Sustainable SoluTions FOR recycling of end-of-life Hydrogen technologies

TRAINING MODULE 1

Chapter_3

Manual to perform the novel dismantling processes developed within the project (PEMFC)

Document Details

Due date	
Actual delivery date	
Lead Contractor	
Version	
Prepared by	ENVI
Input from	CEA
Reviewed by	

Document Details

x	PU - Public
	CO - Confidential, only for members of the consortium (including the EC)

Co-funded by the European Union

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation program, Hydrogen Europe and Hydrogen Europe Research.

Abbreviations

FC	Fuel cells
PEM	Proton Exchange Membrane
SO	Solid Oxide
CCM	Catalyst Coated Membrane
GDL	Gas Diffusion Layer
MEA	Membrane
Pt	Platinum
HRD	Hensel Recycling
CEA	CEA research centre
IDOLab	IDOLab

Clean Hydrogen Partnership

Co-funded by the European Union

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216.

Contents

Co-funded by the European Union

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216.

1 Executive Summary

Within project BEST4Hy, a training kit is to be developed. This will be subdivided into 4 Modules with this content:

- Module 1: How to dismantle a fuel cell
- Module 2: Recovery technologies
- Module 3: Technical results and economical aspects
- Module 4: Measures towards to take up.

Module 1 is dedicated to the dismantling technologies of fuel cell stacks and provides information on how to perform and optimize the existing disassembling technologies and how to perform novel dismantling technologies, considering both PEM and SOFC fuel cells.

Module 1 is organized as follow:

- Chapter 1: Introduction to the FCs: main components and valuable materials in PEM and SOFC;
- Chapter 2: Description and manual to perform the existing disassembling technologies (PEM);
- Chapter 3: Description and manual to perform the novel dismantling processes developed within the project (PEM).

Video tutorials on how to perform the disassembling and dismantling processes above described are also available.

For more information, users can consult the associated deliverables describing the activities performed in BEST4Hy:

- D1.1: Lab scale optimization results on the 3 PEMFC recycling technologies report
- D1.2 Technical report on adaptation of existing technology (hydrometallurgy process) for PEMFC material recovery: results and design
- D2.3: Report on the evaluation of MEA including recycled materials in small single cell of PEMFC
- D3.3: Pilot-scale plant (TRL5) based on two integrated existing recycling technologies for SOFCs_PU
- D4.3: Technical report on developed recovery technologies for LSC cathode materials_PU

<u>The present document refers to Chapter 3: Manual to perform the novel dismantling processes developed within the project (PEMFC).</u>

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216.

2 Introduction

This chapter reports results and achievements linked to WP1 project activity on "Existing and novel technologies of PEMFCs: proof of concept (TRL3 – TRL5).

A first important stage of the recovery and recycling process is the fuel cells disassembly: different methods for PEMFC stacks, cell packages and MEA have been studied by the partners to identify the most convenient way to recover the material, avoiding contamination and pursuing environmental and economic sustainability.

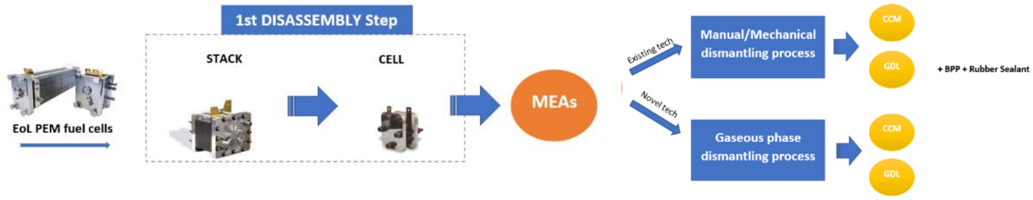


Figure 1 Possible processing of EoL PEMFC adopting the approaches developed within BEST4Hy project

<u>This chapter refers only to the technology developed by CEA for the PEM fuel cells dismantling.</u>

Trials reported below have been performed using end-of-life materials (PEMFC stacks, cell packages) with different time of operation (EoL - fresh, 200h, 2800h, 7800h).

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216.

3 Disassembling PEM fuel cells: developing novel technologies

3.1 MEA Gaseous Phase dismantling concept

The Gaseous Phase dismantling is a novel technology tested by the CEA Liten research center to explore new valuable dismantling process solution for PEMFC at their end of life.

This new technology is based on vapor phase and it separates the different components of MEA (GDL and CCM). The process consists in inserting the MEA in a stirred tank, initially under vacuum, which is fully saturated by injecting a preheated, vaporized solvent. An efficient vaporization could be obtained with ethanol, but due to its bad wettability with GDL, no dismantling was observed.

The new process is based on high pressure to force the penetration of the solvent through the GDL to reach the membrane, promoting the swelling to complete the MEA's dismantling.

This new concept, based on high pressure conditions, can be carried out under both liquid and vapor phases (as shown in Figure 2).

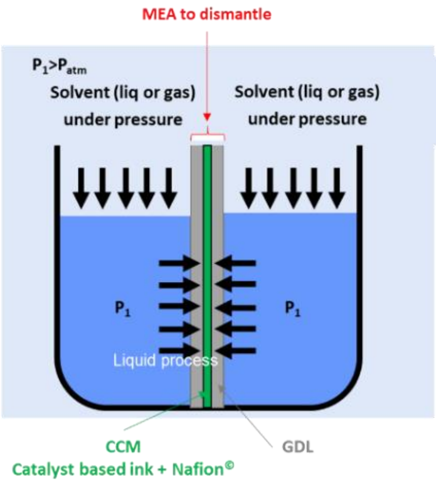


Figure 2 High pressure-based process

3.1.1 High pressure conditions process under liquid phase

The dismantling process can be divided into three steps:

- **High-pressure dismantling process** with liquid solvent: dismantling process using high pressure conditions and **ethanol or isopropyl** alcohol-based compounds as solvent. During the process, the major part of the catalyst is delaminated from the membrane and is brought into the solvent (Figure 3).
- **Post-processing step**: the remaining catalyst is recovered during this step. Two post-processes could be performed:
    - Rinsing in water
    - Treating in ultrasonic bath

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216.

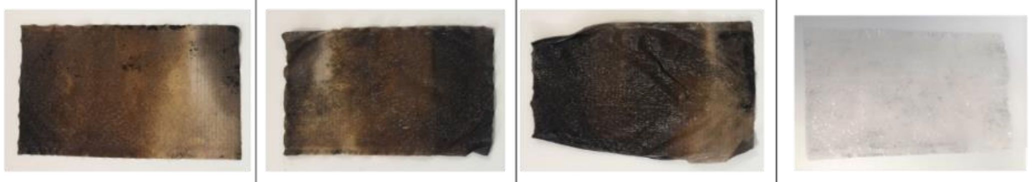
- **Filtration step**: the material is further treated by a filtration process to recover the catalyst. The final membrane aspect directly depends on the solvent composition.

3.1.1.1 High-pressure dismantling process step

In BEST4Hy, the CEA made several tests, first using MEAs provided by the CEA, then using EoL MEAs provided by EKPO company. Tests were initially performed using different solvents for the high-pressure process, such as:

- Pure ethanol
- Mix water/ethanol (50/50)
- Mix ethanol/acetone (70/30)
- Pure isopropyl alcohol
- Pure acetone
- Pure water

Ethanol and isopropyl alcohol showed better performance but only pure ethanol seemed to enable a complete separation of the membranes. The figure below shows membranes after the first step of high-pressure dismantling:



Water/Ethanol 50%/50% vol	Ethanol/Acetone 70%/30% vol	Pure Isopropyl alcohol	Pure Ethanol

Figure 3 Membranes after dismantling performed with high pressure-based process

3.1.1.2 Post-processing step

Different post processing were tested as shown in Figure 4. The ultrasonic bath-based post process appears to be the more effective in removing the catalyst from the membrane.

	High Pressure process	✓	✓	✗
Post-Process	US Bath	✗	✓	✓
	Rinsing	✓	✗	✓

Figure 4 Post Process efficiency studied on membrane from CEA's MEAs and dismantled with high pressure process performed with ethanol

Clean Hydrogen Partnership
Co-funded by the European Union
This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216.

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216.

3.1.1.3 Comparison between different MEAs

Similar tests have been performed on EKPO's MEAs received. Figure 5 shows a comparison between the two different MEAs, provided by CEA and EKPO:

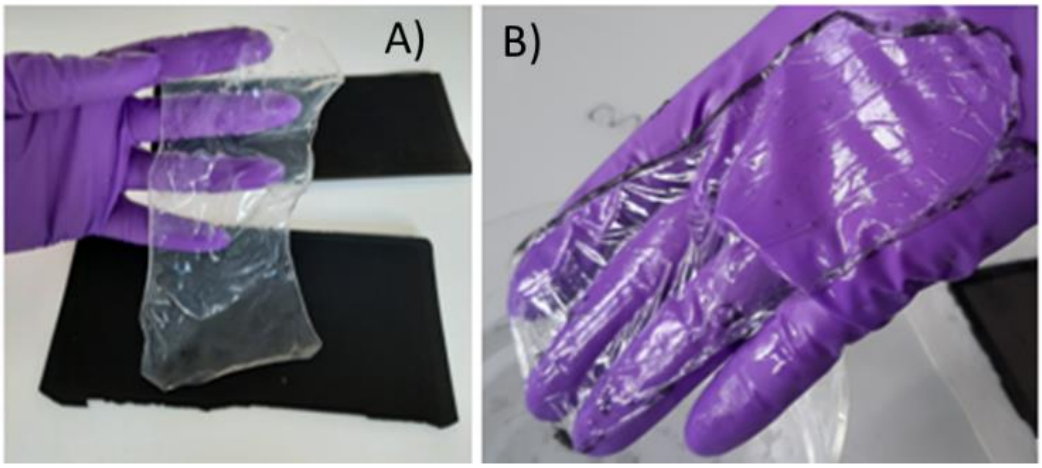


Figure 5 GDL and membranes dismantled thanks to high pressure process. On the left, MEA provided by CEA, on the right, MEA from EKPO.

The different pictures show that the high-pressure process supplemented by an ultra-sonic post-process leads to interesting results for both MEAs from CEA and EKPO.

The high-pressure process in vapor phase is also studied using a complete stack of MEAs. The ethanol is used as solvent and the vapor is injected through inlets of bipolar plates. After dismantling, catalyst ink remains stuck on the membrane, which can be removed in a subsequent process.

3.2 Main findings and results

The high-pressure process is under patent application; therefore, no further details can be shared in the present manual. From the previous showed tests, some main findings can be summarized as follows:

Main findings and results:
▪ MEA recovery after vapor phase exposure. ▪ Very easy GDL and CCM disassembling ▪ Very clean aspect for GDL and membrane ▪ Membrane exposition to ethanol seems more homogeneous and smoother with vapor compared to liquid exposition ▪ Catalyst ink recovery can be easier using vapor phase process.

Figure 6 shows a summary of the overall dismantling processes trials and results performed in BEST4Hy for EoL PEMFC.

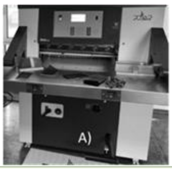
Disassembly	Results	Comments
Manual Dismantling		Ideal sampling. though not scalable
Mechanical Trial 1 (Rotating Knives Shredder)		Contamination inhomogeneous reactive in acid
Mechanical Trial 2 (Erdwich Equipment)		Contamination inhomogeneous
Mechanical Trial 3 (Polar Mohr Equipment)		Inefficient disassembling process
Mechanical Trial 4 (Paper Shredder)		Seem to be promising, but GDL and CCM are difficult to separate
Hybrid Trial 5 (manual dismantling of BPP and rubber sealants and mechanical shredding of CCM)	Not yet performed	Not yet performed, seem to be promising
MEA Gaseous Phase Dismantling		Good results on GDL and membranes dismantled thanks to high pressure process

Figure 6 Dismantling results: Comparison between Manual and Mechanical Trials for Hydrometallurgical Treatment at HRD; Gaseous phase dismantling at CEA

Co-funded by the European Union

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216.