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Advanced Characterizations of Gas-Polymer Interactions: Pioneering Carbon Capture and Storage Research into the ECCSELLENT Project

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Carbon Capture and Storage (CCS) is a crucial technology aimed at reducing greenhouse gas emissions by capturing CO_2 directly from industrial sources and power plants [1,2]. Within the ECCSELLENT project (ECCSEL framework), the University of Bologna is committed to improve the Italian research infrastructure in the **CCUS** field (CO_2 Capture, Utilization, Transport, and Storage), with particular focus on CO_2 capture by membrane and on CO_2 transportation. Equipped with state-of-the-art instrumentation, **MEMLAB** and **Transport LAB** enables comprehensive characterization of polymers, evaluating their transport properties—including permeability, solubility and diffusivity—under a broad range of operating conditions.

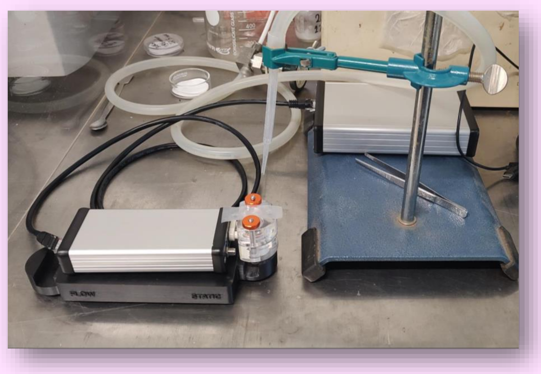
MEMLAB

Polymeric membrane morphology and nanostructure characterization for CO_2 capture capacity, separation and purification performances, in both pre- and post-combustion scenarios.

FT-IR

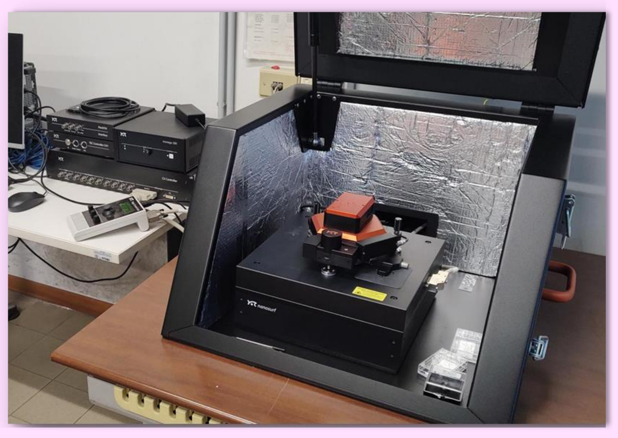
- Interferometer, laser and IR source for streamline data analysis.
- Diamond crystal ATR accessory.
- Temperature controlled plate (273K to 573K).
- Pressure dome from 1 to 70bar

QCM-D



- Real-time frequency and energy dissipation
- Mass adsorption
- Viscoelastic properties
- Gas and Liquid environments

ATOMIC FORCE MICROSCOPY



- High-resolution surface characterization
- Static and dynamic imaging modes
- Air and liquid environments
- Force–distance and tip current–voltage mapping.

TRANSPORT LAB

Characterization of gas and liquid transport through polymeric materials to determine polymer-penetrant interaction, even in cryogenic and supercritical conditions, for transport applications.

HIGH-PRESSURE SORPTION ANALYZER

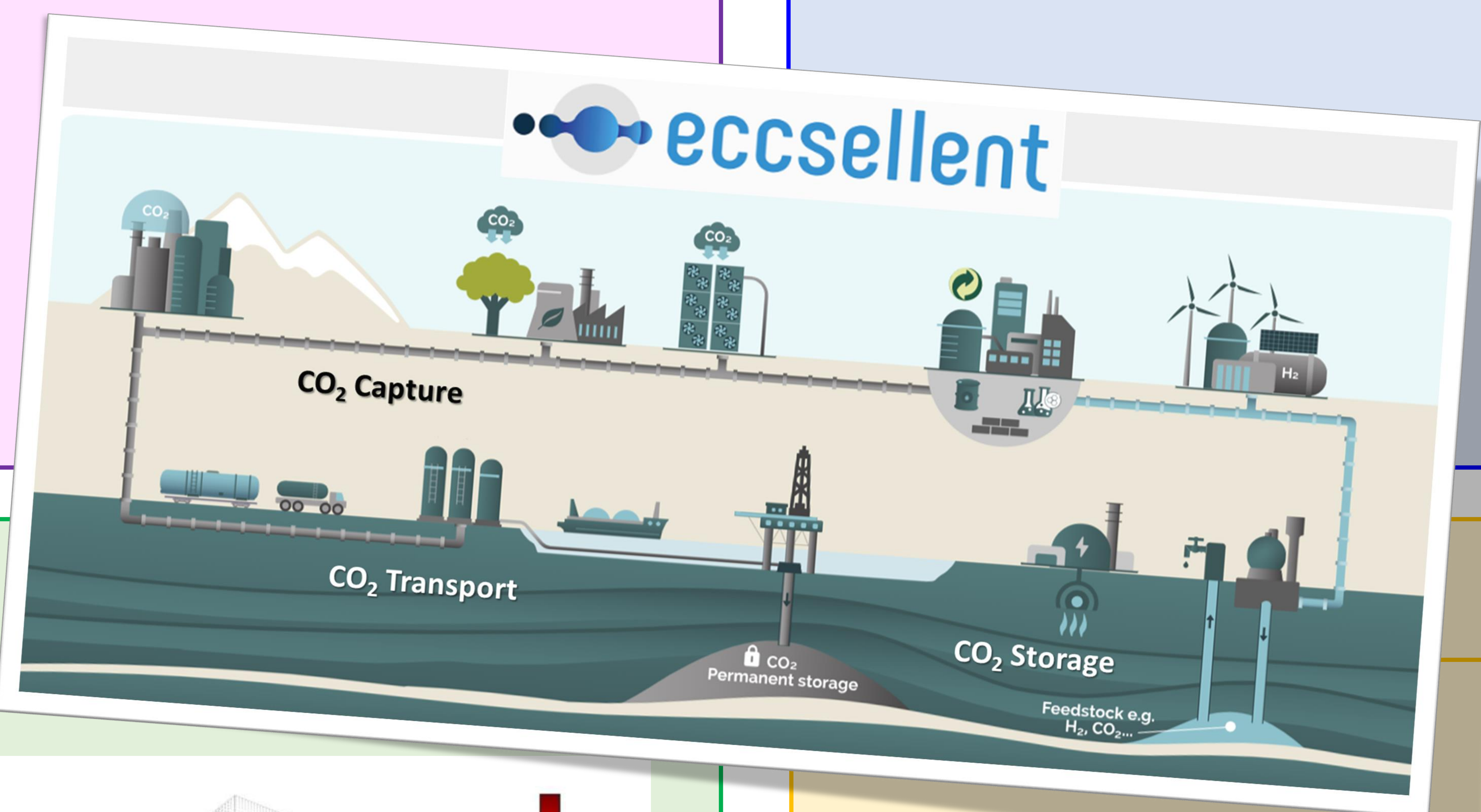
- Automated gas sorption analyser for volumetric measurements.
- Recording adsorption and desorption isotherms
- Temperature: 20K to 773K
- Pressure: 1 bar to 200 bar

DIELECTRIC SPECTROMETER

- Determination of polymeric chain mobility and relaxation.
- CO_2 effects on material's conductivity and permittivity.
- Temperature: 113K to 673K

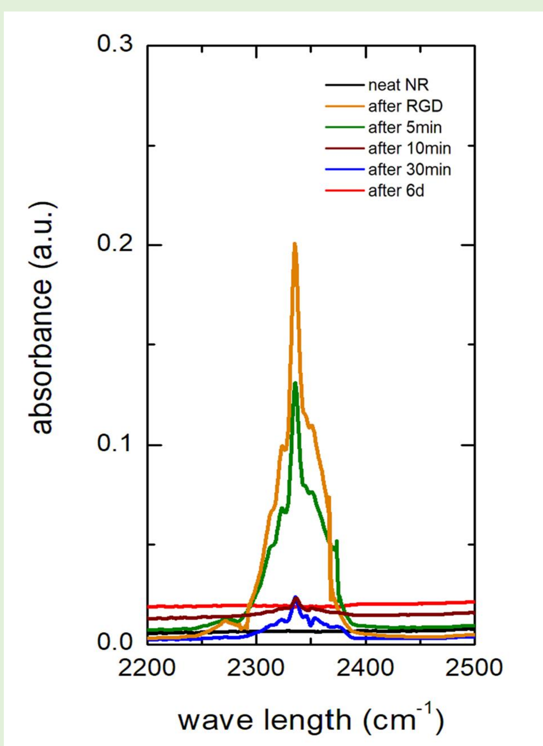
HIGH PRESSURE PERMEOMETER

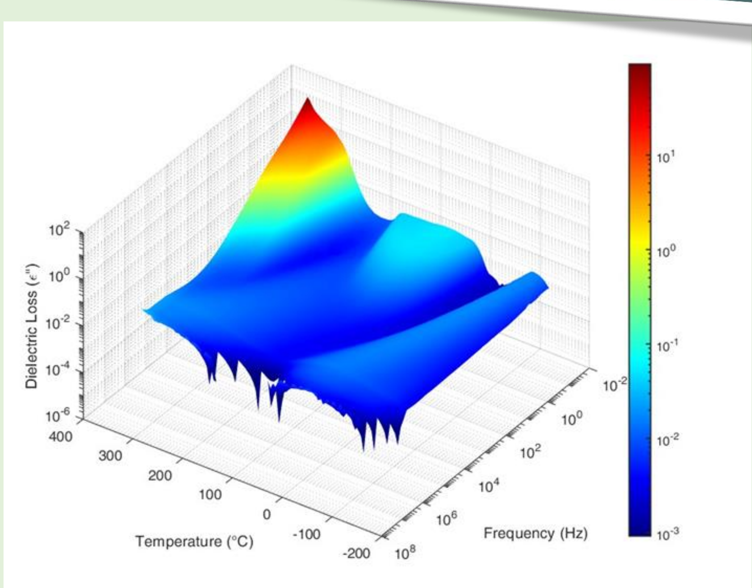
- Fixed volume and variable pressure permeometer
- Determination of Permeability (*P*) and Diffusion Coefficient (*D*)
- Temperature: 260K to 338K)
- Pressure up to150 bar.



THE RESULTS

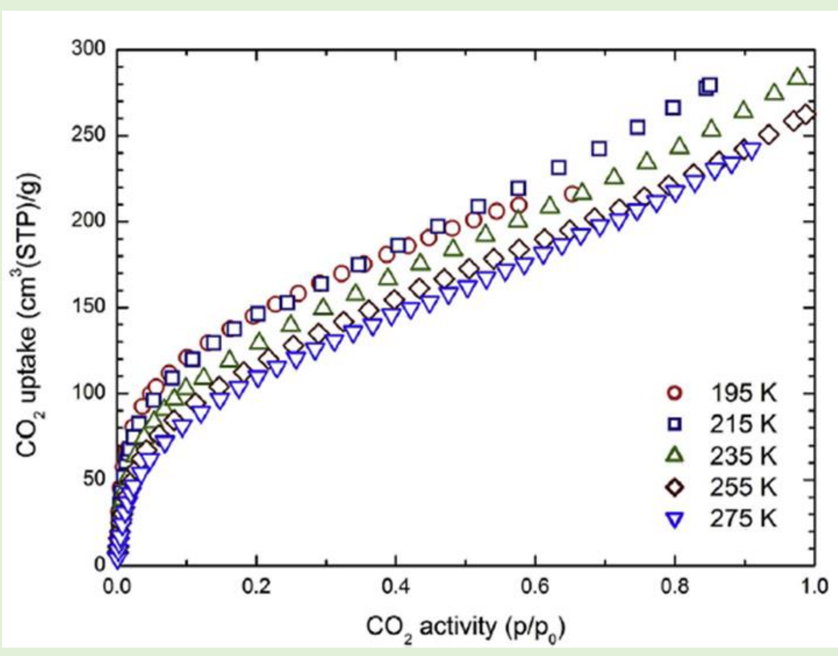
CO_2 desorption in Natural Rubber determined through FT-IR Spectrometer

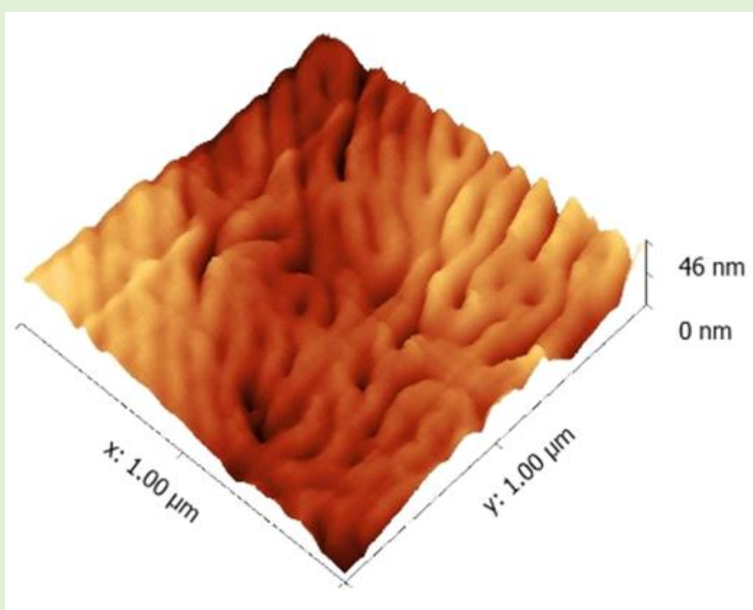




Investigation of Matrimid dielectric properties upon CO_2 exposure at 40 bar

CO_2 uptake isotherms in PIM-1 as a function of gas activity, at various cryogenic temperatures

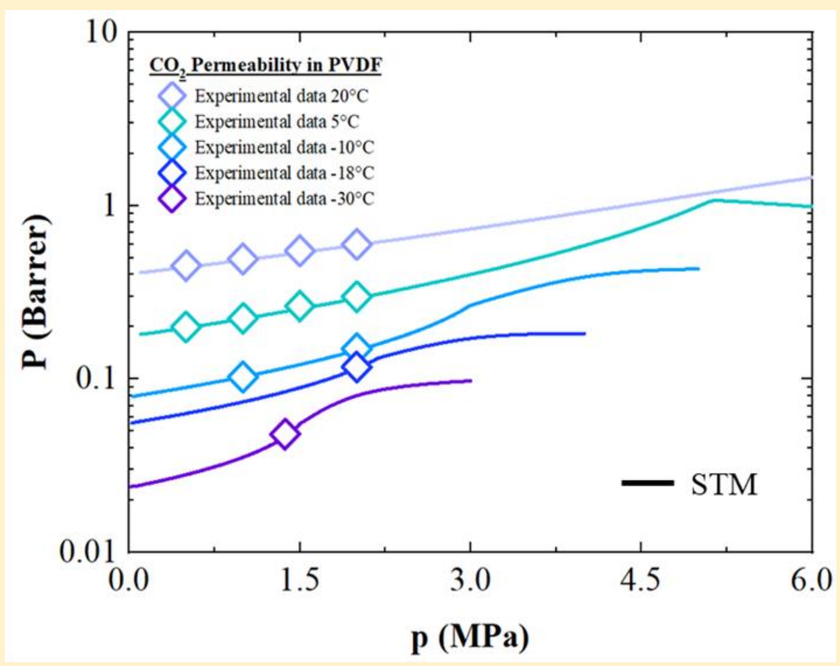




Surface, Phase-segregation, roughness and morphological characterization of PS-PEO Block-copolymers

THE OUTCOMES

Thermodynamic EoS (Lattice Fluid / Non-Equilibrium Lattice Fluid (NELF)) are used to describe the effect of CO_2 on polymers across a range of temperatures and pressures relevant to CO_2 transport and capture applications.



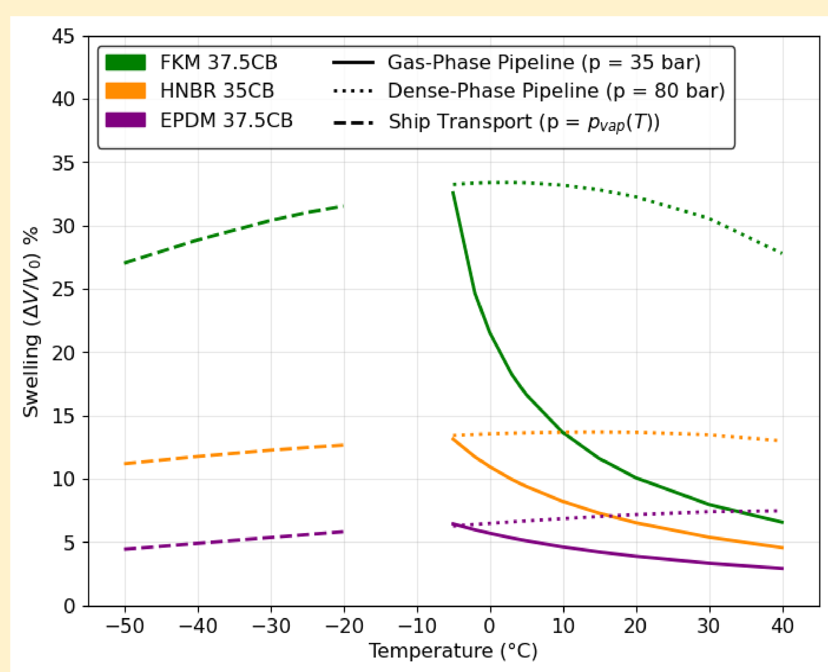
$$\mu_i^{pol}(T, p, \omega_i, \rho_{pol}) = \mu_i^{gas}(T, p, \omega_i)$$

The **Standard Transport Model** (STM) integrates solubility and diffusion coefficient to describe the gas permeability behavior as a function of pressure [5].

$$P_i = \frac{1}{(p_i^u - p_i^d)} \int_{p_i^d}^{p_i^u} L_0 \, e^{\beta \Omega_i} \, S_i \, z_i \, dp_i$$

L_0 mobility coefficient
β plasticization factor
S_i solubility coefficient
z_i penetrant compressibility
dp_i pressure difference

This modeling framework enables a deeper understanding of polymer–penetrant interactions and the effects of dense-phase CO_2 on polymer materials, while predicting polymer behavior across a range of temperatures and pressures. As a result, it supports the rational design and optimization of materials for CO_2 capture and transport applications.



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