TRA275 Fuel Cell Systems:
Spent fuel cells waste management and challenges in the materials recycling

CHALMERS

Introduction

The waste management and materials recycling of spent fuel cells is very important to reduce the environmental impact. Recycling fuel cells is a challenge as it contains complex components, rare metals, and polymers. However, there are some limitations with current technologies in terms of cost and regulatory support. To cope with the problems and to enhance circular economy, new innovative technology, future strategies, and market readiness would be looked up to promote recycling.

Chemical Recycling of MEA

The membrane electrode assembly (MEA) is replaced with the new assembly, while the MEA undergoes chemical processing to reclaim the platinum and other precious metals. This is followed by a pyro-hydrometallurgical treatment, in which carbon-based gas diffusion layers (GDLs), membranes, and electrodes are incinerated. The resulting ash is then subjected to acid dissolution, allowing for the subsequent recovery of platinum group metals (PGMs) by precipitation. The materials recovered from fuel cells are these:

Platinum Group Metals (PGMs)

Platinum is the predominant catalyst material in PEMFCs. Other platinum group metals may also be present in smaller quantities. The recycling of PGMs is critical due to their high cost, scarcity and importance to catalytic activity. So, due to the following factors their recovery is economically attractive as PGMs constitute a major fraction of the fuel cell's cost.

Membrane Material

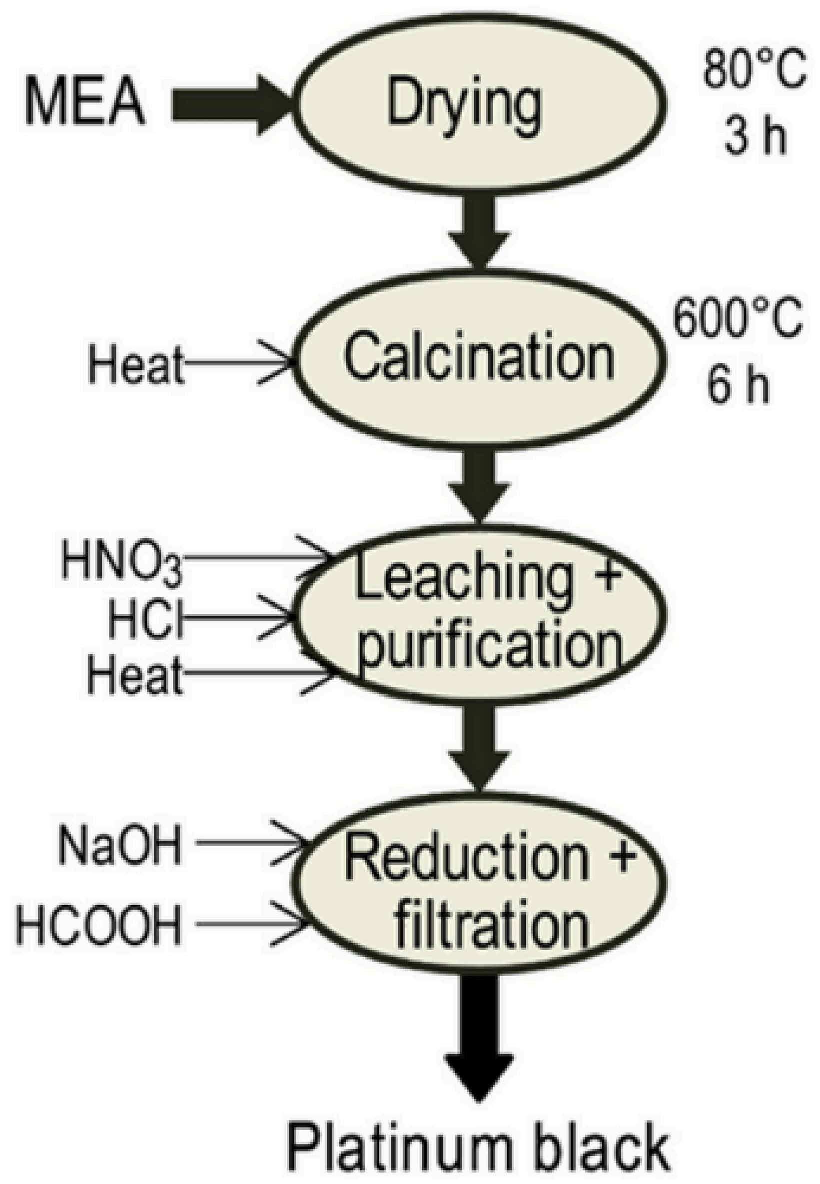
Proton exchange membranes are often perfluorosulfonic acid (PFSA) membranes. Recycling membranes can be challenging due to the fluoropolymer's chemical stability but research exists on methods to recover fluorinated compounds or reuse membranes after chemical or thermal treatments.

Catalyst Support

The catalyst is typically dispersed on a high surface area carbon support. While carbon is less expensive than PGMs, recycling or reusing the carbon support can still reduce waste and environmental impact.

Bipolar Plates (Graphite or Metal-Based)

Bipolar plates can be made of graphite composites or stainless steel coated with corrosion-resistant layers. Their recycling involves recovering metal alloys or refurbishing graphite-based plates.



Reasons for recycling fuel cell material

Economic Sustainability

PGMs particularly platinum can represent a significant portion of fuel cell manufacturing costs. Recovering them lowers the overall cost of the fuel cells.

Resource Scarcity

Platinum is a critical raw material with limited global supply and concentrated mining regions. So, recycling and the reusing the metals will reduce the need to mine for more of these metals for future applications.

Environmental Benefits and waste Reduction

Reduces the environmental footprint associated with mining and refining raw materials and the end Life of fuel cells can contain materials that would otherwise go to landfills. Recycling diverts material from landfills and helps close the loop.

Regulatory and Policy Drivers

Many regions have regulatory frameworks promoting material recovery and recycling and Companies are increasingly obliged or encouraged to meet sustainability targets and reduce carbon footprints.

Technical Advancements and Material Recovery Efficiency

Innovations in hydrometallurgical, pyrometallurgical, and Other recycling process continue to improve platinum recovery rates and membrane reclamation techniques And In some cases, catalysts can be rejuvenated and reused, lowering both material and energy inputs for new catalyst production.

Method

1. **Thermal decomposition**
High temperatures break down the PFSA membrane
2. **Metal recovery**
The ash will contain the precious metals and with chemical treatment these are extracted and cleaned

Aim

The aim of this project is to study the most sustainable, cost-effective, and efficient industrial scale processing techniques for recycling valuable materials and to address existing challenges in fuel cell waste management while minimizing the environmental impact of end-of-life fuel cells.

Table 3 – Summary of relevant aspects regarding EoL technologies for FHC products (++ very favourable performance; + favourable performance; 0 regular performance; - unfavourable performance; – very unfavourable performance).

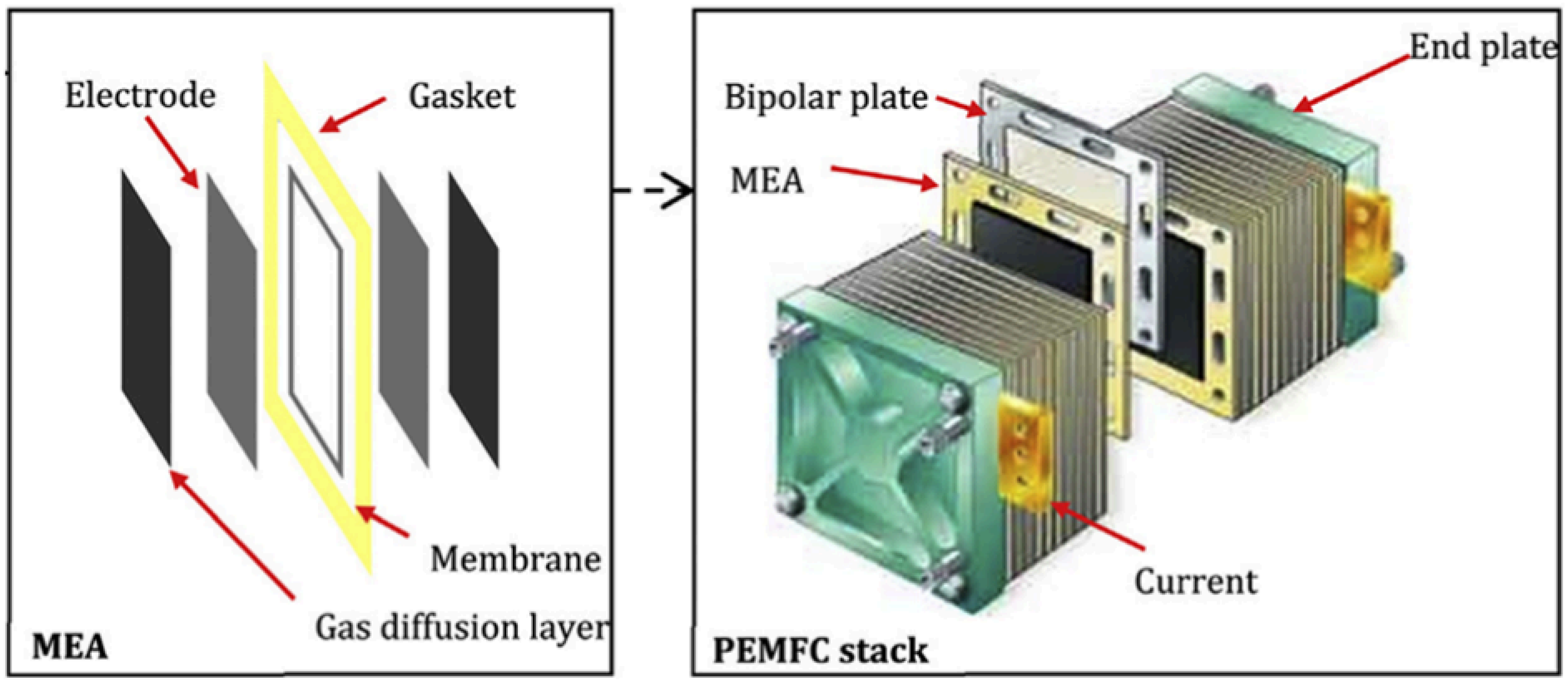
EoL technology[a]	PMT	HMT	HTH	AP	SED	TD
Investment cost	–	+	–	–	+	+
Operating cost	–	+	0	–	0	0
Recovery efficiency	+	–	0	++	+	+
Energy requirements	–	++	–	–	–	++
Hazard/toxicity	–	–	–	–	0	–
Other environmental concerns	–	0	++	–	0	++

[a] PMT: pyro-hydrometallurgical treatment; HMT: hydrometallurgical treatment; HTH: hydrothermal treatment; AP: acid process; SED: selective electrochemical dissolution; TD: transient dissolution.

Incineration Recycling of MEA

A former method used for recycling fuel cell MEA is Incineration. It is no longer a viable alternative for MEA recycling due to the release of harmful fluorinated compounds in the incineration process. These compounds are toxic and harmful to the environment and human health and as such should not be released into the environment. The alternatives are to either clean the gas from the harmful compounds or find an alternative way to recover the precious metals in the MEA.

The incineration method has been updated to remove the harmful compounds in the exiting gas. A company called Umicore did a publication in 2004 where an inorganic additive is mixed with the MEA scrap material, this additive will chemically bind the fluoride containing compounds in the following thermal treatment process. The fluoride content will reduce to 1-2% of original fluoride content in the gas. The metal recovery works like usual and recovers around 80-95% of the precious metals.



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