Plate
- Cell Unit Type Stack
- CAE Type Monopolar Pack
- 1W, 40W, 100W & 200W

Technical Achievements at SAIT

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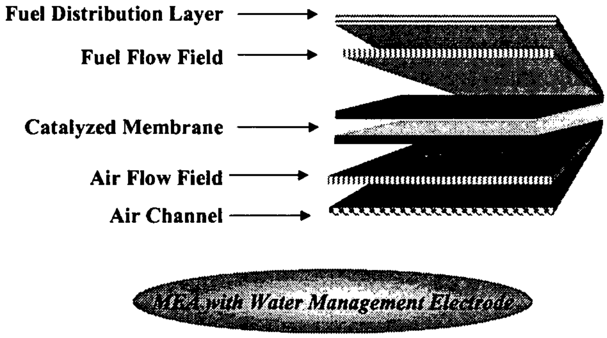
MEA Process



Technical Achievements at SAIT

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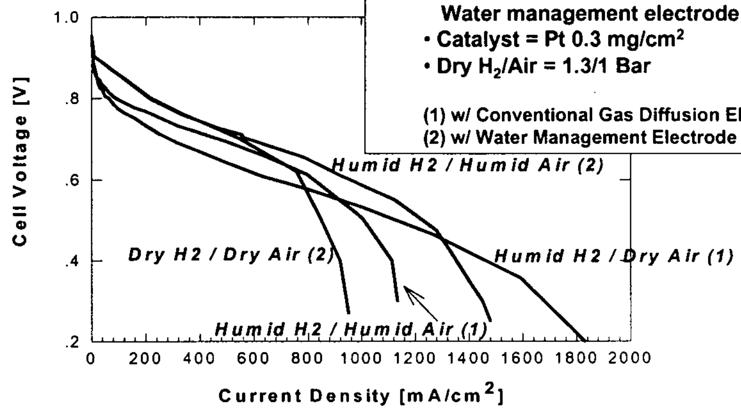
H_2-Air Operation (PEMFC)

- Catalyzed membrane (Naf.112) assembled with Water management electrode
- Catalyst = Pt 0.3 mg/cm^2
- Dry H_2/Air = 1.3/1 Bar

(1) w/ Conventional Gas Diffusion Electrode
(2) w/ Water Management Electrode



Technical Achievements at SAIT

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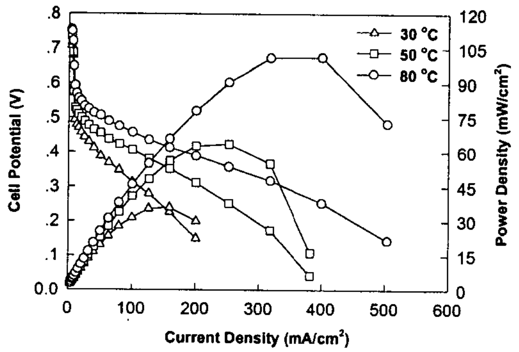
Methanol -Air Operation (DMFC)



Technical Achievements at SAIT

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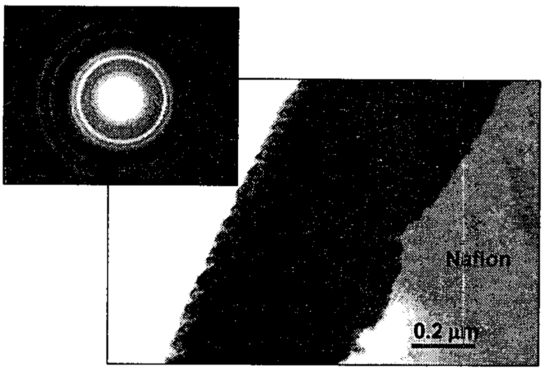
TEM Microstructure (PtRu-C/Nafion)



- Columnar growth with voids in between
- Rigid Contact
- Layer thickness : 0.5 µm (conventional : 20 ~ 30 µm)
- Nanocrystalline with 10 nm grain width
- Diffraction pattern shows fine crystalline
- Co-sputtering with Carbon retards the directional growth of PtRu
- Uniform distribution of PtRu and Carbon

Technical Achievements at SAIT

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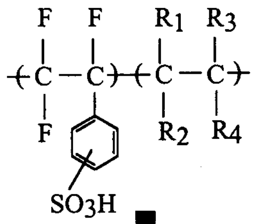
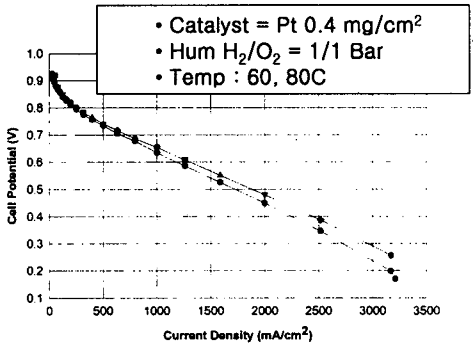
Partially Fluorinated (Sulfonated PTFS) Membrane





- ✓ Low Cost Membrane
- ✓ High Protonic Conductivity
- ✓ Mechanical & Chemical Stability

Technical Achievements at SAIT

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Composite Membrane

■ Second Phase Dispersed Membrane

Matrix : Nafion

Dispersoid : Silica (3 wt.%, 15nm)

⇒ Thickness < 100 μm

Ionic Conductivity : 0.08 s/cm at R.T

■ Reinforced Membrane

Matrix : Nafion / PTFS

Substrate : Microporous PTFE / PVDF

⇒ Thickness< 30 μm

Ionic Conductivity : 0.07 s/cm at R.T

- ✓ Water Absorption
- ✓ Mechanical Stability
- ✓ Thin & Higher Conductance
- ✓ Low Methanol Cross-over

Technical Achievements at SAIT

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Light Weight Bipolar Plate

- Electrically Conducting Carbon Composite Laminate Plate
- Conductance : 1850 s/cm^2
- Thickness : 250 ~ 300 μm

⬇

✓ Cost effective / Highly flexible / High conductance
✓ Gas tight at the hydrogen pressure of 1.4 Bar
✓ Attached gas flow field
⇒ Anode : Parallel & orthogonal flow field
⇒ Cathode : Thin carbon/plastic channel structure & flow field

Technical Achievements at SAIT

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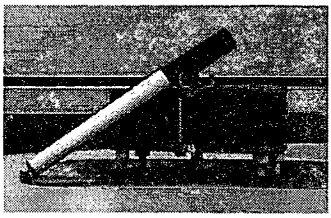
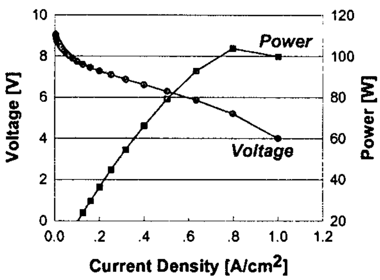
Stack I



- Nominal Power : 90 W
- Operation : R.T ~ 70 °C, Dry H_2/Air
- 150 g / 100 cc
- 600 W/kg, 900 W/L

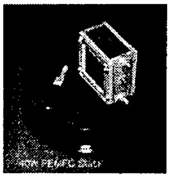


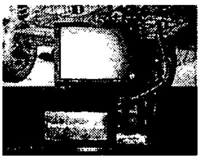
⬇

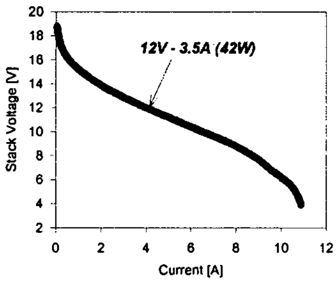
✓ Dry Fuel Operation
✓ Small & Light Stack

Technical Achievements at SAIT

Stack II







- Nominal Power: 40 W
- Energy Density: 140 Wh/kg (w/MH)
- Operation: 30°C, Dry H_2/Air
- 90g / 90cc
- 440 W/kg, 440 W/L

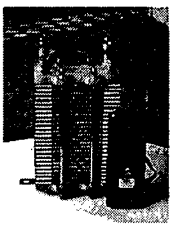
✓ Ambient Temp. / Pressure Operation

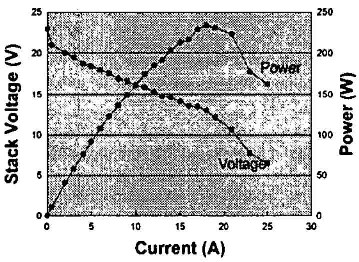
✓ No Moving Part (Except for Mini Fan)

✓ Operating Note PC for 6 hrs w/o refueling

Technical Achievements at SAIT

Stack III





- Nominal Power : 200 W (12V)
- Max. Power : 250 ~ 300 W
- Operation: 40~50°C Dry H_2/Air

✓ Portable Power Source

✓ Leisure or military application

Technical Achievements at SAIT

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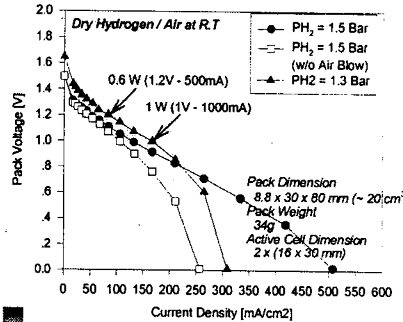
Cell Pack I



✓ Monopolar Type 1W Cell Pack

✓ Concept Design of Cellular Phone Operated by Fuel Cell

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Technical Achievements at SAIT

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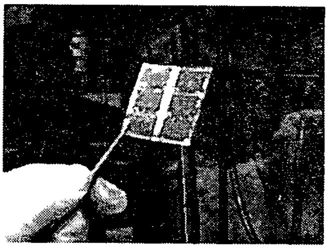
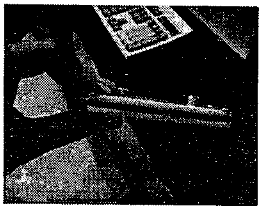
Cell Pack II





- Power Output: 2V – 40 mA
- Operation: Room Temp., 2M MeOH/Air
- 1.5g / 600 μm Thick

✓ Achievement of Basic Performance for 6 Cell Monopolar Cell Pack

✓ Under Development of Miniature Fuel Cell Technology

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Further Studies

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• Methanol Oxidation Catalyst • CO Tolerant Catalyst
• Oxygen Reduction Catalyst • Catalyst Supporting Materials
• Catalyst Electrode Process • Catalyzed Membrane Process
• 고출력 밀도 MEA

• Monomer 합성 및 Polymer
• Nafion 대체 Ionomer • Methanol Cross-over Membrane
• Composite Membrane 개발 • Membrane Casting 공정

• Liquid Flow Field 재료 및 Design
• Gas Flow Field 재료 및 Design

• Methanol Storage 및 Flow Mechanism • Circuit Design
• Sealing 기술 • Packaging 기술 • 연속 공정
• Cellular Phone용 Module • Cellular Phone 탑재
• Cycle Test • 고출력사용특성 개선

Conclusion
(Energy Storage Device Technology Roadmap)

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