3R

Recycle

Reuse

Reduce

EUDP

The Energy Technology Development and Demonstration Programme

IRD

Cost-efficient and environmentally friendly recycling of materials in PEM fuel cells and electrolysis cells

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IEA Annex 31 Topical Meeting,
Graz, November 10, 2021

IRD Fuel Cells A/S

- Manufacturer of membrane–electrode assemblies (MEAs) and flow plates for proton-exchange membrane fuel cells and electrolyser cells (PEMFC & EC).
- Focusing mainly on low-temperature (LT) PEMFC, DMFC and PEMEC technology.
- Founded in 1995 in Svendborg, Denmark, as a fuel-cell R&D company.
- Headquarter, R&D and production in Odense plus MEA production line in New Mexico, USA.
- 58 employees within R&D, customisation, production, sales, QHSE and administration.
- Close collaboration with many research groups worldwide.

EUDP 3R Recycle Reuse Reduce

Current project on recycling

- **Title:** 3R – Recycle, Reuse, Reduce
- **EUDP file number:** 64019-0551
- **Duration:** 45 months
- **Period:** 01.04.2020–31.12.2023
- **Coordinating partner:** IRD Fuel Cells A/S
- **Other partners:** CriMaRec ApS and SDU Dept. of Green Tech.
- **Total budget:** 14.02 MDKK (1.88 MEUR)
- **EUDP grant:** 9.45 MDKK (1.27 MEUR)

3R

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Danish Energy Agency

EUDP

The Energy Technology Development and Demonstration Programme

CRIMAREC

Critical Material Recovery

SDU

University of Southern Denmark

Project partners

- University of Southern Denmark (SDU), Department of Green Technology, Chemical Engineering:
  - Research group of Associate Professor Shuang Ma Andersen.
  - Preparation of new catalysts and ionomer from spent MEAs.
- CriMaRec ApS:
  - Danish start-up company, headed by CEO Lars Christian Larsen.
  - Developing an alternative method for recovering platinum-group metals (PGMs) from various scrap materials.
- IRD Fuel Cells A/S:
  - Danish private company specialised in manufacturing MEAs for LT-PEMFC & EC.
  - Efforts on integrating recycled material into MEAs led by Senior Research Engineer Mikkel Juul Larsen, manager of the 3R project.

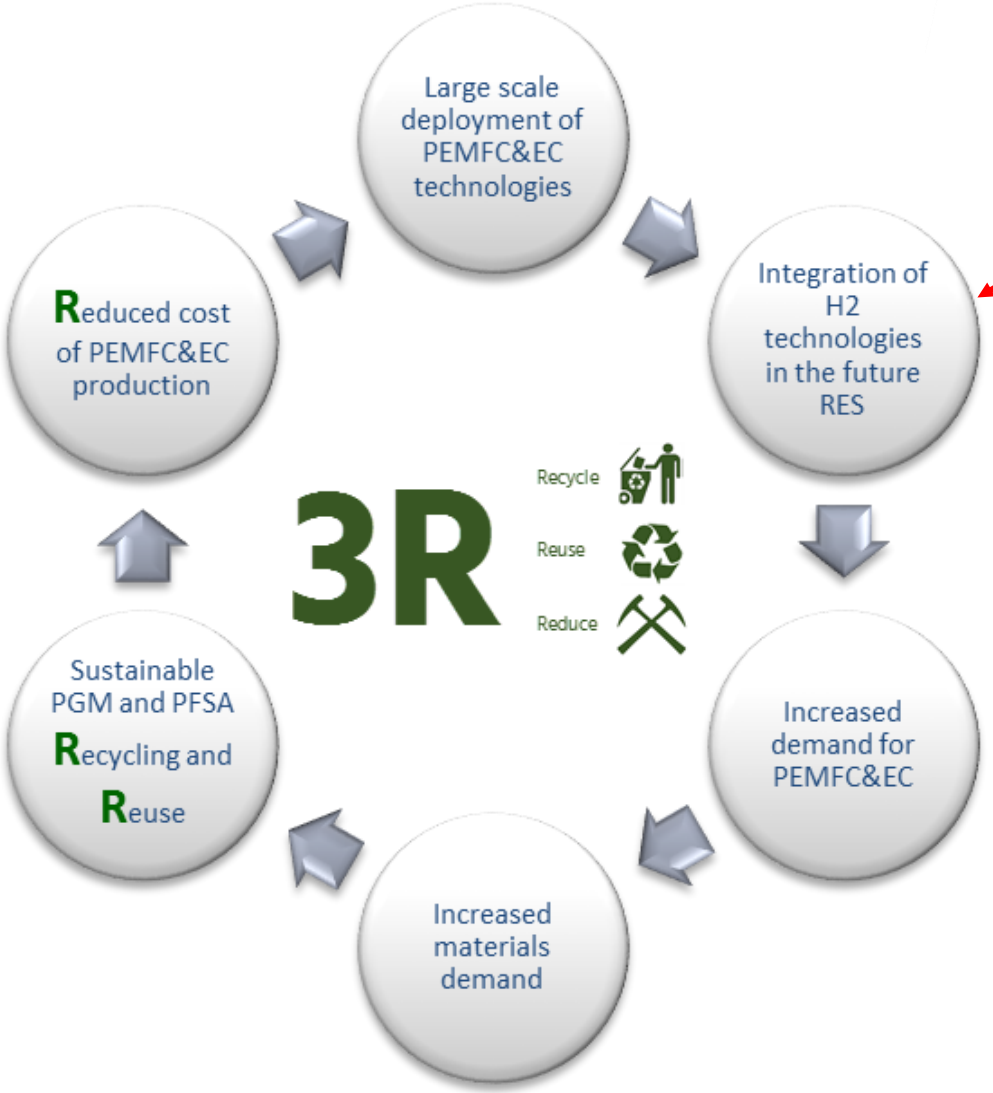
Objectives

- To develop methods to recycle and reuse constituents of MEAs from PEMFCs & PEMECs in environmentally safe and sustainable ways.
  - Of particular interest are the costly and critical PGMs, mainly Pt and Ir, and PFSA polymer since it represents significant value and/or potential environmental risk if not recycled properly.
- To develop a large-scale manufacturing process to recover precious metals from spent catalysts from exhaust systems of automobiles to be reused in PEM MEAs.
- To offer end users of PEMFC&EC the cost-reducing possibility of returning products for recycling at EoL and ensure adequate reuse/recycling of process waste to reduce the amount of scrap.
- To reduce materials cost for MEA production through MEA recycling and flow of secondary (recycled) PGM from other industrial sectors.
- To accelerate the green transition from fossil-fuel-based energy to renewable energy by facilitating the expansion of the PEMFC&EC technology and meeting the growing demand for renewable energy.

Impacts

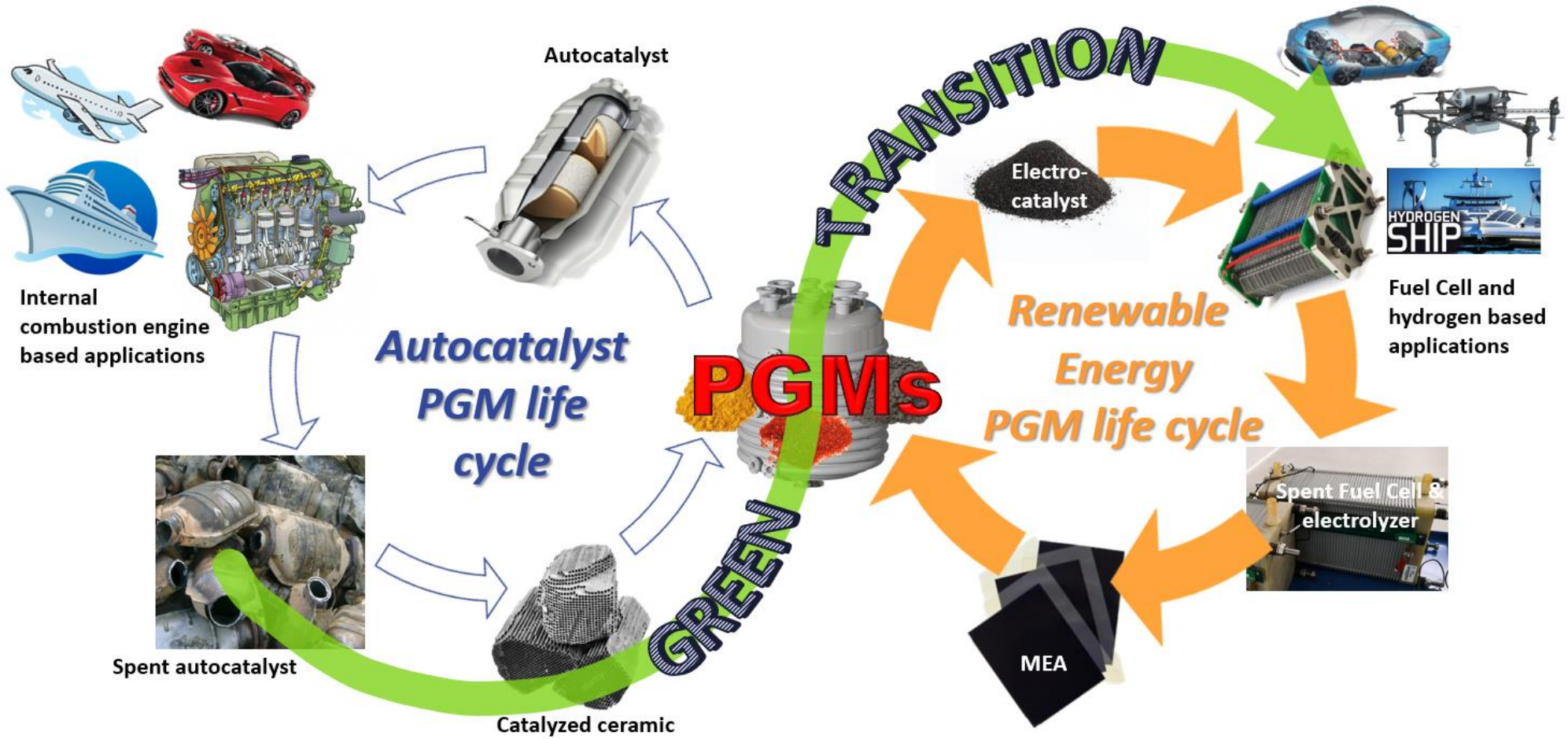
- **Recycle** PGMs sustainably
- **Reuse** PFSA material
- **Reduce** the economic and environmental costs of the PEMFC&EC technologies

⇒ Green transition enabled



Necessity!

Underlying concept



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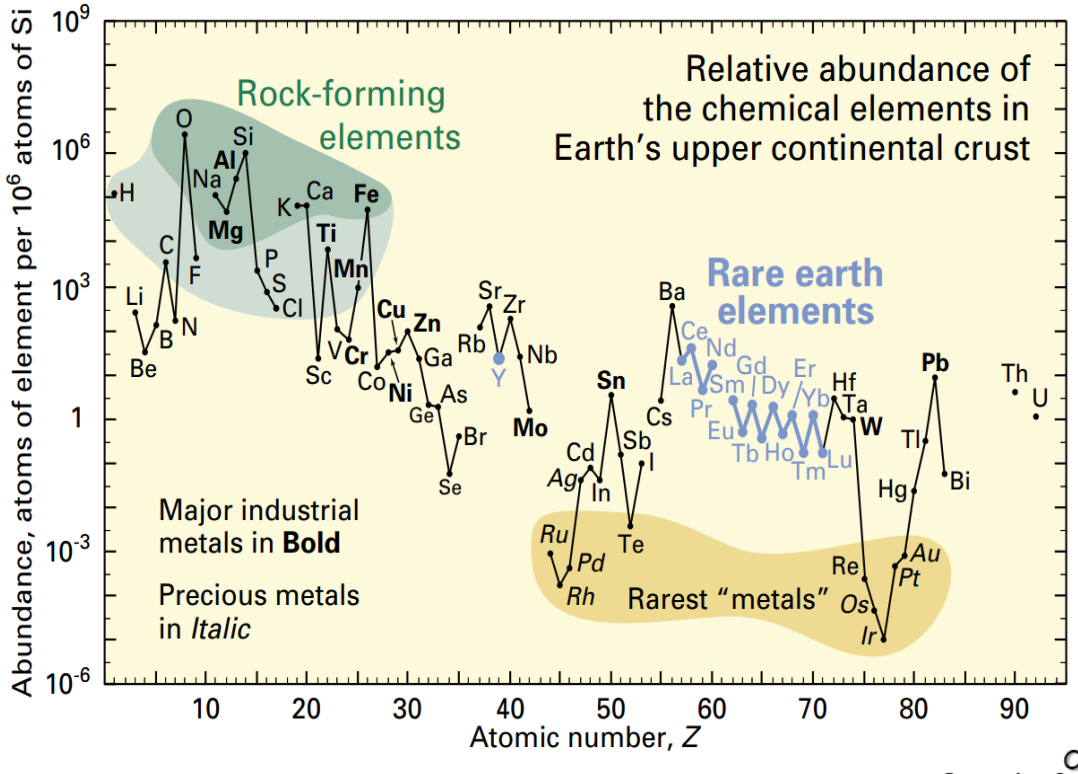
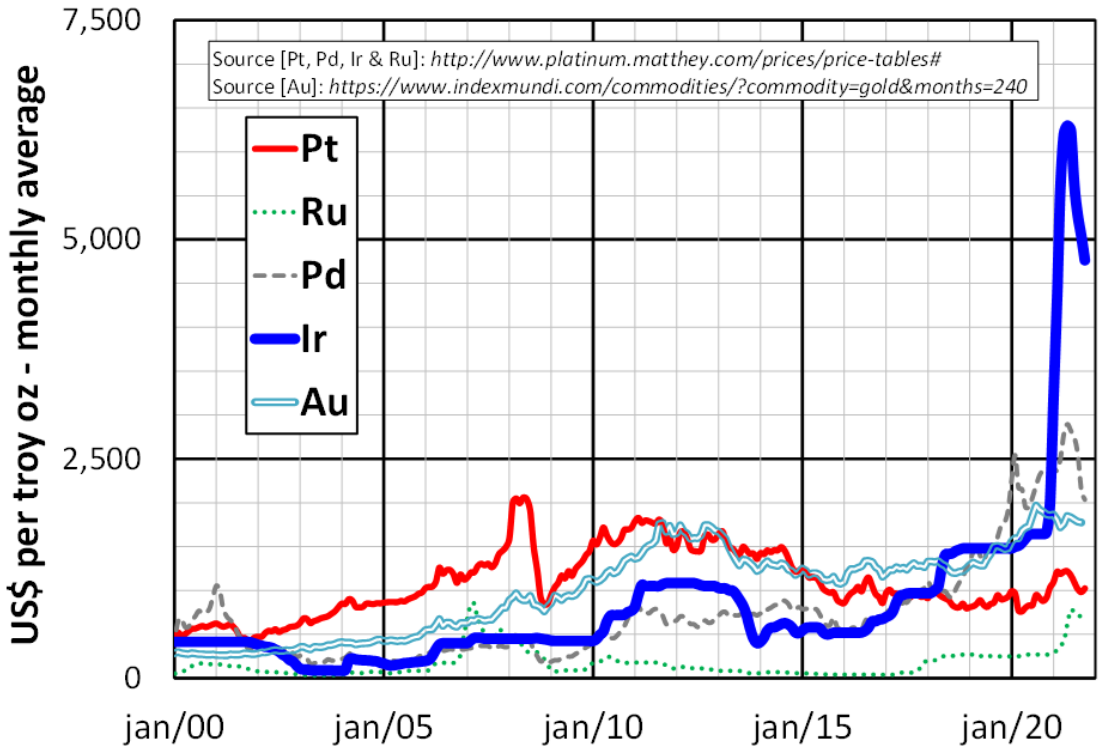
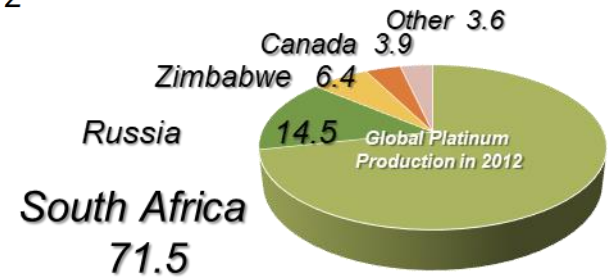
PGM abundances, prices and suppliers



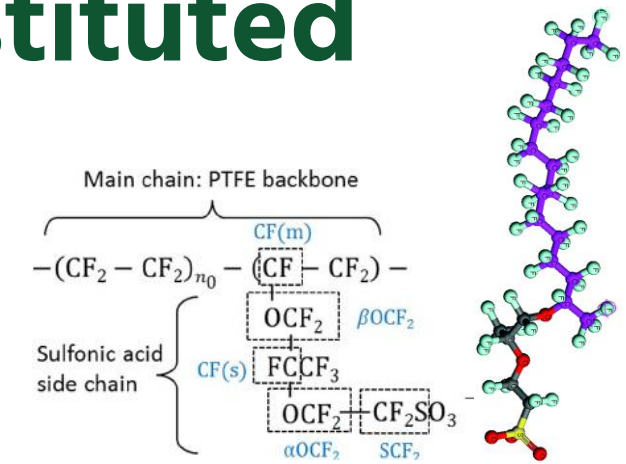




G. B. Haxel, S. Boore, and S. Mayfield from USGS

Processes to be substituted

- Incineration to remove less thermally stable components



Emissions from incineration of fluoropolymer materials

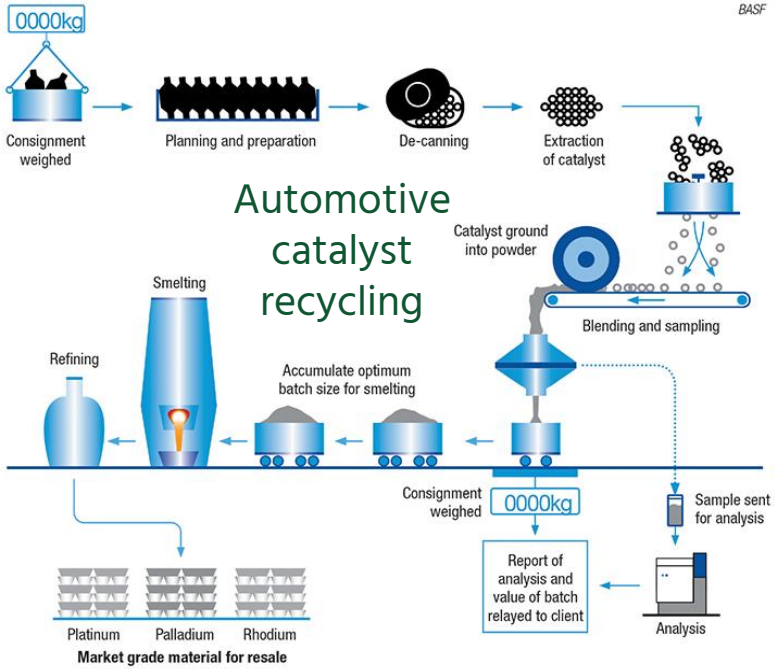
A literature survey

Sandra Huber, Morten K. Moe, Norbert Schmidbauer, Georg H. Hansen and Dorte Herzke

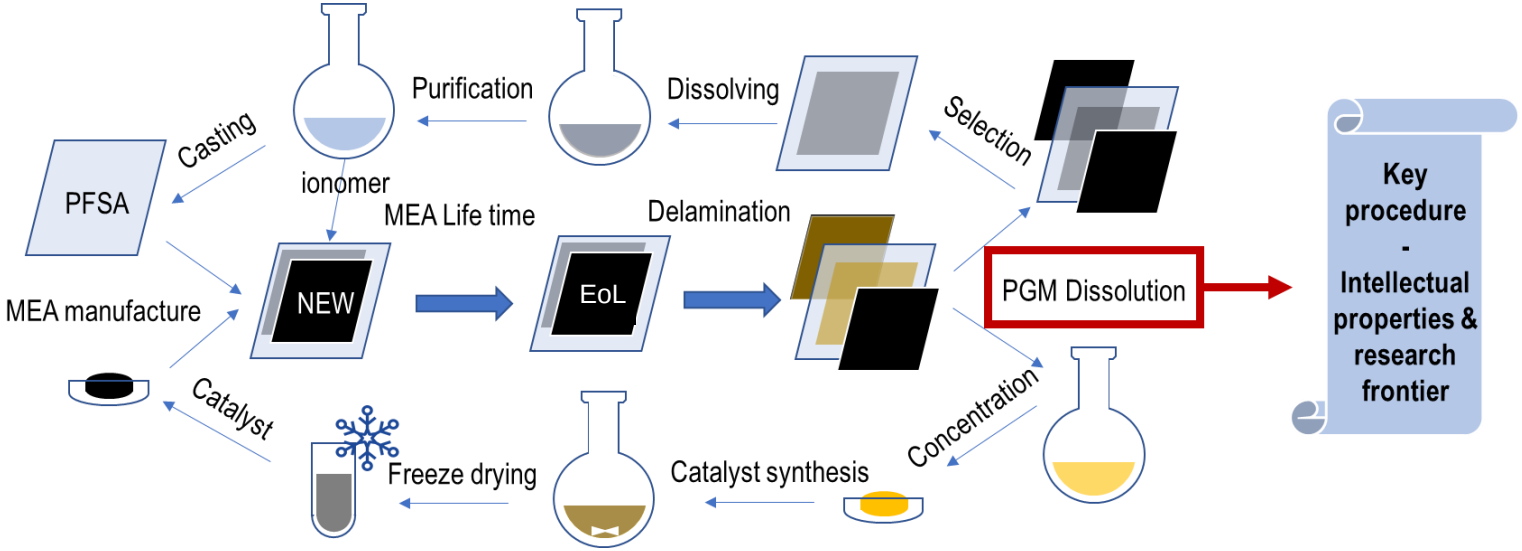
Energy Conversion and Management **48** (2007) pp. 450–453

- Direct PGM dissolution using lixiviant, oxidant or ionic liquid with high temperature and pressure

- Autocatalyst recycling processes with huge energy consumption, pollution, emission and investment needs



Approaches

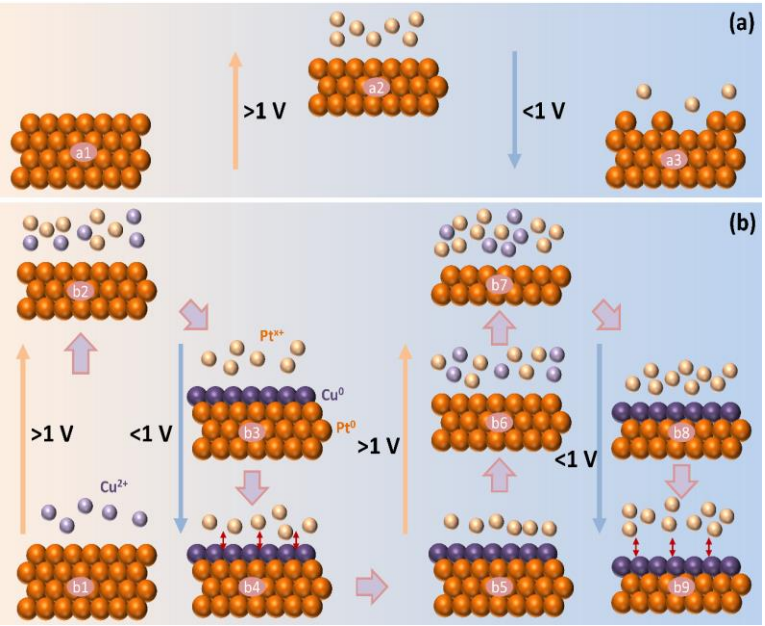


Hydro-electrochemistry based recycling process

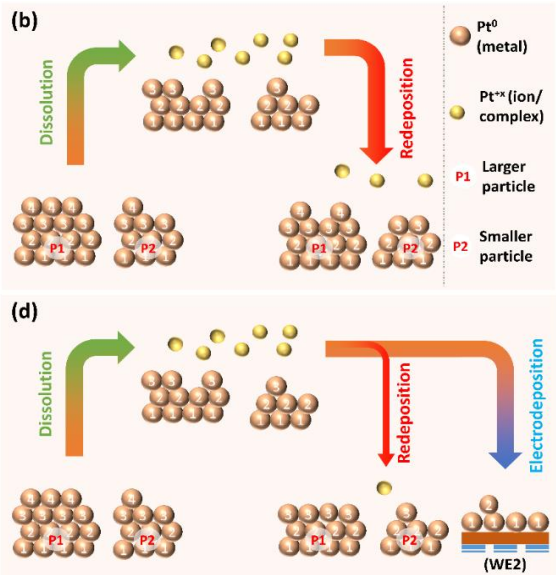
Described in several SDU publications, e.g.:

R. Sharma, S. J. Andreasen, J. Chamier, S. M. Andersen: Pt/C Electrocatalyst Synthesis from Recycling of the Spent PEMFC Membrane Electrode Assembly: A Closed Loop Circular Economy; *Journal of The Electrochemical Society* **166** (2019) pp. F963–F970

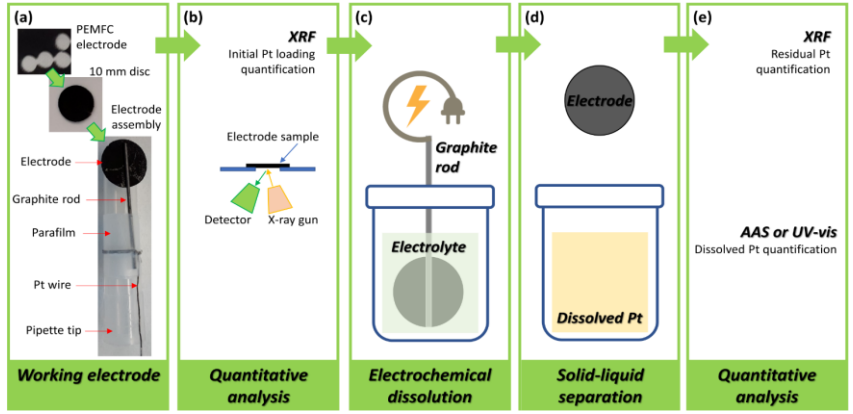
Approaches



Electrochimica Acta **321** (2019) 134662



ChemSusChem **11** (2018) pp. 3742–3750



ChemElectroChem **6** (2019) pp. 4471–4482

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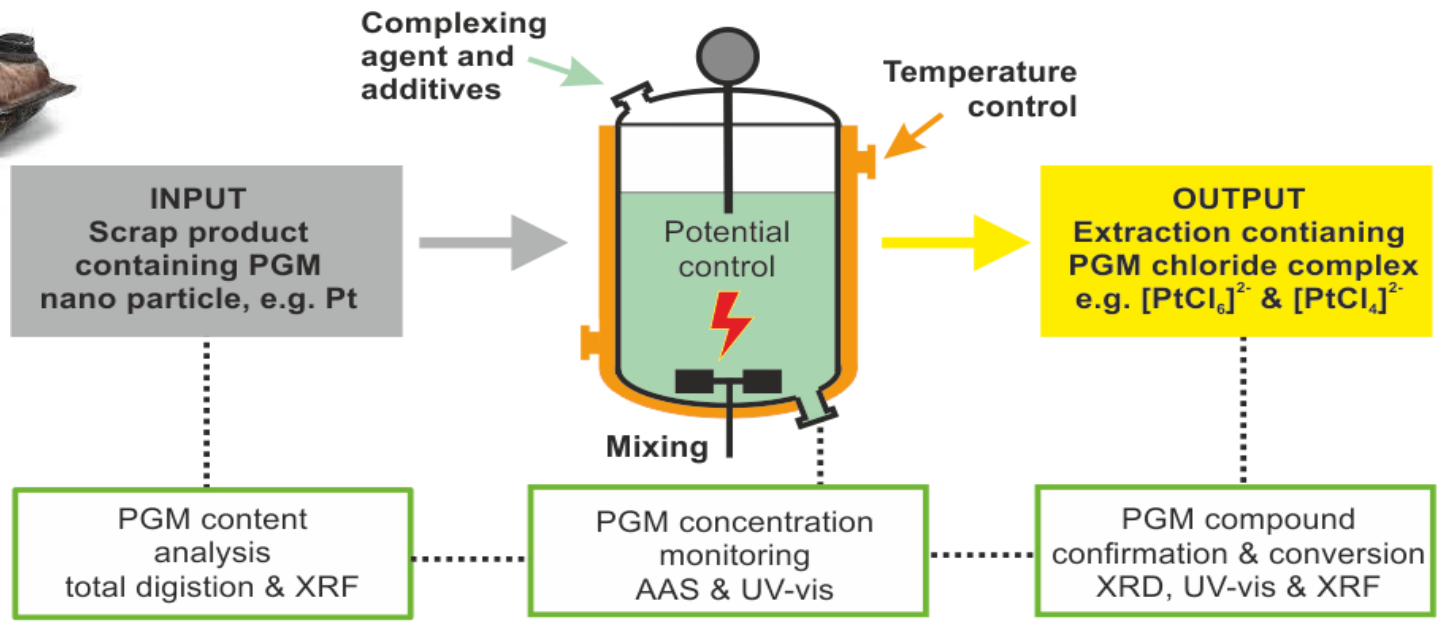

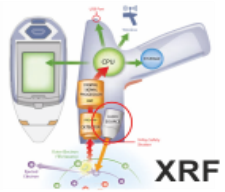

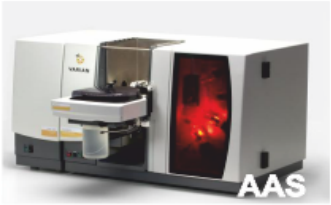

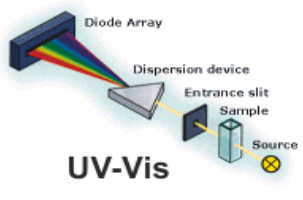

US009580826B2

(12) **United States Patent**
Skou et al.

(10) **Patent No.: US 9,580,826 B2**
(45) **Date of Patent: Feb. 28, 2017**

(54) **METHOD FOR RECOVERING PLATINUM GROUP METALS FROM CATALYTIC STRUCTURES**

(71) Applicant: **Syddansk Universitet**, Odense M (DK)

(72) Inventors: **Eivind Skou**, Odense SØ (DK); **Casper Noergaard**, Frederiksberg (DK); **Serban Nicolae Stamatin**, Bucharest (RO)

(73) Assignee: **Syddansk Universitet**, Odense M (DK)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(52) **U.S. Cl.**
CPC ***C25C 1/20*** (2013.01); ***C22B 3/44*** (2013.01); ***C22B 11/04*** (2013.01); ***C22B 11/048*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC C25C 1/20; C25C 5/02; C22B 11/48
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,775,452 A 10/1988 Kuninaga et al.
5,156,721 A 10/1992 Whewell
(Continued)

- US 9,580,826 B2: Method for recovering platinum group metals from catalytic structures
- EP 3 788 177 A1, WO 2019/211318 A1: Method for dissolving precious metals

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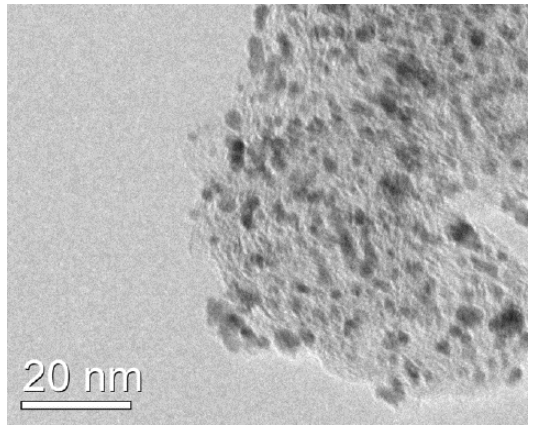
Status as of November 2021 (M20)

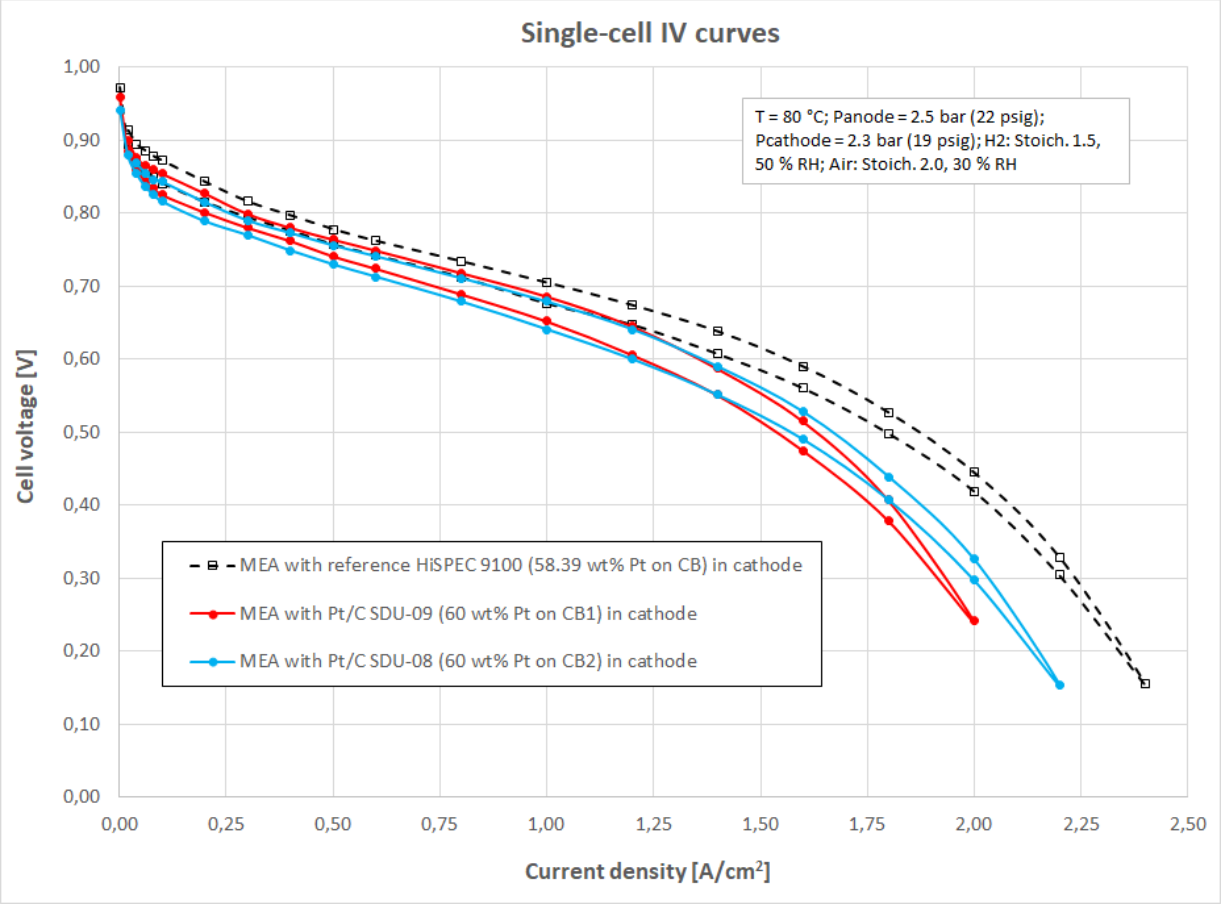
- More than 100 Pt/C catalysts manufactured (microwave-assisted polyol method) with Pt recovered from spent PEMFC MEAs and autocatalyst ceramic material.
- Characteristics like particle size and ECSA similar to relevant reference catalysts (e.g., HiSPEC® 9100) obtained.
- Efficiency of Pt recovery > 90 %.
- Samples of Ir and ionomer recovered from MEAs also made.

R. Sharma, S. M. Andersen: Circular use of Pt/C through Pt dissolution from spent PEMFC cathode and direct reproduction of new catalyst with microwave synthesis; *Materials Chemistry and Physics* **265** (2021) 124472 pp. 1–9



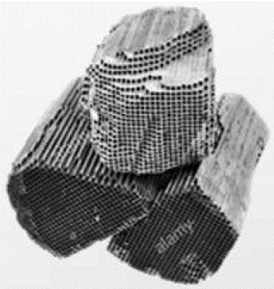
Status as of November 2021 (M20)

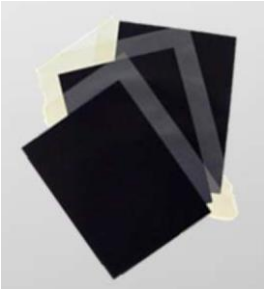
- Performance of 25-cm^2 PEMFC MEAs with recycled catalyst in the cathode evaluated in single cells.
- Proof of concept achieved: Success criterion met as the voltage read from the single-cell IV curve ≥ 95 % of that of the relevant reference at 0.50 A/cm^2 as well as at 1.0 A/cm^2 (95-98 % for the samples shown).
- Different carbon types under investigation for further improvement; performance and durability.



Status as of November 2021 (M20)

- Prototype reactor just about to be ready.
- Finetuning of reaction parameters ongoing (time, temp., pH, conc., reagents, etc.).
- Low-impact recovery process (energy, secondary emissions, cycle time (< 2 h), etc.).
- Competitive PGM recovery costs: < 10 % of PGM market price. Validation of cost efficiency ongoing.
- Process first prepared for handling processed EoL catalysed diesel particle filters based on SiC.
  Later adapted to handle also MEAs.





Wrap-up

- Recycling concept proved for Pt.
- Benefits offered for the renewable-energy industry:
  - PGM self-sufficiency.
  - Possibility for expansion through PGM recycling from a fossil-fuel-based industry.
- Impacts:
  - Decreased dependence on primary PGM mining.
  - Continuous supply of the critical raw materials secured.
  - Reduced MEA costs.
  - Promoted deployment of PEMFC&EC.
  - Improved penetration of renewable energy.
- Various marketing models being considered (involving returning of products).

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Thank you for your attention!

About IRD Fuel Cells A/S:

IRD Fuel Cells A/S is a small high-technology company founded in 1995. IRD operates internationally and is devoted to the development and production of fuel-cell and electrolyser materials, MEAs and other components. The core competences of the company include advanced ink/slurry mixing and coating on all scales of MEA manufacture, from prototypes to full-scale production. IRD has established large-scale manufacturing processes and facilities based on internal and co-funded R&D activities. The current product range includes PEMFC and DMFC MEAs for stationary, back-up-power and automotive applications as well as PEM electrolyser MEAs, based on state-of-the-art PGM catalysts. IRD is involved in several R&D activities related to low-PGM MEAs and is highly interested in promoting the early application of MEAs with recycled PGM in the fuel-cell industry as a first-mover.

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