

GOHAL!: SUSTAINABLE MEMBRANES FOR ALCOHOL DEHYDRATION

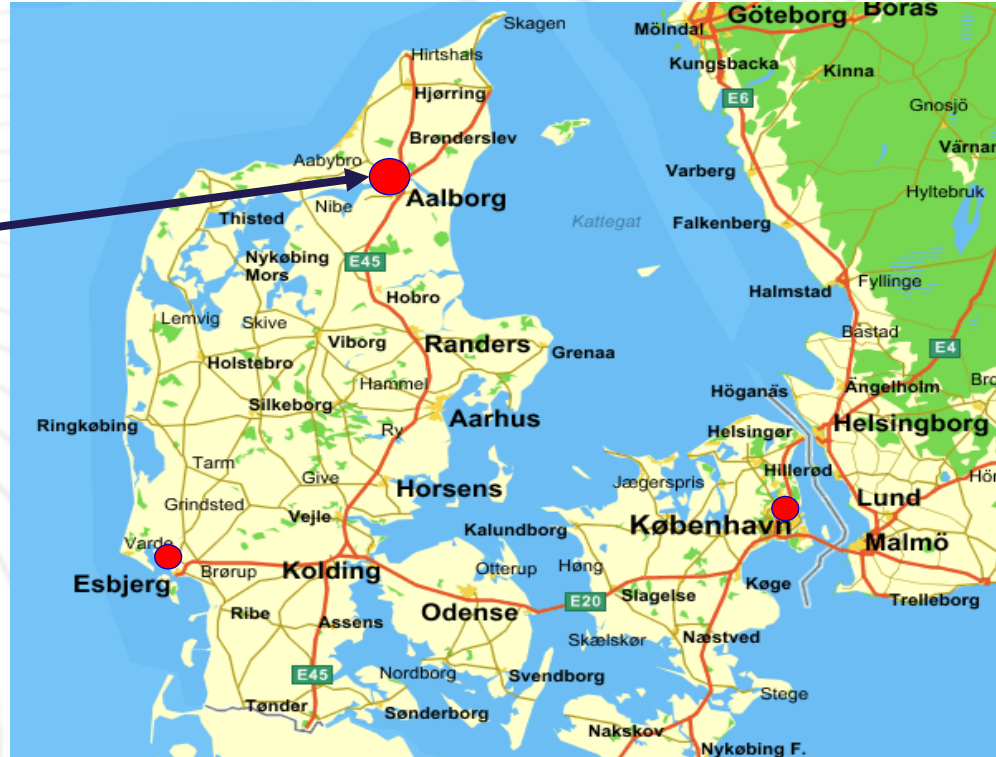
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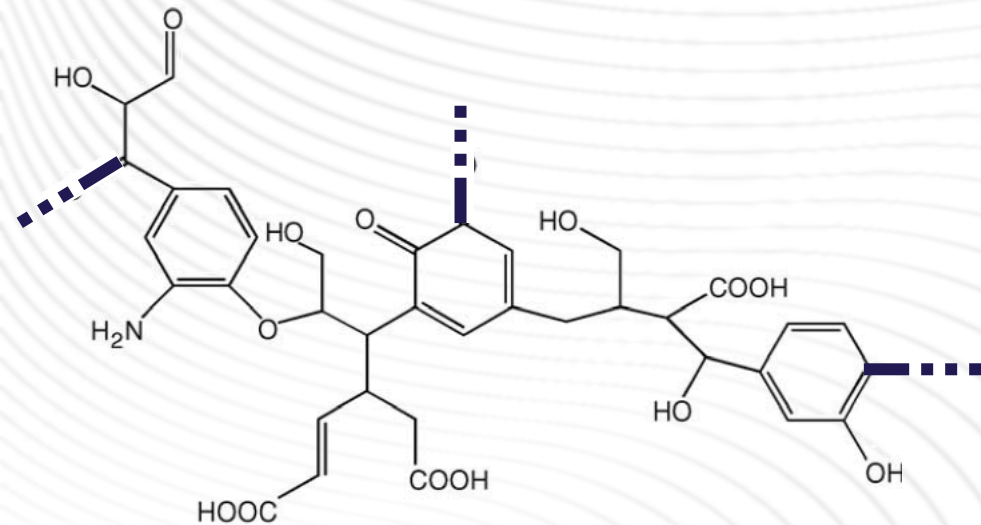
- Aalborg Centre for **Problem Based Learning**
- in Engineering Science and Sustainability
- under the auspices of UNESCO

Outline

- **Fabrication of GO-HAL: new membranes, which consist of graphene oxide (GO) and a humic-acid-like biopolymer (HAL)**
- **Morphological characterization**
- **Vapor permeation tests**
- **Discussion of material and performances**
- **Conclusions**

HUMIC SUBSTANCES

Virtual fragment of aquatic humic acid



adapted from

S. Mc Donald et al., *Analytica Chimica Acta* 527 (2004) 105



**Among the responsible of
membrane fouling**

Vital resource affecting food chains

- directly
- indirectly (turbidity, pH, metal chelation,...)

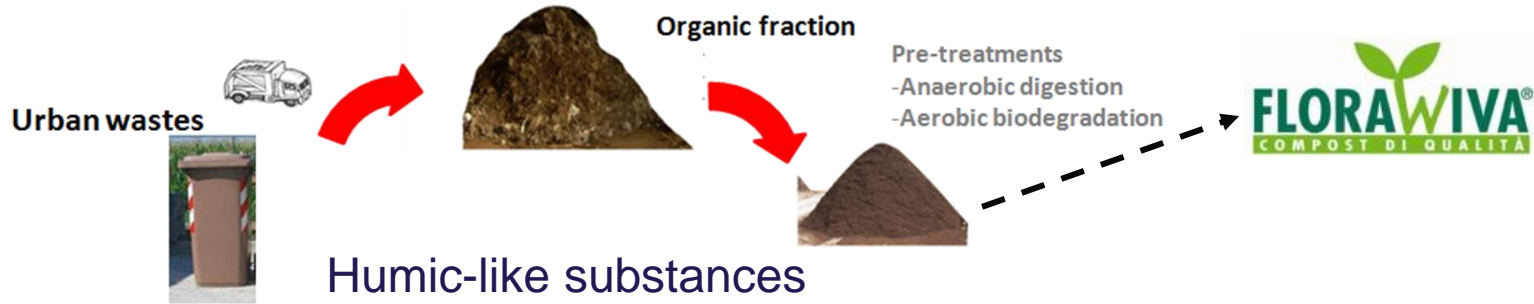
Technological properties

- polyelectrolyte
- supramolecular structures, micelles

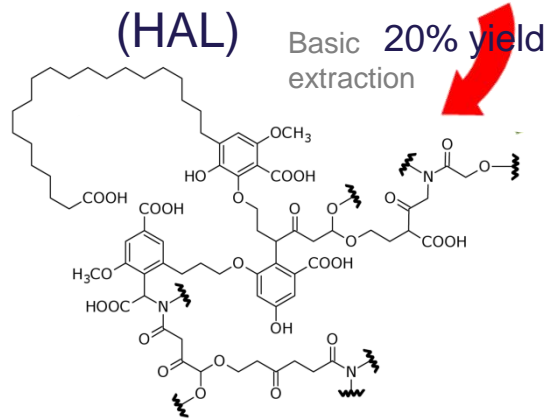
Availability?

Humic carbon in the oceans is comparable to the amount of the carbon in the atmosphere.

But... diluted (typically mg/L)



Humic-like substances (HAL)



Valorization of the organic urban refuse

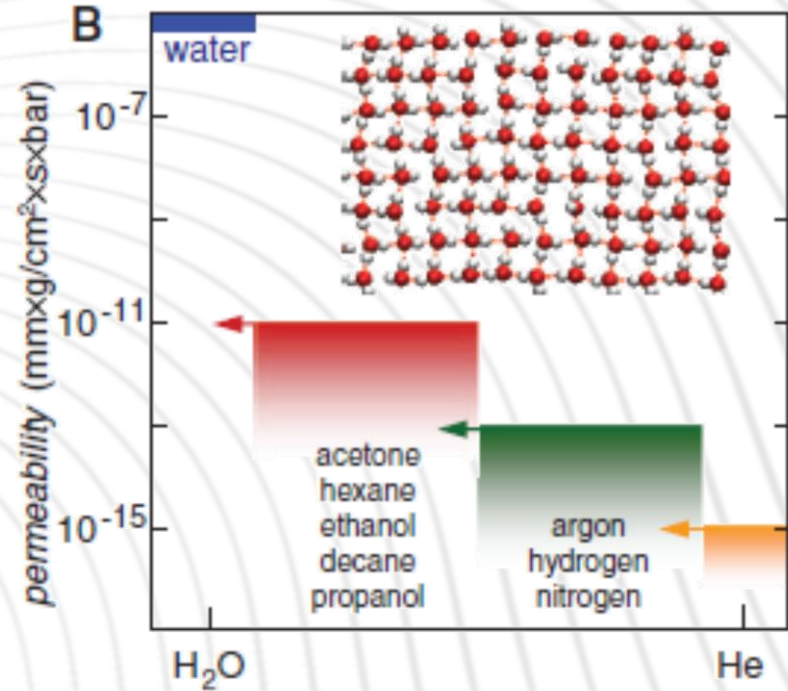
Graphene oxide (GO) membranes

Advantages:

- Outstanding water permeability
- High water selectivity
- Easy-to-process

However:

- Low stability under cross-flow filtration
- Thermal densification



R.R. Nair et. al. *Science* 335 (2012) 442.

GO & HAL

Chemical similarity:

carbon backbone functionalized with oxygen-containing moieties

Structural differences:

GO → 2D layers

HAL → 3D branched structure

Hypotheses:

- HAL can intercalate GO layers, thus inducing structural disorder
- HAL can increase water permeability of GO membranes upon thermal stabilization



sustainable membrane material

Inexpensive raw materials

Natural graphite

Simple extraction procedure

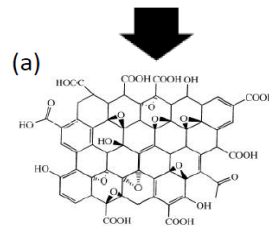
Nanomaterials

Dispersion in aqueous ammonia pH = 9.8

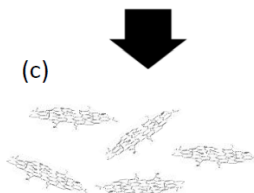
Membrane building blocks

Mixing and casting

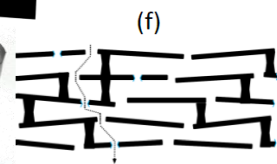
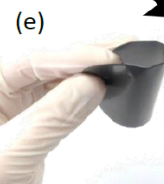
Self-assembly, drying and annealing



Graphene oxide (GO)

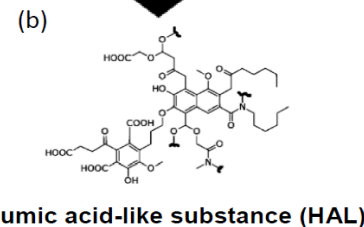


GO dispersion

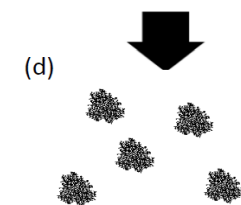


GO-HAL membrane

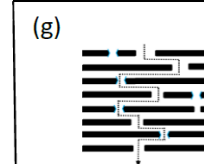
Compost from organic waste



Humic acid-like substance (HAL)

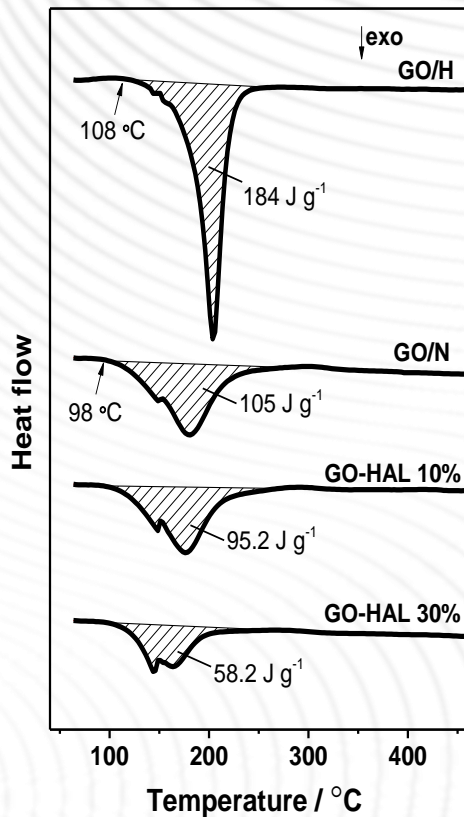


HAL solution

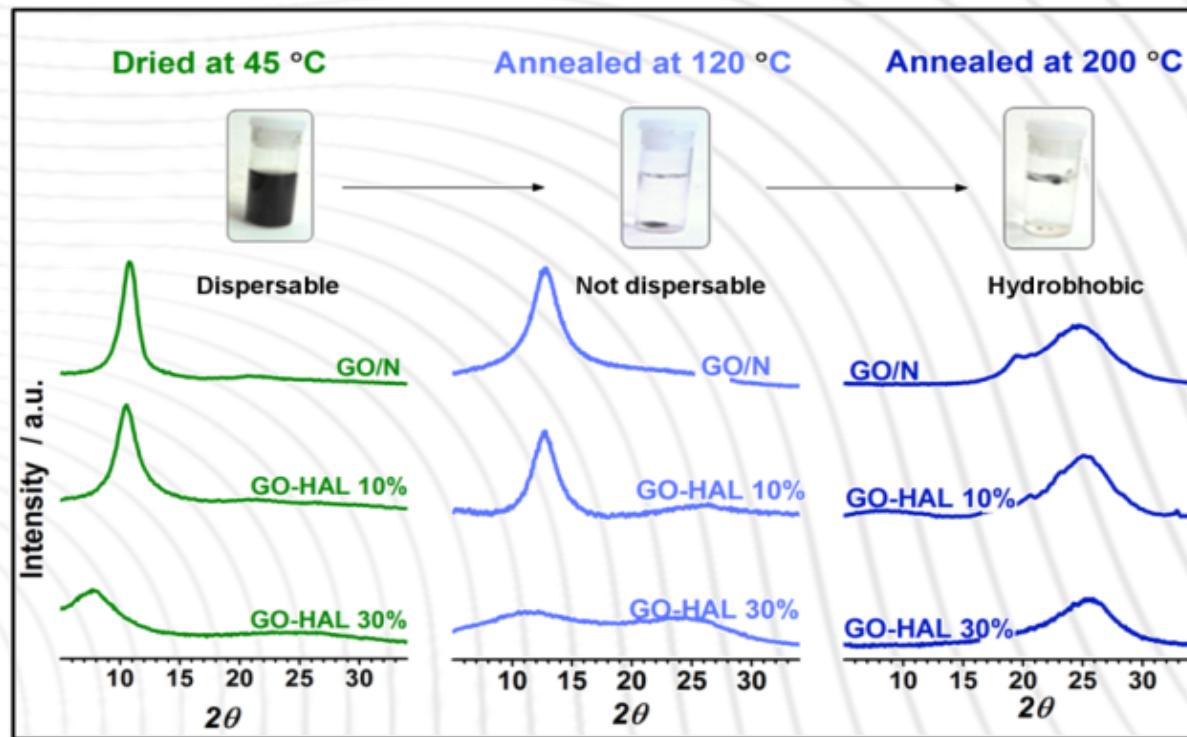


GO membrane

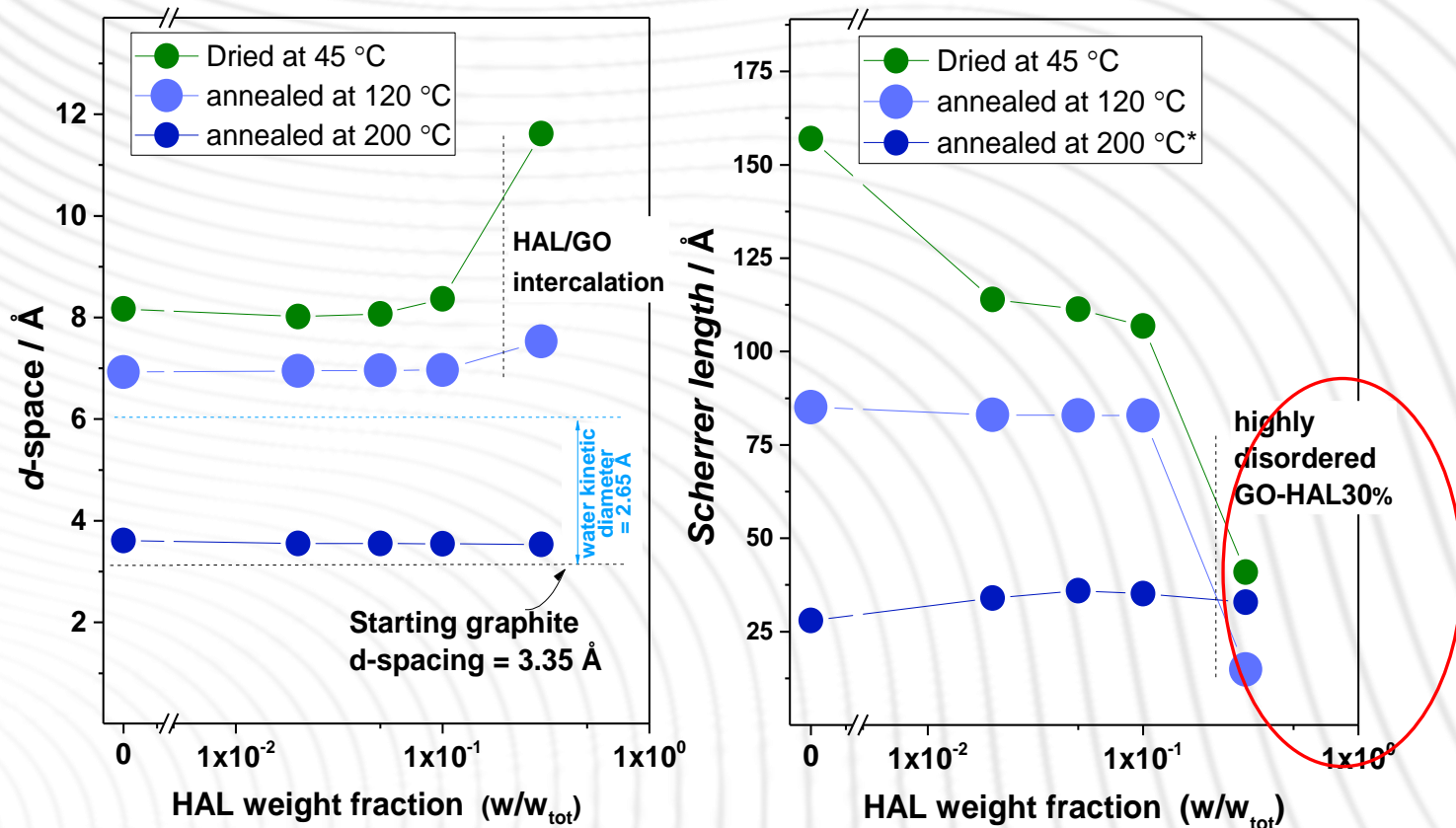
DSC



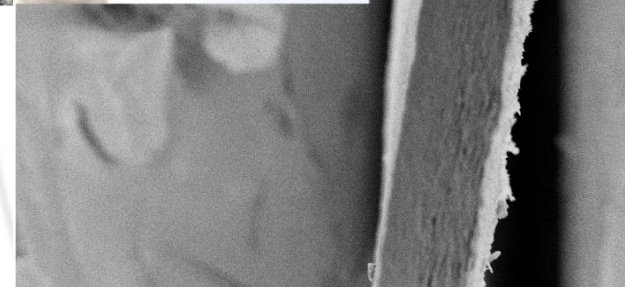
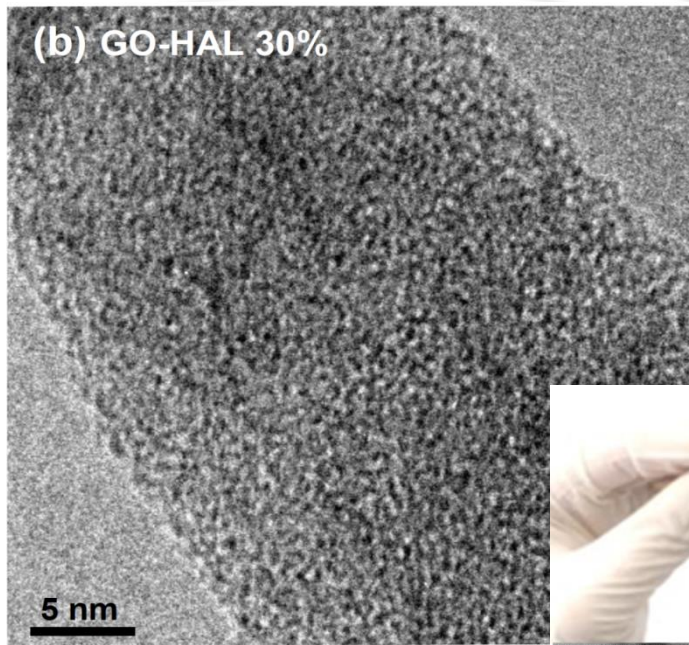
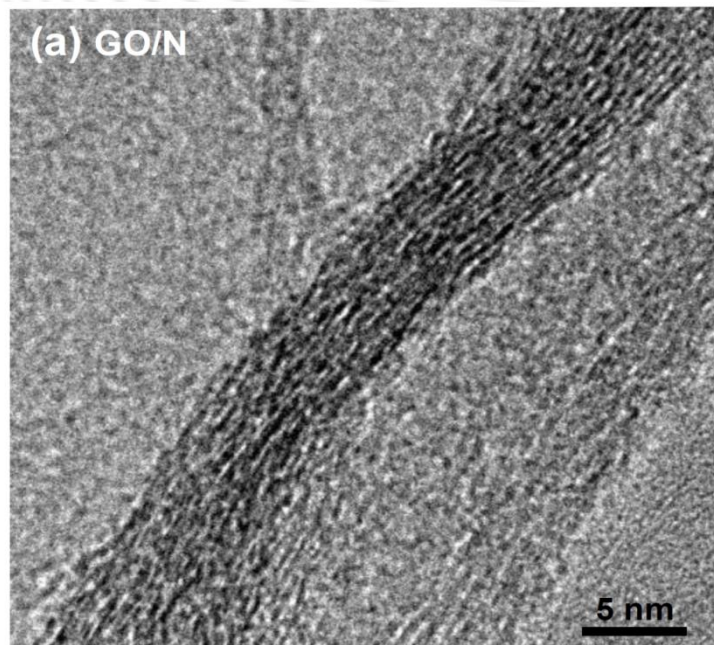
XRD



order vs disorder



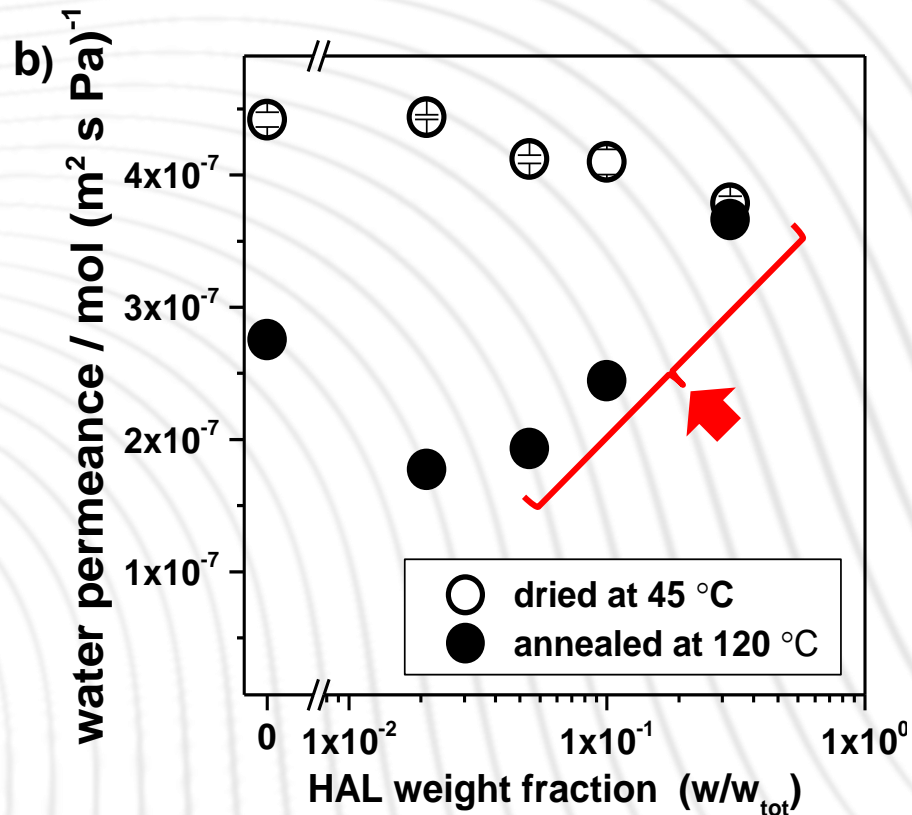
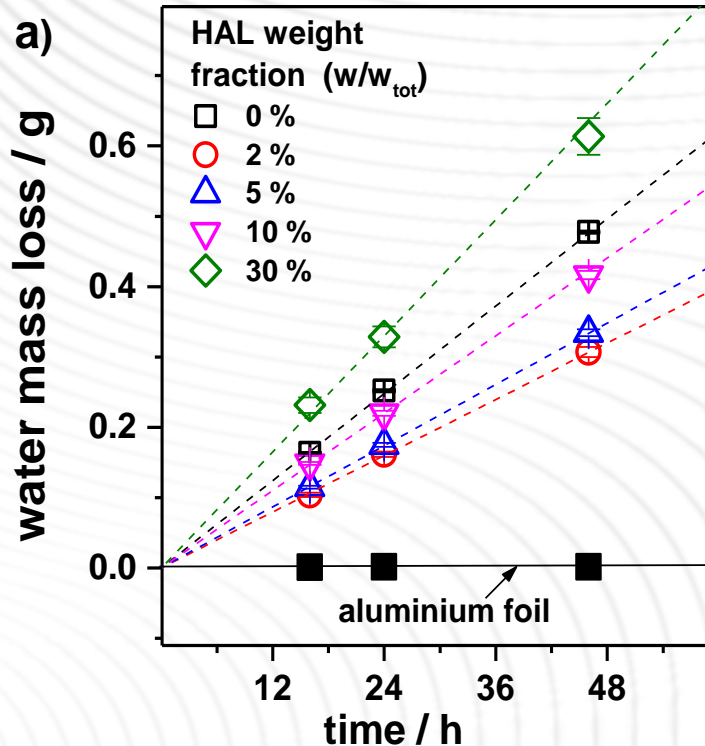
order vs disorder (after annealing at 120 °C)



V. Boffa et. al. *Carbon* 118 (2017) 458

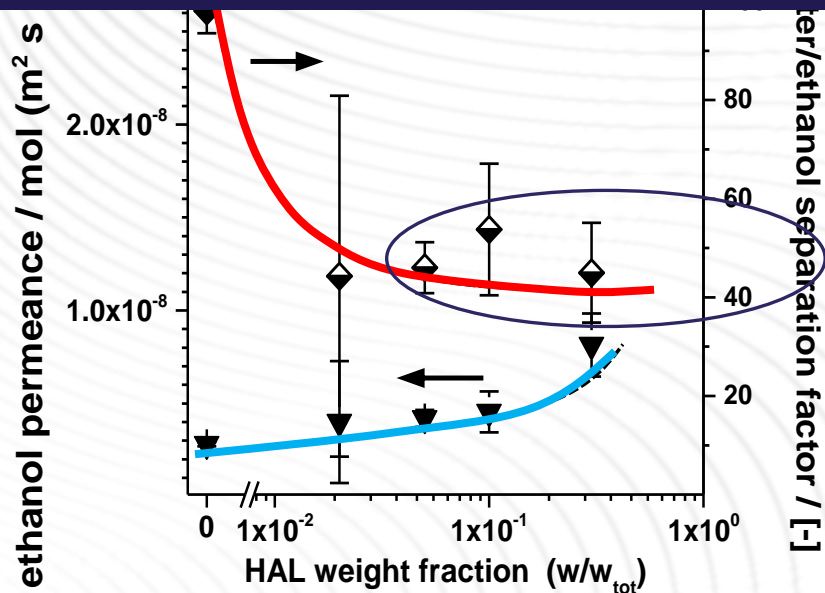
Membrane water permeability

Annealed at 120 °C

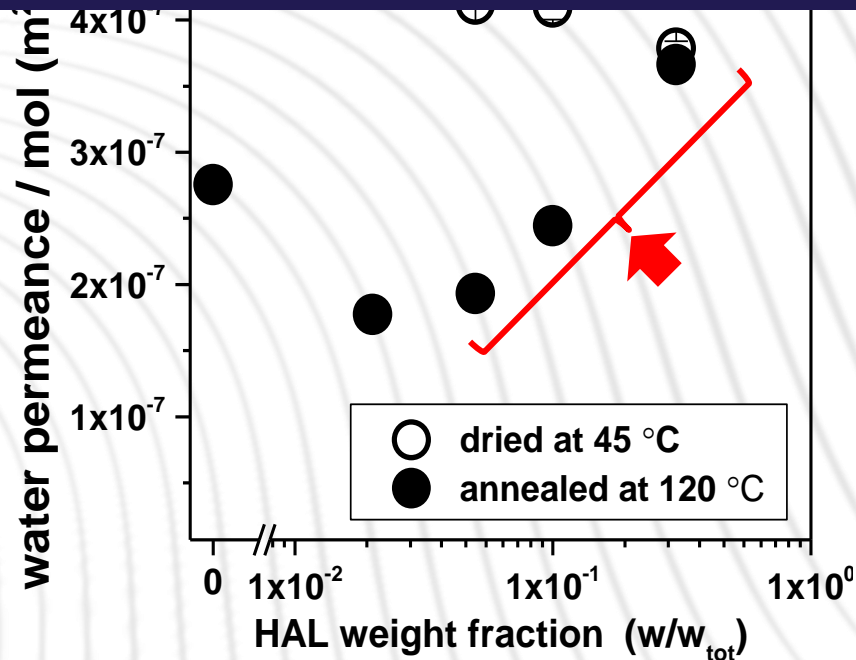


Membrane Perm-selectivity

selective
retention of ethanol



good water
premeability



In summary

- GO-HAL films were **fabricated via a facile process**
- After annealing at 120 °C, GO-HAL 30%:
 - shows **stability** to dispersion tests in basic solution
 - has **water permeance** 33% higher than pristine GO
 - shows an **ideal water/ethanol selectivity** of 45
- **Disorder** in the GO-structure is a crucial parameter for GO membranes

Is GO-HAL a sustainable membrane material?

Yes, because:

- 1. Cheap, natural, and abundant starting materials: graphite and organic compost**
- 2. Recycling organic urban waste**
- 3. Easily, scalable and water-based synthesis and processing**
- 4. Heat recovered at the membrane end-of-life**

But, there are some challenges:

- Impurities**
- New green methods for GO production**
- Valorization of the insoluble residue after HAL extraction**

Acknowledgments



- P.E. Mallon (University of Stellenbosch, South Africa)
- G. Magnacca (Turin University, Italy)