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# Research Requirements for Efficient Low CO<sub>2</sub> Power Plants

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February 10 and 11, 2005  
Leipzig

# Outline

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## **Structural materials focused on use in the near future - 2015:**

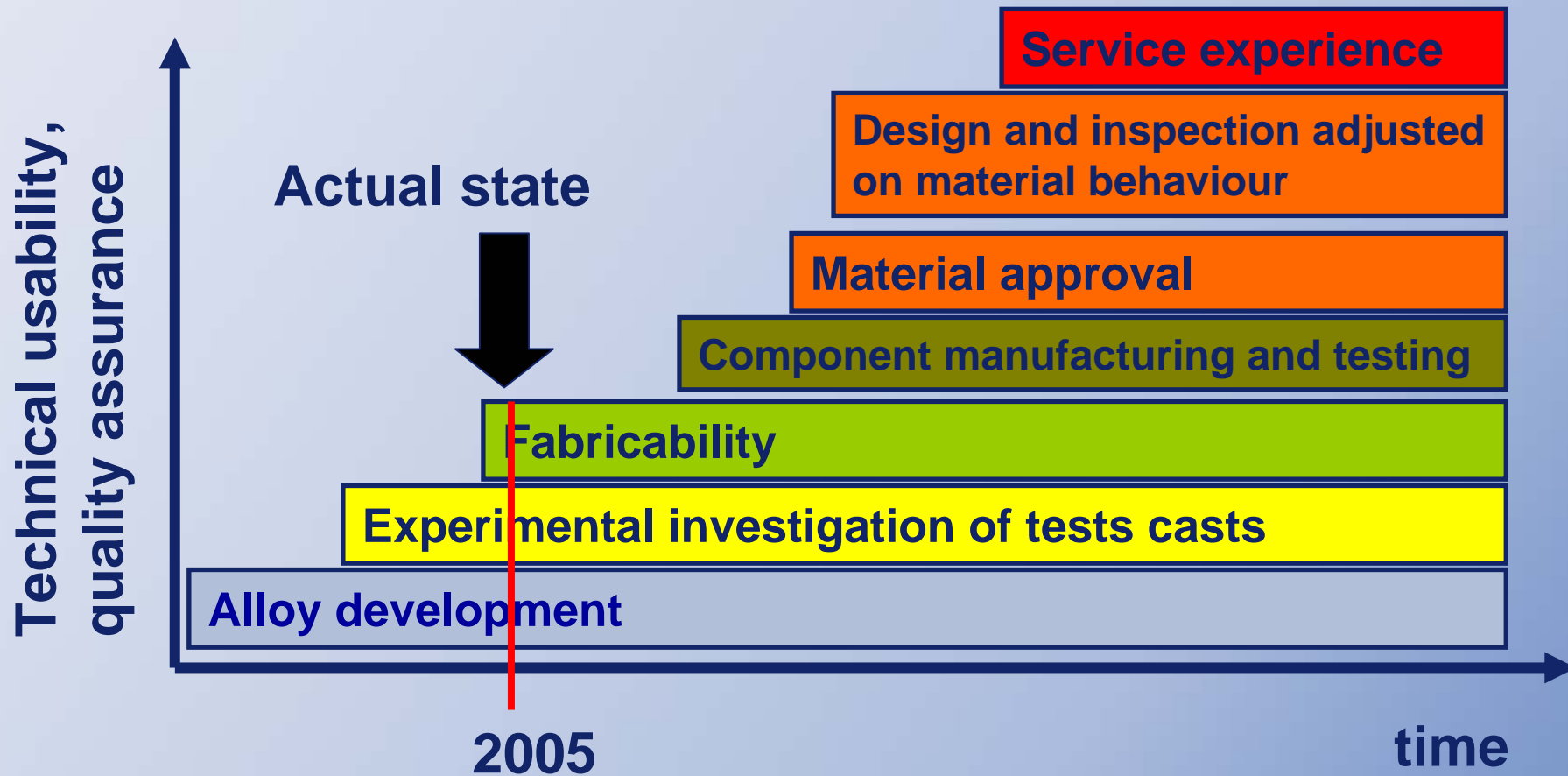
- **Presentation Husemann**
- **Presentation Kern**
- **Scientific challenges in this context**

## **Technologies for the future exceeding limits of existing materials:**

- **Gas turbine**
- **Steam turbine**
- **Boiler**

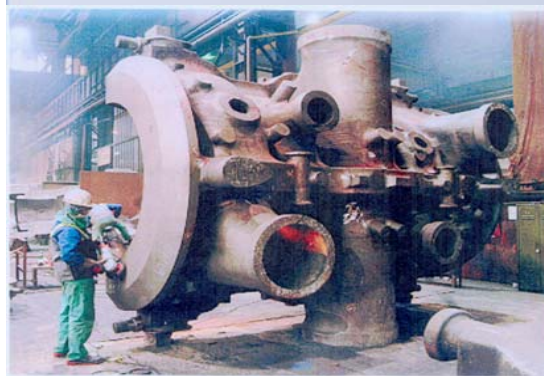
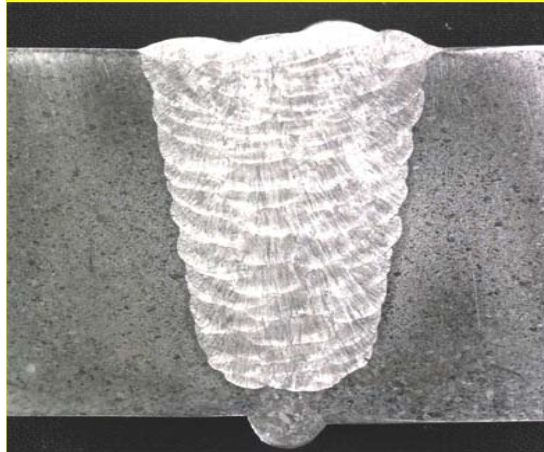
# Materials for boiler and turbine application

## Material development and use in technical practise



# Materials for boiler and turbine application

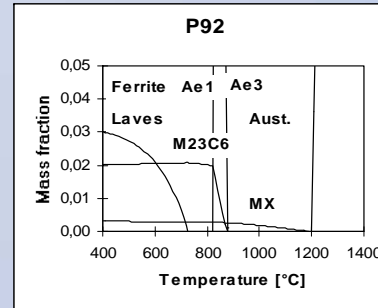
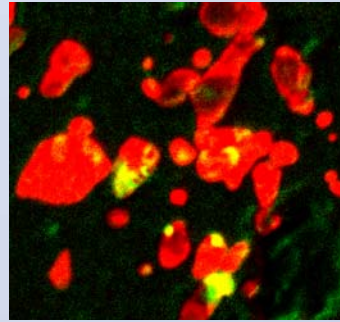
## Need for further R&D based on existing ongoing programmes



- Material development: thick section components, up-scaling manufacturing
- Coatings to prevent corrosion and oxidation, erosion and wear
- Determination of material characteristics: database for design, life assessment
- New numerical modelling tools
- Repair strategies
- Modelling of oxidation behaviour and surface reaction with environment
- Improvement of NDT defect identification – link fracture mechanics approach (integrity analysis)
- Load appropriate selection of material to assure economic design

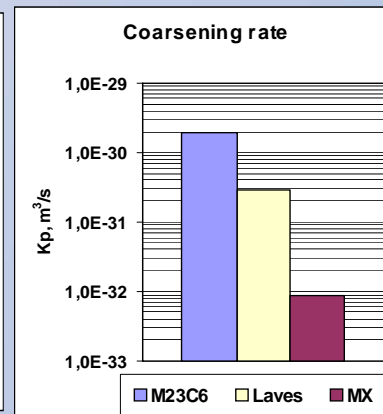
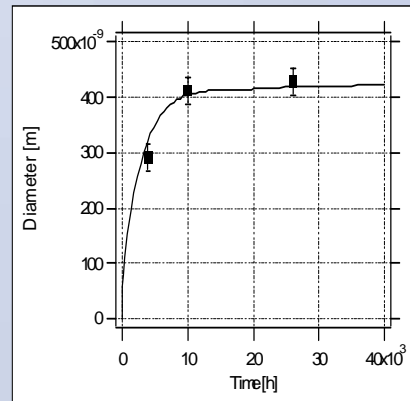
# Optimisation of materials for boiler and turbine application: Modelling of Microstructure – Input for Component calculation

**Microstructure studies- TEM**



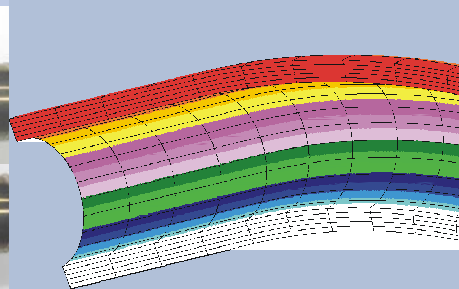
**Microstructure modelling – phase equilibria eg Thermocalc**

**Microstructure modelling – growth eg DICTRA**



**Microstructure modelling & coarsening eg Ostwald ripening**

**Validation – creep tests**



**Component -Design -Damage development Inspection strategies**

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## **Structural materials focused on use in the near future - 2015:**

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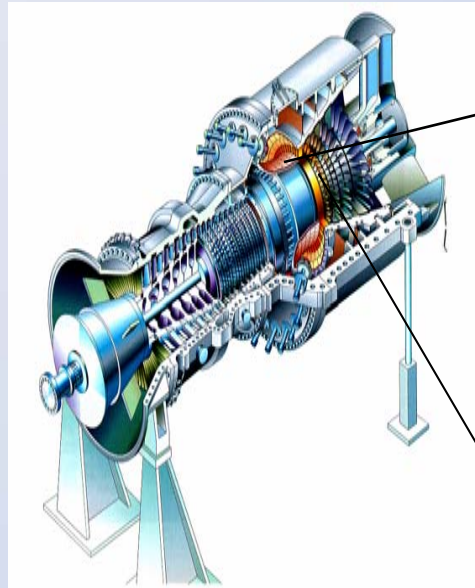
## **Technologies for the future exceeding limits of existing materials considering**

- **Gas turbine**
- **Steam turbine**
- **Boiler**

# Technologies for the future

<b>New base materials</b>	Creep strength, Oxidation and corrosion behaviour Fabricability Thermal flexibility	New super alloys, Multifunctional materials Graded materials	new design tools based on computational material science
<b>Thermal barrier coatings, cooling systems, Protective coatings</b>	higher metal temperature, Oxidation and corrosion behaviour, Wear and erosion	New TBC architecture in combination with new base materials	Modelling and sophisticated online diagnostic tools
<b>Membrane Technology for CO2 capture</b>	Nano-sized porous membranes, Mixed Ion Electron Conducting Membranes > 700 °C with -high permeability -high selectivity Upscaling of components Manufacturing technologies	Stability at low oxygen pressures, Mechanical and structural integrity Permeability has to be increased by new compositions / thin film technologies	Development of molecular sieves
<b>Design and life time management tools</b>	Consideration of service load and subsequent damage mechanisms of individual materials	Advanced material models, consolidated material data base, Probabilistic design, New NDT methods, On line diagnostics	Integrated approaches

# Materials Research for Gas Turbines



Source: Siemens Journals

**Gas temperature target:** > 1400 °C  
**Base material life:** 50000 h  
**Coating life:** 25000 h  
**Rotor life:** 100000 h

- reliable thermal barrier coatings (TBCs) for combustors and front stage blading
- new TBCs with higher temperature capability
- life prediction methodologies for TBC coated SX alloys as integral part of the design
- Ni-base rotors (also for steam turbines)
- light weight blading (e.g. TiAl) for last stage blades to increase turbine size

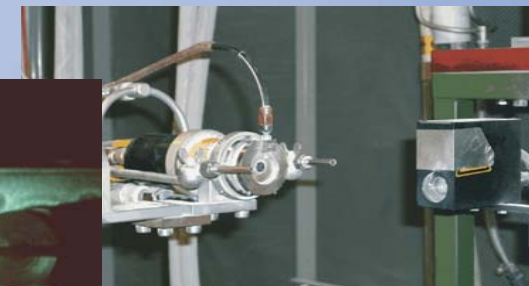
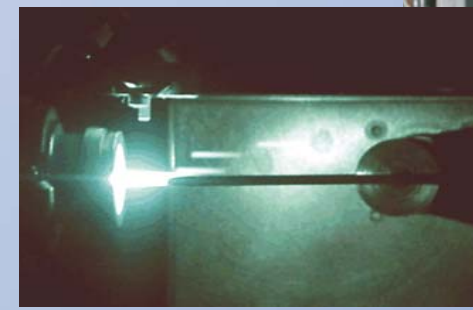
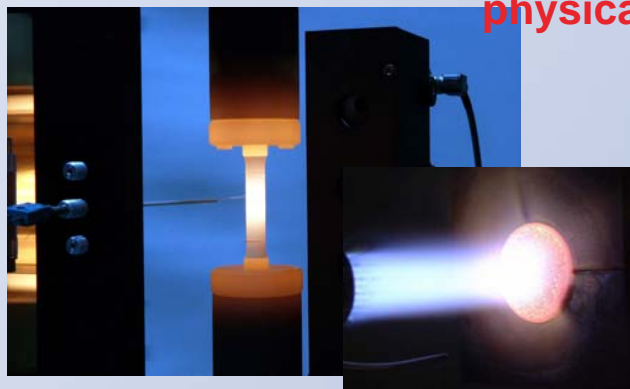
to ensure efficiencies  
> 65 % (2010)  
> 70 % (2020)

# Coatings and robust process parameters become key technology for power plants



APS  
HVOF  
VPS

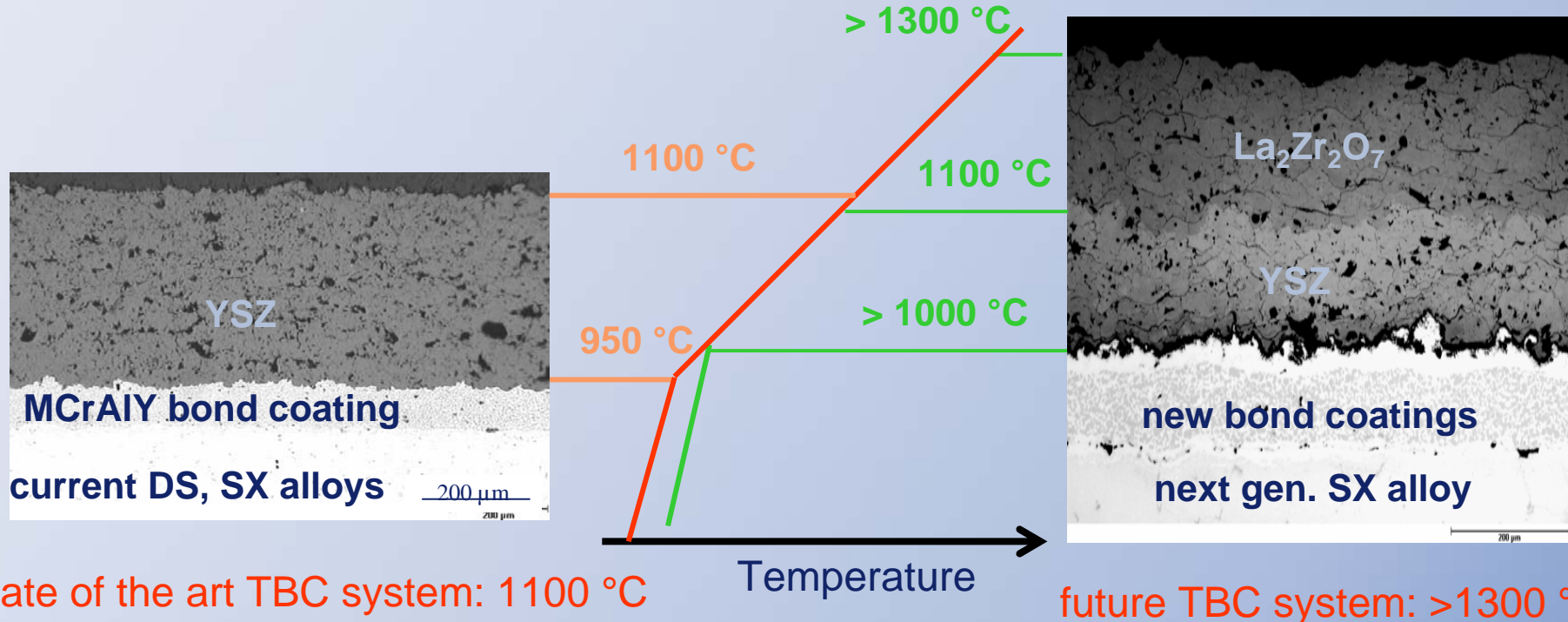
**Modelling and sophisticated online diagnostic tools required to produce coatings with reliable microstructure and physical-mechanical properties**



diagnostics

Vaßen et al.

# Advanced TBCs for Efficient Gas Turbines

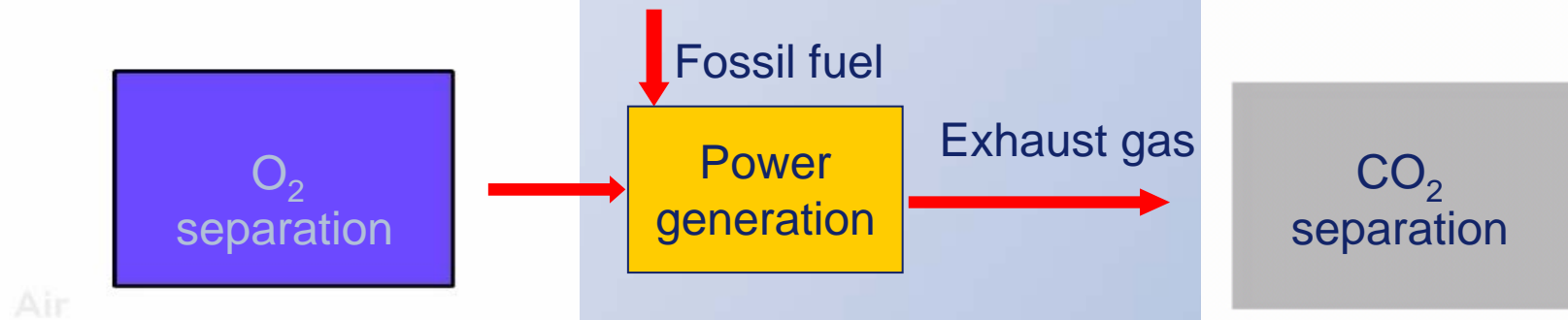


## TBCs offer:

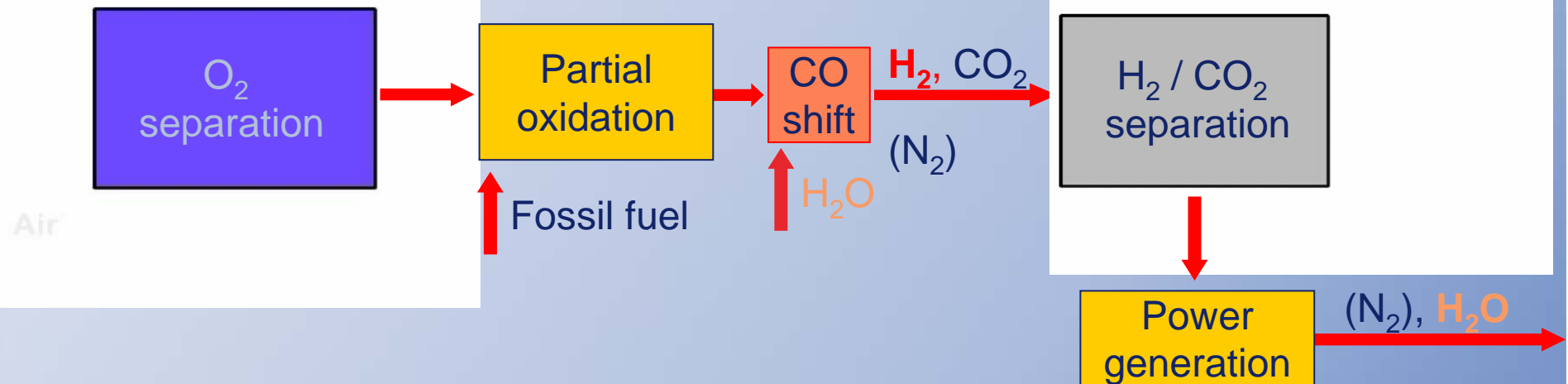
- highest potential to increase gas inlet temperatures and efficiency of IGTs combined with high strength nickel based alloys

# Membrane technology for CO<sub>2</sub> - capture

## 1. Combustion Technologies



## 2. Gasification

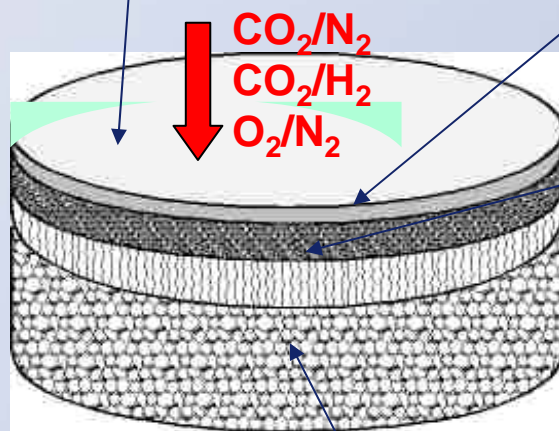


# Porous membrane Systems

## Separation by molecular sieves

Ceramic membrane

pore size < 1 nm



Porous interlayer

Ceramic interlayer pore size about 2-100 nm

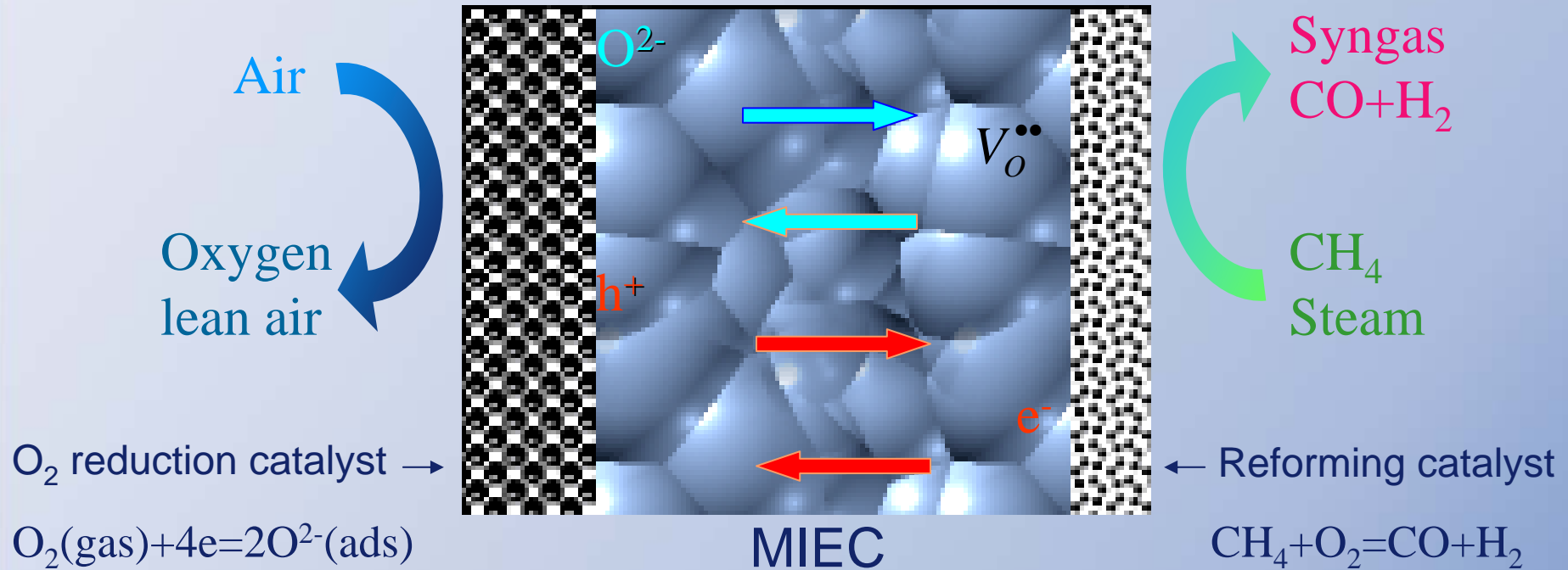
Metallic or ceramic substrate pore size about 0,08-1  $\mu\text{m}$

Gas	$d_{\text{kin}}$ in $\text{\AA}$
$\text{CH}_4$	3,80
$\text{N}_2$	3,64
$\text{O}_2$	3,46
$\text{CO}_2$	3,30
$\text{H}_2$	2,89
He	2,60

### Requirements:

- high permeability
- high selectivity
- Environmental long-term stability

# Operating Principle of a Ceramic MIEC (Mixed Ionic Electronic Conductor) Membrane Reactor for the partial oxidation of methane to syngas



## Problems:

- stability at low oxygen pressures
- high operation temperature > 700 °C
- permeability has to be increased by new compositions / thin film technologies
- Manufacturing technologies, up-scaling, integration into process

# Summary

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- **New materials for boilers, steam turbines and gas turbines required to increase gas & steam temperatures for higher efficiencies**
- **Sound understanding of materials degradation is basis for design, maintenance, monitoring and inspection**
- **Corrosion resistant and thermal barrier coatings become key technology for efficiency, reliability and lifetime.**
- **Coatings are essential to make full use of optimized materials**
- **Membrane development and up scaling of components key technology for CO<sub>2</sub>- capture**