SULFONATED GRAPHENE OXIDE AS INNOVATIVE SELF-ASSEMBLING ELECTROLYTE FOR PEM FUEL CELLS

POLITECNICO MILANO 1863

Andrea Basso Peressut, Saverio Latorrata, Luigi Brambilla, Chiara Castiglioni, Giovanni Dotelli

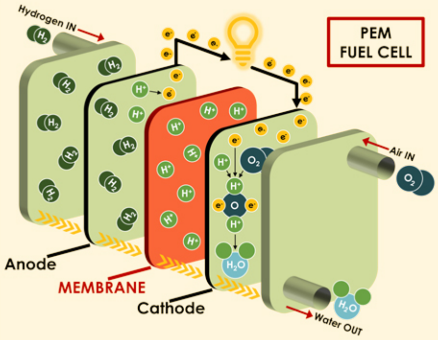
Department of Chemistry, Materials and Chemical Engineering, Politecnico di Milano

Piazza Leonardo da Vinci, 32, 20133 Milan, Italy

MAT4EN2 MATERIALS FOR ENERGY AND ENVIRONMENT

INTRODUCTION AND AIM OF THE WORK

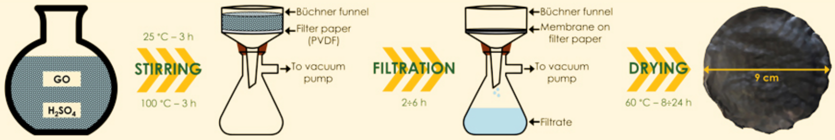
A fuel cell **membrane** serves as **electrolyte** between anode and cathode. Therefore, it has to exhibit a rigorous set of properties, referring to proton exchange membrane fuel cells [1]: high protonic conductivity; low permeability to H_2 and O_2 gases; chemical, mechanical and thermal stability; electrical insulation.
Even though **Nafion®** is currently the most widely used electrolyte in PEMFC systems, some **drawbacks** induce the need of finding feasible replacements [2]: severe conductivity drop upon dehydration, limiting the possibility of fuel cell operation in conditions of high temperature and low relative humidity; swelling and shrinkage, leading to membrane deterioration at high water content.



As shown in previous works, graphene oxide (GO) appears to be an excellent candidate for making both **freestanding** [3] and hybrid membranes [4], thanks to its good mechanical properties and to the presence of oxygen-bearing functionalities that are likely to improve water retention. Its properties may also be enhanced by functionalization with some acid groups more tightly bound to its skeleton, e.g. sulfonic acid groups ($-SO_3H$) analogous to those of Nafion®.
Hence, this work presents an effective method for the preparation of **sulfonated graphene oxide (SGO)** membranes, which have been evaluated as a viable alternative to Nafion® for operation at low humidity and high temperature.

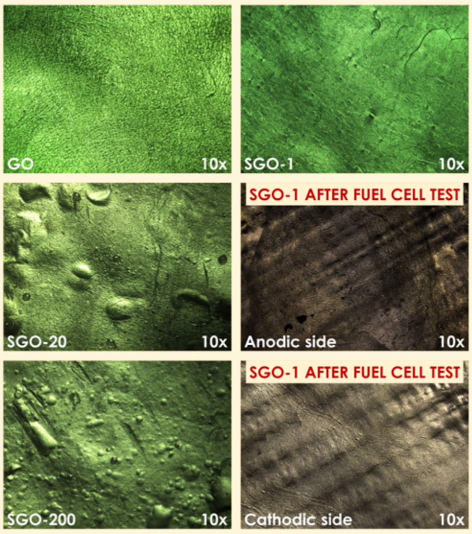
MEMBRANES PREPARATION

The original recipe [5] has been adapted by testing different **sulfonation ratios** (sulfuric acid-to-GO = 1; 20; 200), identified by considering an **empirical formula** that has been derived from the elemental analysis of the commercial dispersion of GO: $C_{1.5}H_{0.2}N_{0.01}S_{0.03}O$.

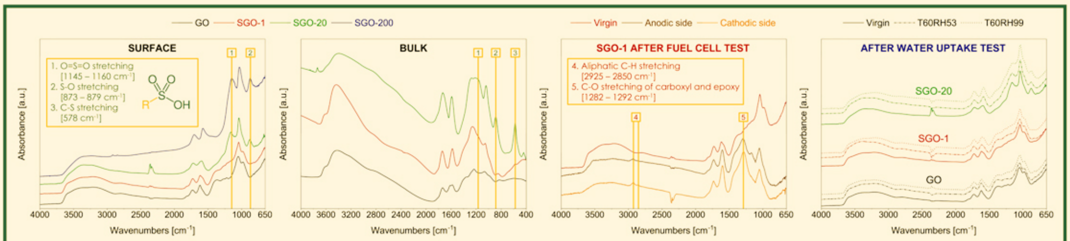


THICKNESS [µm]	
GO	13
SGO-1	27
SGO-20	76
SGO-200	> 100

MEMBRANES CHARACTERIZATION

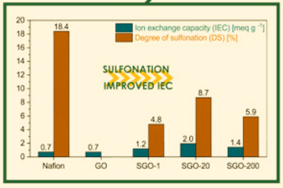


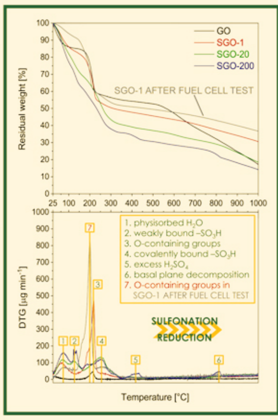
OM



FTIR-ATR

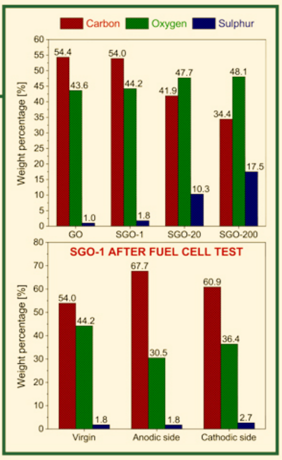
IEC-DS

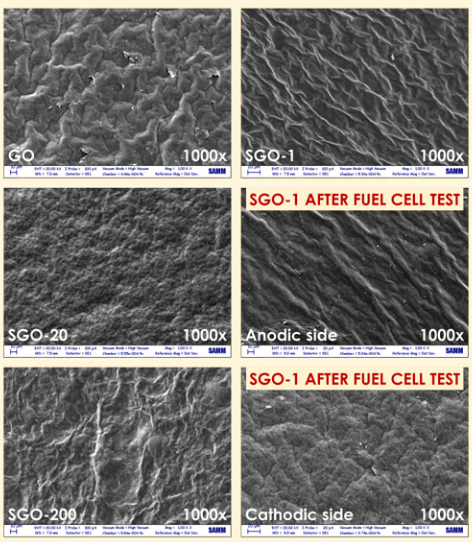




A preliminary test, carried out in a hydrogen-fed fuel cell on a sample of **SGO-1**, revealed a **promising mechanical resistance**, even though a low open circuit voltage has been measured (0.63 V) at 40 °C, due to possible hydrogen crossover issues. A subsequent OM examination of the active area showed the sporadic presence of **carbon residues** left by the gas diffusion electrode (typical problem for Nafion®), confirming a better resistance of SGO-1 to this kind of contamination. However, the results of FTIR-ATR and SEM-EDX analyses suggest that both anodic and cathodic surfaces of the membrane suffered **severe changes**, ascribed to the action of the fluxing gases.

SEM-EDX

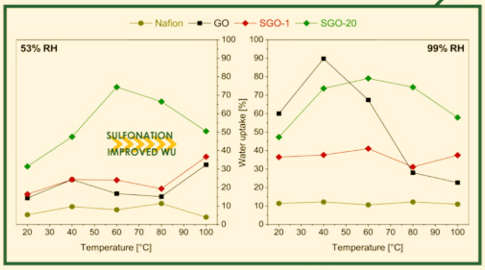


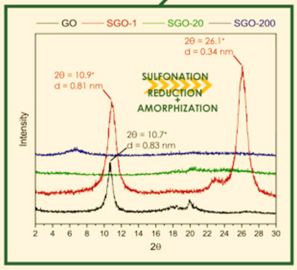


TG-DTG

WATER UPTAKE

XRD





CONCLUSION

- Functionalization stability after water uptake tests
- Improved ion exchange capacity and water uptake (at low T and RH) with respect to both GO and Nafion
- Promising mechanical resistance in the fuel cell
- Reduction and amorphization of SGO structure caused by functionalization process and fuel cell test

REFERENCES

[1] F. Barbir, PEM Fuel Cells: Theory and Practice, 2nd Ed., *Academic Press*, 2013
[2] Q. Li et al, *Chem. Mater.*,15, 4896 (2003)
[3] T. Bayer et al, *J. Power Sources*, 272, 239 (2014)
[4] M. Vinothkannan et al, *Rsc Adv.*, 8, 7494 (2018)
[5] T. Cheng et al, *Ionics (Kiel)*, 23, 2143 (2017)

MATERIALS FOR TODAY'S ENERGY CHALLENGES
University of Padova, 3rd – 4th June 2019

andreastefano.basso@mail.polimi.it
saverio.latorrata@polimi.it