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Mechanical properties of $La_2NiO_{4+\delta}$ membranes for gas separation

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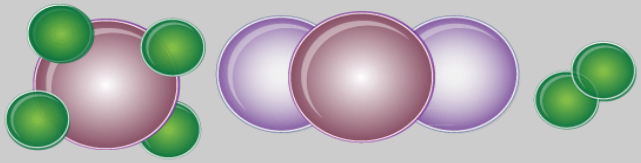

2nd Trondheim
Gas Technology Conference
2-3 November 2011

Outline

- Introduction
- Material
- Water based tape casting
- Mechanical properties
- Summary

Introduction / *oxygen production*

Cryogenic Distillation: Proven Oxygen Supply Technology

- Mature, reliable technology
- Energy consumption intensive
- complicated process

Pressure swing adsoption: Convinient Oxygen Supply Technology

- Mature, flexible technology
- Low oxygen purity

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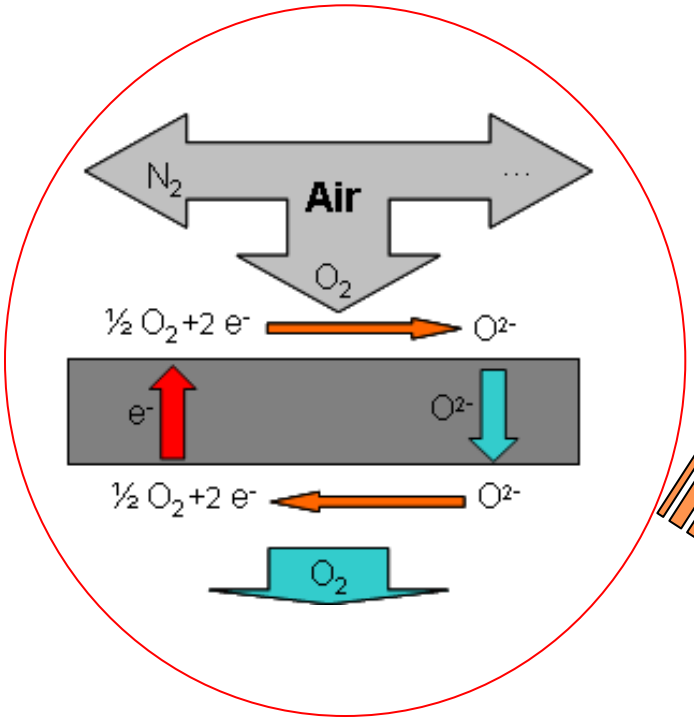
Introduction / *MIEC membranes*



Mixed ion and electron conducting (MIEC) materials

- Gas sensor
- Cathode for SOFC
- Oxygen separation membrane
- Combined reactor for syngas production or natural gas conversion

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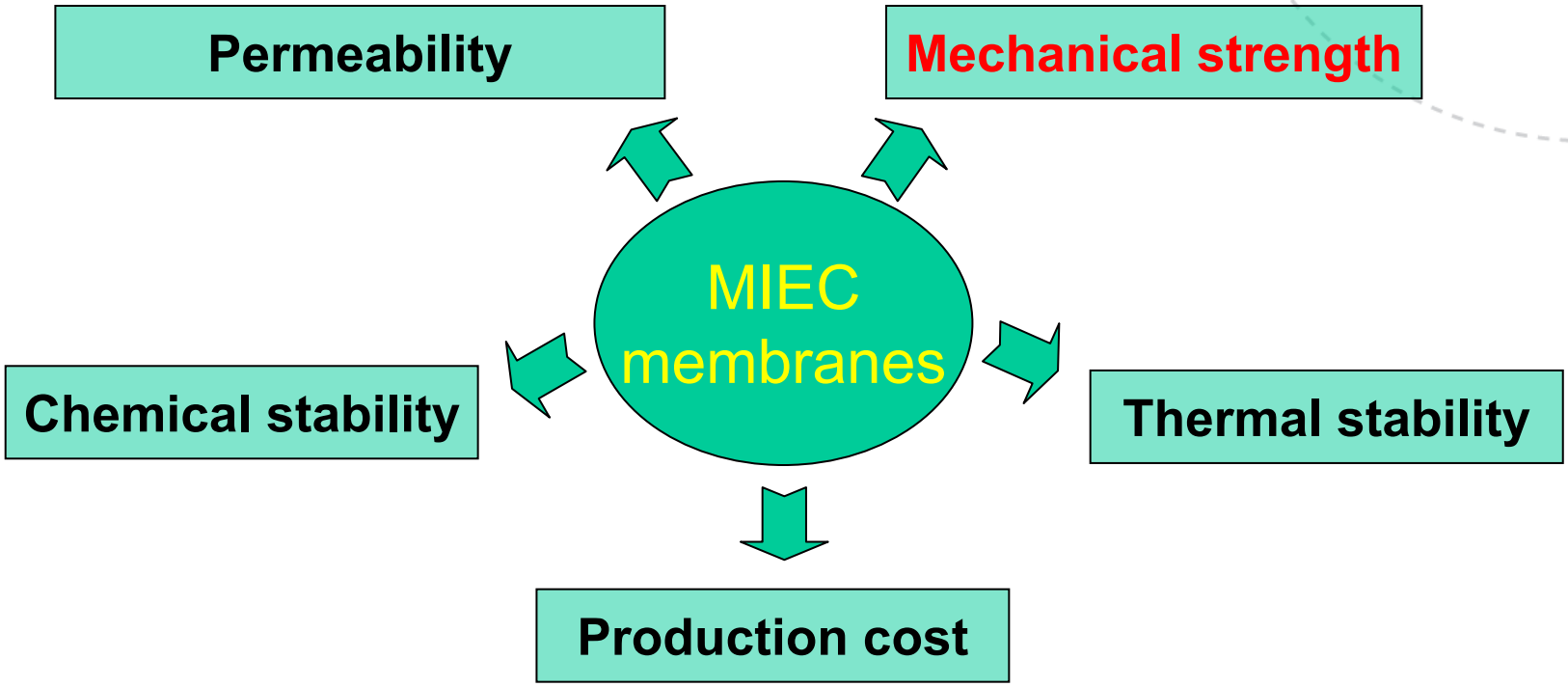
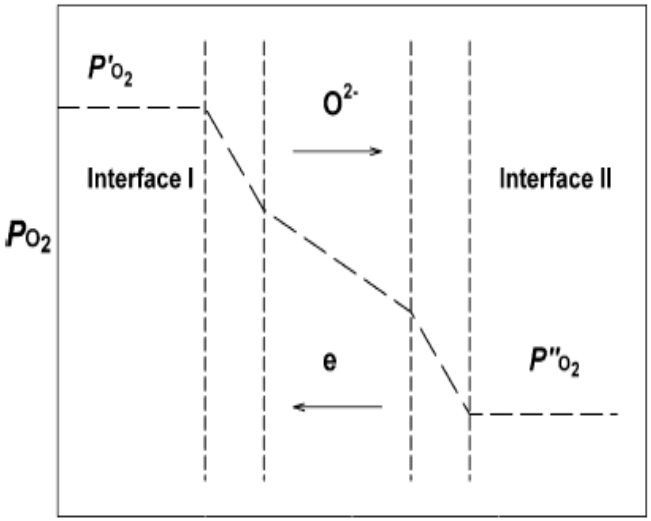
Introduction / *requirements*

Requirements for high temperature ceramic oxygen permeation membranes

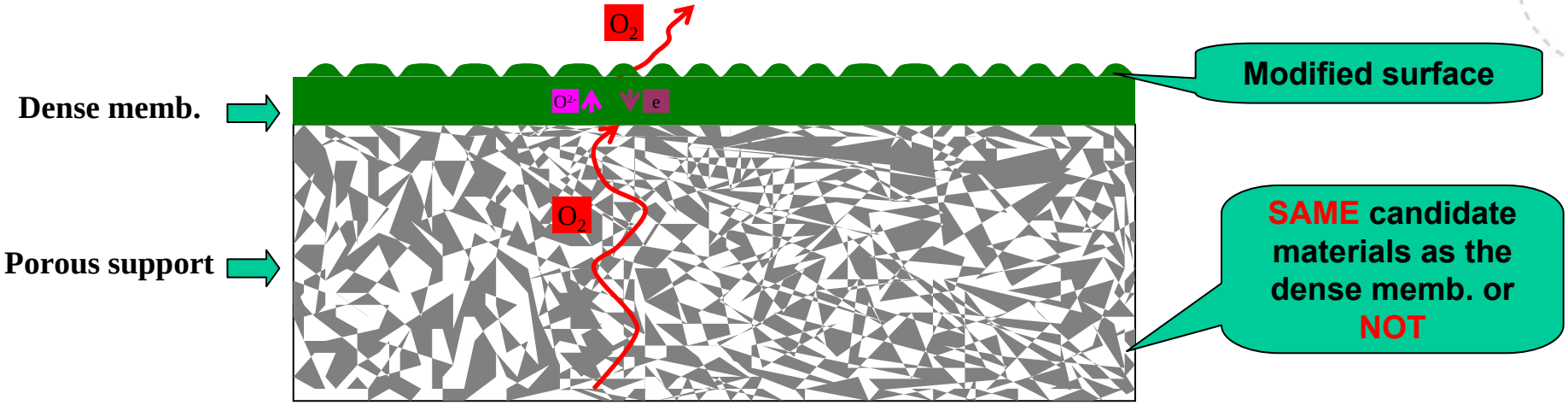


Introduction / *model*



Decreasing the thickness of dense membrane → Increasing the flux

Appropriate porous support → Providing main mechanical strength



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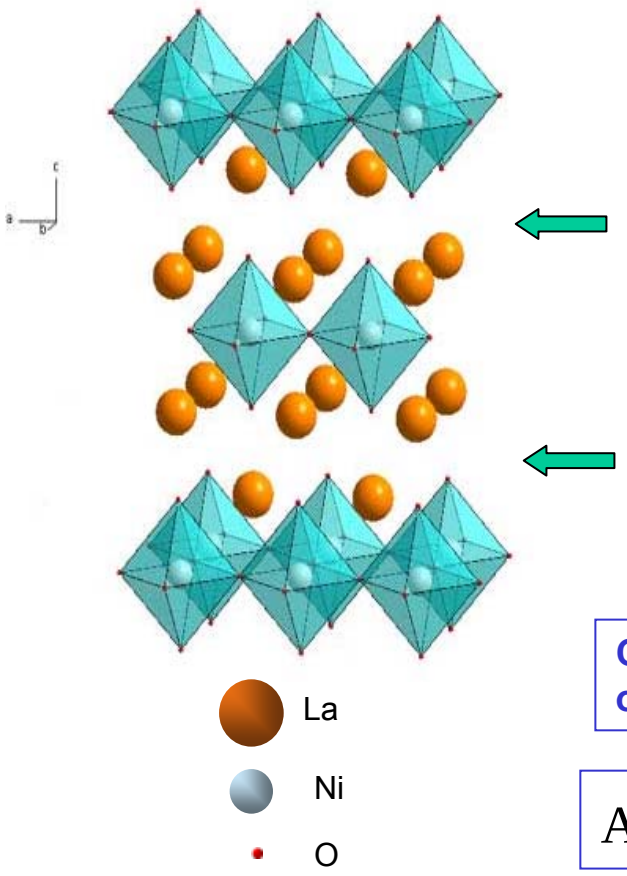
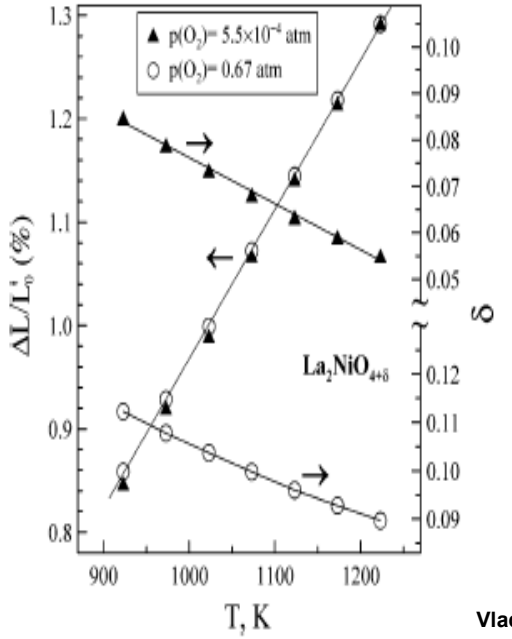
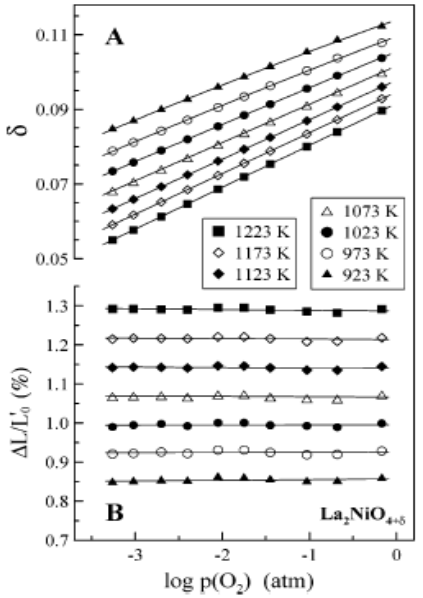
Material / $La_2NiO_{4+\sigma}$

Candidate material for dense thin membrane



Ideal structure of $La_2NiO_{4+\sigma}$





Vladislav V. Kharton, et.al. *Chem. Mater.* 2007, *19,* 2027-2033

Chemical expansion of $La_2NiO_{4+\sigma}$ is almost independent of oxygen content variation due to anisotropic crystal structure

Additionally

- Sufficient permeation flux
- High catalytic activity
- Anisotropic diffusion

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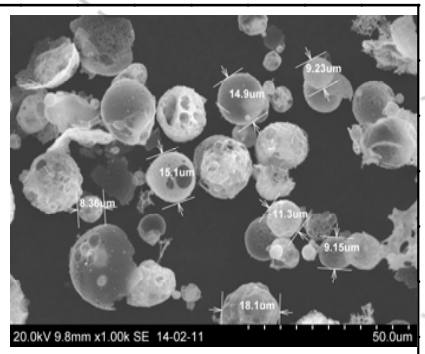
Material / $La_2NiO_{4+\sigma}$

Synthesized by spray pyrolysis

$La_2NiO_{4+\sigma}$ as-synthesized powder

Agglomerate size: 8 ~ 20 um



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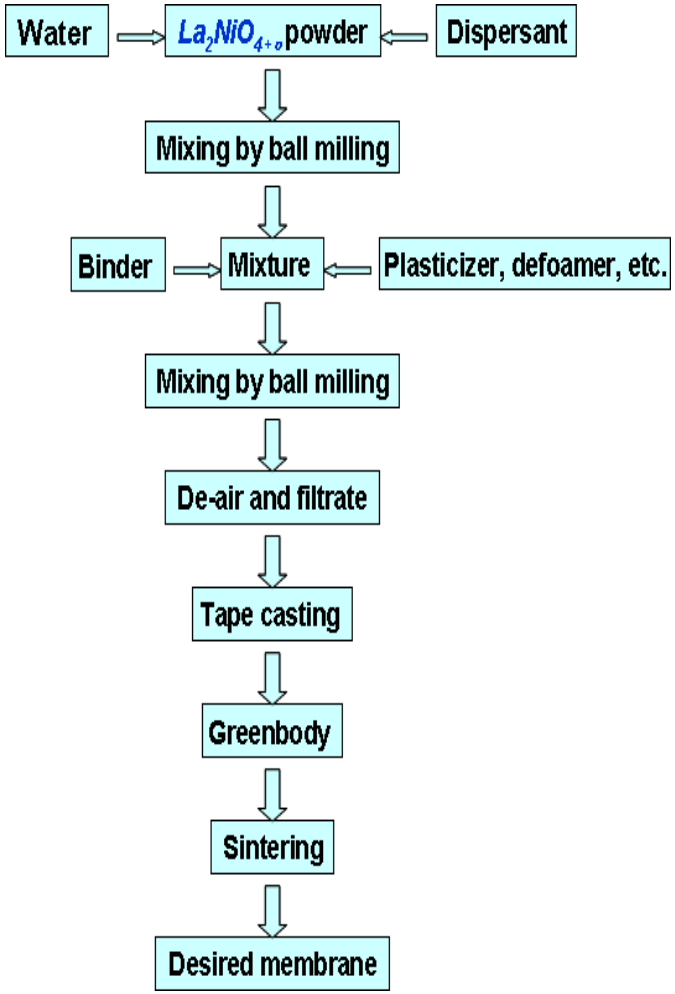
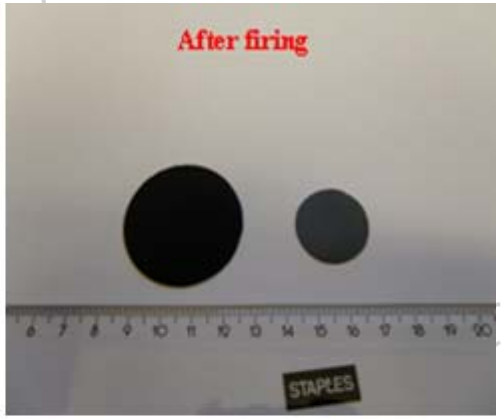
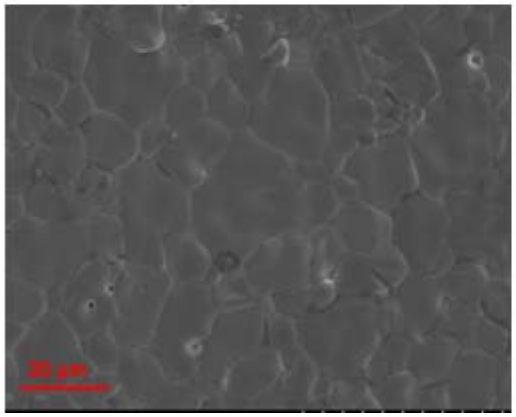
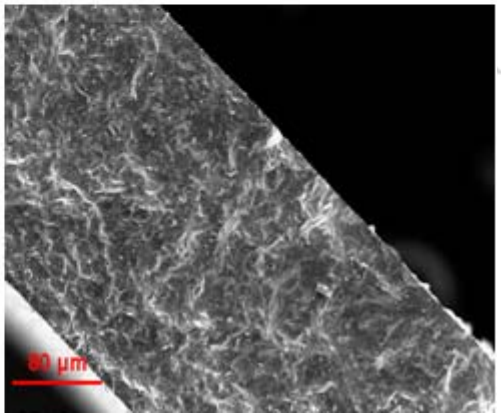
Water based tape casting / $La_2NiO_{4+\sigma}$ membranes









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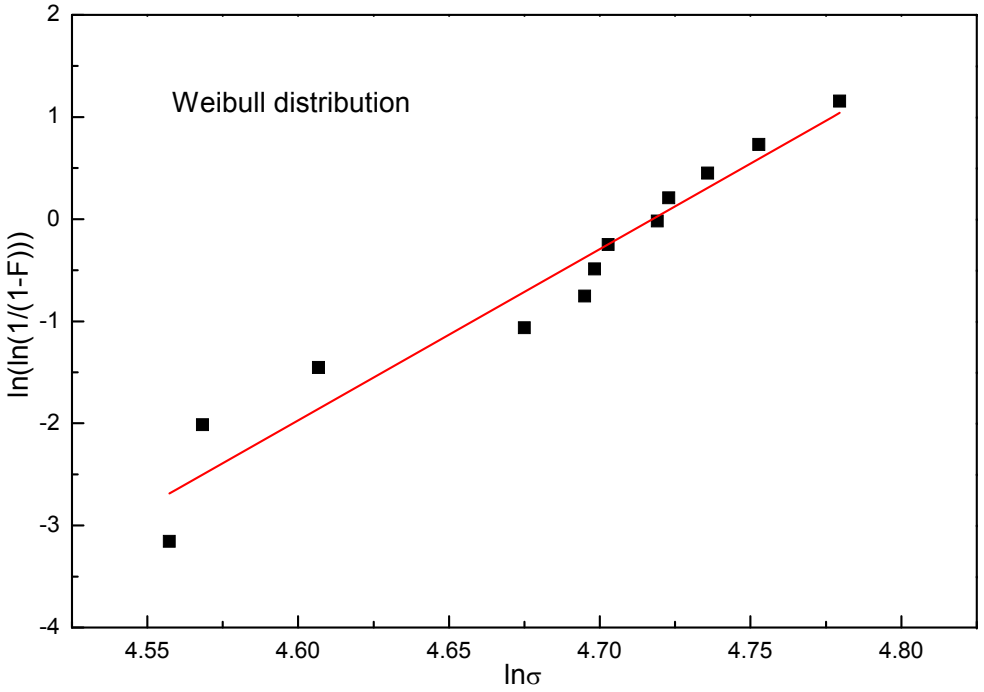
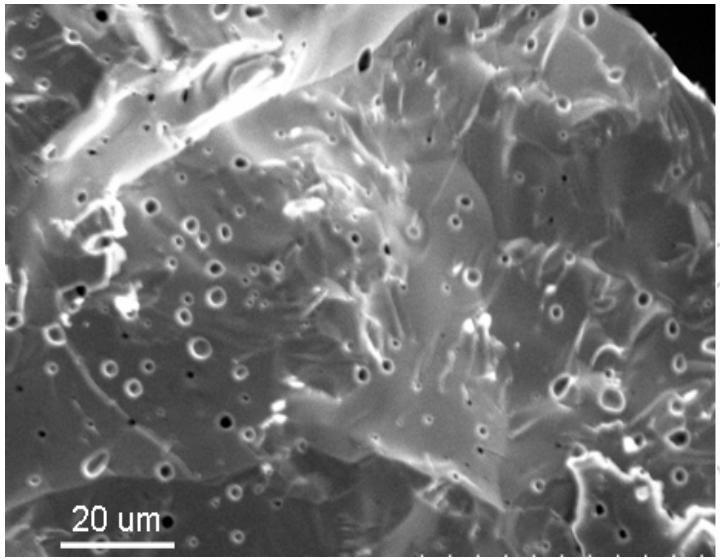
Mechanical properties / *fracture strength*

Ball on ring test of $La_2NiO_{4+\sigma}$ membranes





Fracture surface

Average biaxial fracture strength: 109 MPa

Weibull modulus : 17

Relative density: 96 %

Fracture strength value (porosity ~ 52 %) in literature is less than 25 MPa at R.T

Transgranular fracture mode is expected

B.X.Huang, et.al, Thermo-mechanical properties of La_2NiO_4. J.Mater Sci (2011) 46:4937 - 4941

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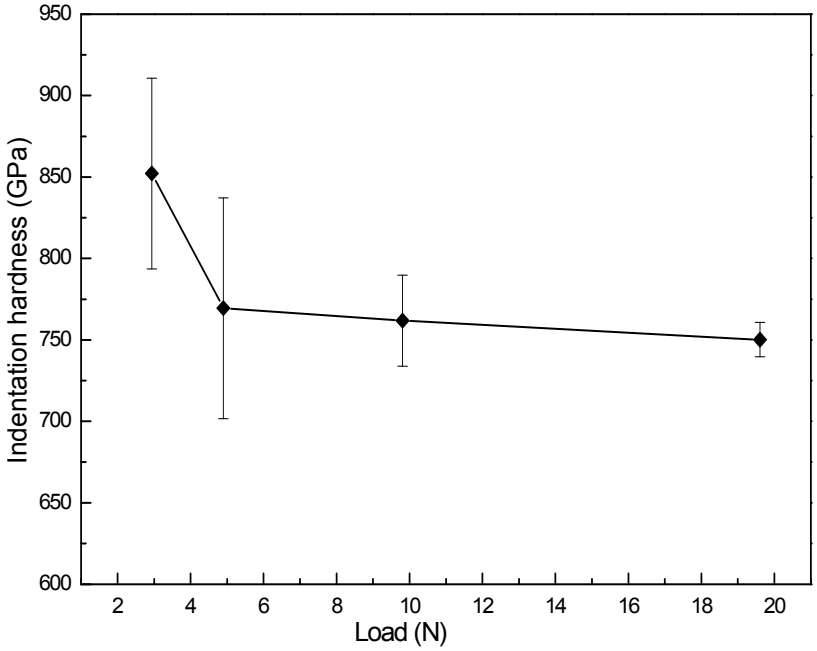
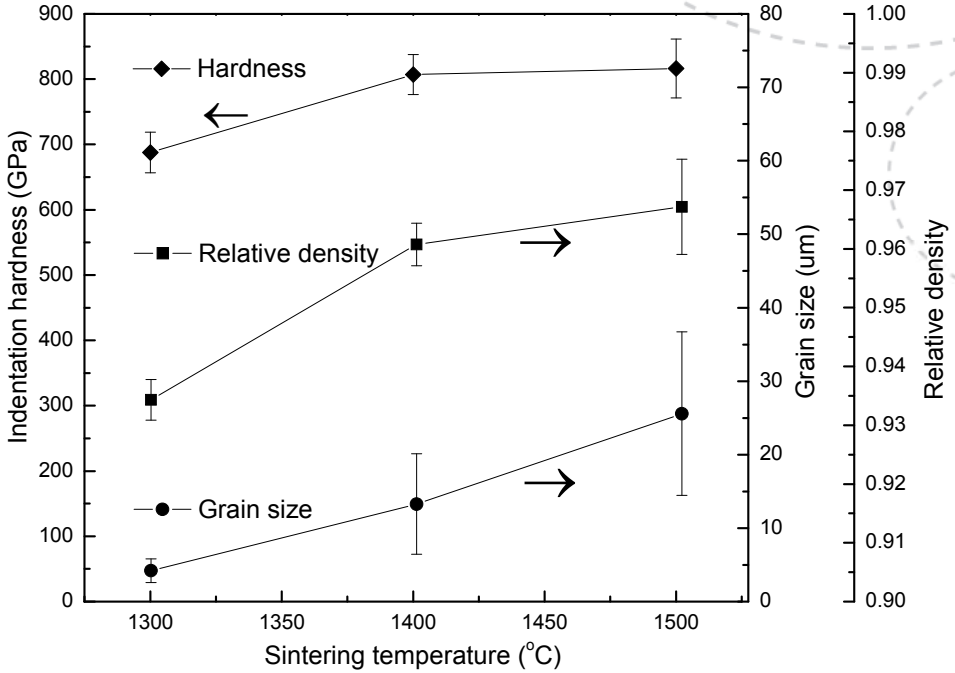
Mechanical properties / *hardness*

Indentation hardness of $La_2NiO_{4+\sigma}$ pellet



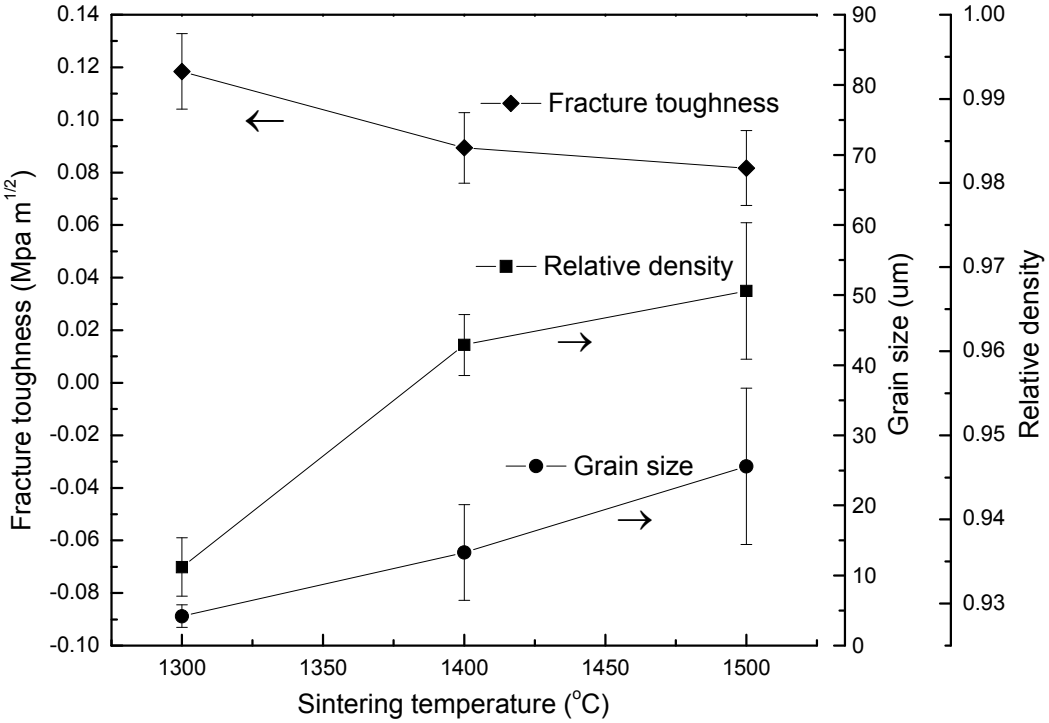
Indentation size effect can be found

Load: 1.96 N

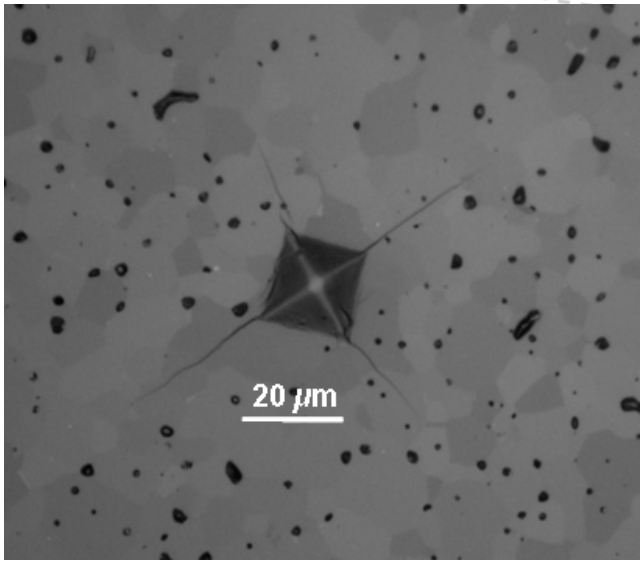


Mechanical properties / *fracture toughness*

Indentation fracture toughness of $La_2NiO_{4+\sigma}$ pellet



Load: 1.96 N



Optical microscopy image of indent

The fracture toughness value is much lower than the typical value of ordinary polycrystalline ceramics (2-6 MPa $m^{1/2}$)

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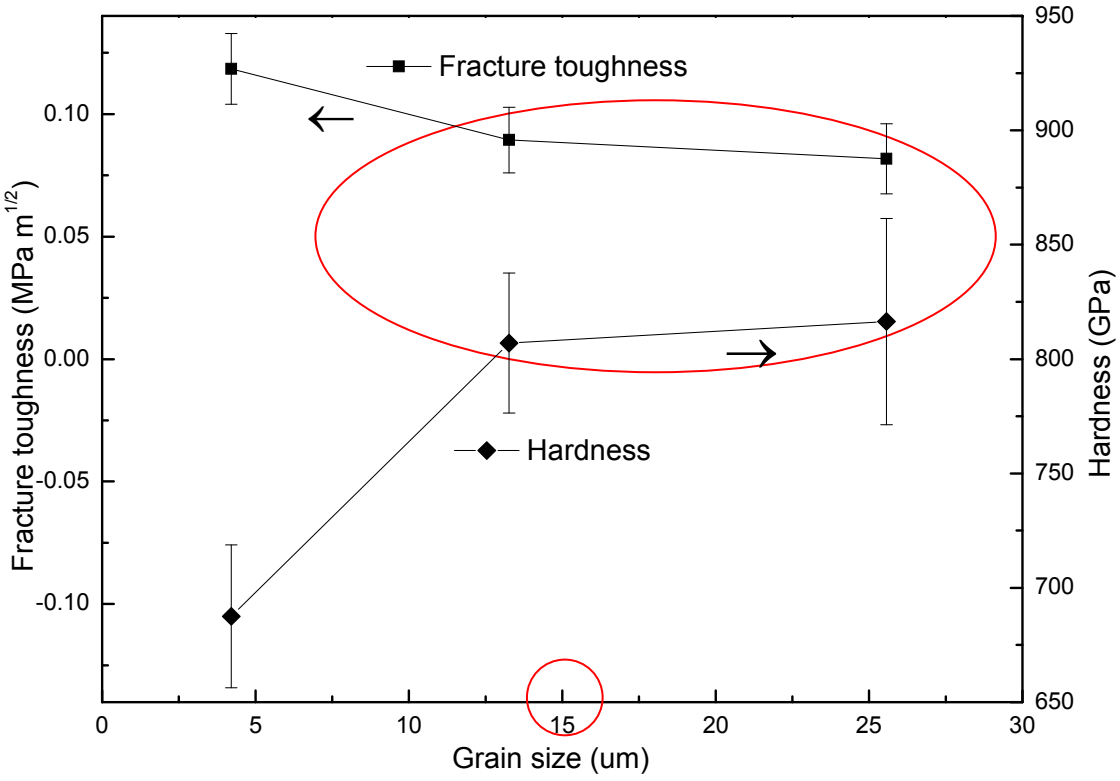
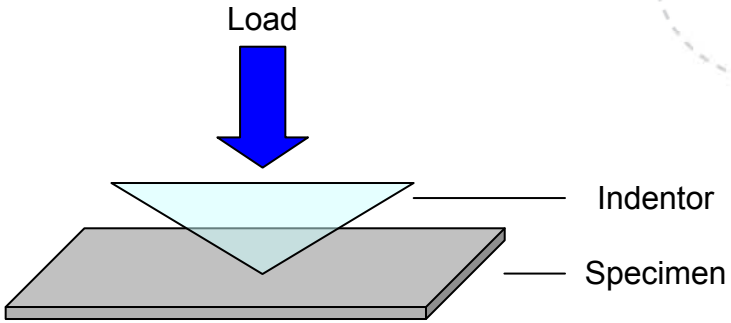
Mechanical properties / *discussion*



Load: 1.96 N

Indentation size: ~15 um



Grain boundary effect would be less and less when the grain size is larger than indentation size

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Summary

- Developed a successful method for $La_2NiO_{4+\sigma}$ water based tape casting, membranes with a density of above 96 % of the theoritical density were prepared by this method.

- $La_2NiO_{4+\sigma}$ has very good chemical stability, but a poor mechanical properties, fracture strength: ~109 MPa; hardness: ~780 GPa; fracture toughness: ~0.1 MPa $m^{1/2}$

- Asymmetric membranes with $La_2NiO_{4+\sigma}$ as support are expected to have poor mechanical performance in long term operation condition, therefore alternative materials as the porous support are necessary.

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Acknowledgement

This work has been carried out with support from the BIGCCS Centre, performed under the Norwegian research program *Centres for Environment-friendly Energy Research (FEM).*

The authors acknowledge the following partners for their contributions:

AkerSolutions DNV GASSCO Shell TOTAL Statoil ConocoPhillips HYDRO Statkraft GDF SUEZ The Research Council of Norway

Thanks for your attention

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