Infrastructure Factsheet

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	**TA4.4 SINTEF MEMBRANE LABORATORIES FOR CCS- OSLO (MLAB)**
Location (town, country):	Oslo, Norway
Website:	www.sintef.no
Legal name of organisation operating the infrastructure:	SINTEF AS
Location of organisation (town, country):	Trondheim, Norway
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****Infrastructure (s)**: means a facility, a resource (or a coherent set of them) together with the related services that are used by the scientific community to conduct research.*
*****Installation:** means a part of an infrastructure that could be used independently from the rest.*

Description of the facilities

Brief general description of the infrastructure to which access is offered highlighting its state-of-the-art equipment and services offered to users that make it rare or unique in Europe. Outline the areas of research normally supported by the infrastructure, as well as any possible new areas opening to users. If the infrastructure is composed of several installations**, are these described here including their specific features. If parts of the infrastructure are still under construction, the description includes the starting date of construction and indicative date when access can realistically be made available.

TA4.4 SINTEF MEMBRANE LABORATORIES FOR CCS- OSLO (MLAB)

Purpose and brief technical description, including figures as appropriate

Fabrication facilities for inorganic membranes. The manufacturing laboratory enables to produce a final product starting from raw powders. Final products may be flat sheet membranes of maximum size 6 cm x 6 cm, symmetric or thin film coated tubular membranes up to 20 cm long. It comprises ventilated benches and hoods for synthesis of powder and its conditioning via various milling processes (planetary milling, ball milling). The powders are then shaped as tubular membranes (dense or porous) by water-based extrusion using a 40 tons Loomis piston extruder located in a clean room facility (ISO class 7). The extruder is equipped with automatic capping system for the production of close-end tubes, as well as automatic cutting tool. The tubes are delivered on an automatic air flow transport belt, thereby limiting contamination and surface damage. Planar membranes can also be prepared via tape-casting (using solvent or water based slurries). Additional milling equipment is available for tuning the rheology of pastes and slurries (sonotrode and ultrasound baths). Paste and suspension rheology is characterised using Kinexus and DV2t rheometers. Deposition of thin and thick films on ceramic substrates is carried out by various techniques, including an automatic 3D spray-coater, a semi-automatic screen-printer and a multi-sample holder dip-coater, which is also located in the clean room. Necessary furnace facilities for annealing and sintering of materials of up to 1600°C are available. Furnace for annealing of 30 cm long tubes are available.

A sputter for fabrication of alloy membranes such as Pd alloy is available. It is possible to produce thin films of alloy membranes on Si or glass substrates, with thickness at the micron level. The sputtered layers can be used in making flat or tubular membranes. The sputtering equipment as well as electron beam deposition equipment for deposition of metal, alloys and ceramics are available in a clean room facility.

Testing units for inorganic and organic membranes. A well-equipped membrane permeation characterisation laboratory allows studies of permeation up to 40 bars and 1000°C (e.g. for studies of Pd-based, polymeric-based and ceramic membranes in Water Gas Shift, Methane Steam Reforming processes, as well as post combustion capture). The gas mass flow and pressure controllers are regulated by a PC and the gas composition of feed and permeate are monitored continuously by MS and GC units. An advanced gas distribution infrastructure for multiple gasses (O_2, H_2, N_2, CO, CO_2, CH_4, Ar, He, etc) and mixtures is installed. The infrastructure have been upgraded in 2017 by a furnace with three heating zones enabling to test tubular membranes of 10 to 15 cm length, and an impedance spectrometer for accurate measurement of samples with low impedance.

Automated atmospheric and pressurised Thermal Gravimetric (TG) equipment. Both TG units have automated gas feeding, switching and mixing systems (H_2, CO_2, CO, CH_4, N_2, H_2O, Ar) that enable multiple cycle sorption measurements at temperatures from ambient to 1000ºC. The High Pressure TG (HPTG) is placed in a laboratory with a separate ventilation system which allows experiments in a sulphur environment.

Sulphur laboratory for material and component testing. This unique facility allows for investigation of materials from ambient conditions to high pressure (40 bars) and high temperature (1100°C) conditions in the presence of harsh chemicals (e.g. H_2S for investigation of membrane and adsorbent materials for use in power cycles based on coal, sour NG and biomass as fuel). It has high degree of automation for gas control and monitoring. It provides data for studies of reactions kinetics, transport properties, and stability of materials, e.g. used as adsorbents and membranes. Also, stability against corrosion for critical components can be studied with this type of apparatus. An advanced gas distribution infrastructure for multiple gasses (O_2, H_2, N_2, CO, CO_2, CH_4, Ar, He, etc.) and mixtures is installed.

The laboratory includes a well-equipped membrane permeation characterisation setup, a sorbent test station, and a high-pressure TG (thermo-gravimetric analysis). The laboratory is very flexible, and is equipped with a separate ventilation system and alarms for safe operation.

Sulphur lab

Membrane coating in clean room

Membrane testing

State of the Art, uniqueness (if applicable), and any specific advantages (e.g. technical, economic etc)
The major part of this infrastructure contains various experimental techniques used to evaluate the performance of sorbents and membranes. All techniques offered are modern and the results obtained are expected to be of high scientific quality. The experiments can be conducted under realistic conditions at high temperatures, pressures, and under high partial pressures of steam. Various gases are available. Also, tests in a sulphur environment (or other special gases) can be carried out in a separate laboratory with dedicated setups. The equipment is monitored and used only by skilled technicians and scientists. The choice of the right experiment and experimental conditions for a specific test can also be established through discussion with our experts.

Many of the equipment and test setups are considered unique. We have, as an example, analysed extremely high hydrogen fluxes that it is possible to obtain using ultra-thin Pd-Ag membranes (see publication list below) in our laboratory.

Scientific environment (related and potentially available scientific and technical services at RI's location e.g. analysis, material preparation etc.)

We offer the abovementioned experiments to be carried out in one infrastructure. Skilled scientists and technicians are available to assist visiting researchers. Beside the infrastructure itself, more standard laboratories are available where sample preparation and other tasks can be performed. A number of GC, MS and IR gas analysers are available, if needed. Also, a desk with internet access will be available during the stay.

SINTEF Industry has implemented and maintains a quality management system which fulfils the requirements of the standard NS-EN ISO 9001:2008 within research and development in materials technology, advanced materials and nanotechnology, applied chemistry and bio technology, oil and gas, and green energy and process industry.

CCS PROJECTS:

EU-funded CCS projects:

The infrastructure has been central in the accomplishment of several national and international projects, and $6^{th}/7^{th}$ FP and H2020 projects such as DECARBit, CAESAR, CACHET, CACHET II, Democlock, iCap, HETMOC, and HiPerCap.

Other CCS projects:

BIGCCS and several other Norwegian membrane and sorbent-related CCS projects

Main/major non-CCS projects:

EU projects; GAMER, AH2A, CARENA, ReForCELL, and Electra

Patents:

Selected publications:

- Peters, T.A., Rørvik, P.M., Sunde, T.O., Stange, M., Roness, F., Reinertsen, T.R., Ræder, J.H., Larring, Y., Bredesen, R., Palladium (Pd) membranes as key enabling technology for pre-combustion CO2 capture and hydrogen production, Energy Procedia, 114 (2017) 37-45.
- Polfus, J.M., Xing, W., Sunding, M.F., Hanetho, S.M., Dahl, P.I., Larring, Y., Fontaine, M.L., Bredesen, R. Doping strategies for increased oxygen permeability of $CaTiO_3$ based membranes, J. Membr. Sci., 482 (2015) 137-143.
- Polfus, J.M., Xing, W., Fontaine, M.L., Denonville, C., Henriksen, P.P., Bredesen, Hydrogen Separation Membranes based on Dense Ceramic Composites in the $La_{27}W_5O_{55.5}$–$LaCrO_3$ System, J. Membr. Sci., 479 (2015) 39-45.
- Peters, T.A., Kaleta, T., Stange, M., Bredesen, R., Development of ternary Pd-Ag-TM alloy membranes with improved sulphur tolerance, J. Membr. Sci., 429 (2013) 448-458.
  Peters, T.A., Kaleta, T., Stange, M., Bredesen, R., Inhibition of hydrogen transport through a selection of thin Pd-alloy membranes by H_2S: membrane stability and flux recovery in H_2/N_2 and WGS feed mixtures, Cat. Today, 193 (2012) 8-19.
- Egil Bakken, Paul D. Cobden, Partow Pakdel Henriksen, Silje Fosse Håkonsen, Aud I. Spjelkavik, Marit Stange, Ruth Elisabeth Stensrød, Ørnulv Vistad, Richard Blom “Development of CO_2 sorbents for the SEWGS process using high throughput techniques” Energy Procedia, 2011, 4, 1104-1109.

FACILITY AVAILABILITY:

Unit of access:

Day

Availability per year:

120 days

Expected duration of single experiment:

2- 30 days

OPERATIONAL OR OTHER CONSTRAINTS:

Specific risks:

Legal issues: