WORKSHOP

From basic to applied research towards durable and reliable fuel cells

AST: THE EFFECT OF PRESSURE ON THE INTERCONNECT AGING

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Lucerne (CH) – 5 July 2022

OUTLINE

Aging of interconnects

Accelerated Stress Tests

Materials and methods

Feasibility study

AST and comparison with stacks

Conclusions

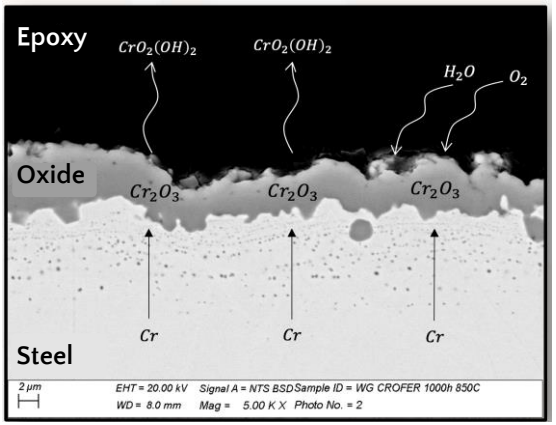
AGING OF INTERCONNECTS: LABORATORY VS STACK

Working conditions

- ✓ **High temperatures**
- ✓ **Oxidant/reducing environment**
- ✓ Humidity
- ✓ Electrical current flow

Degradation mechanisms

- **High temperature oxidation**
- Chromium evaporation
- **Increase of electrical resistance**
- Delamination of the oxide scale



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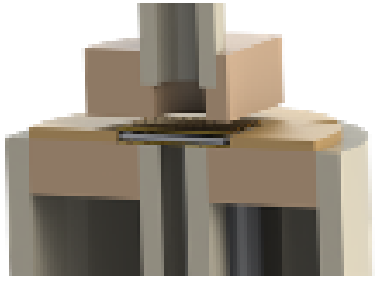

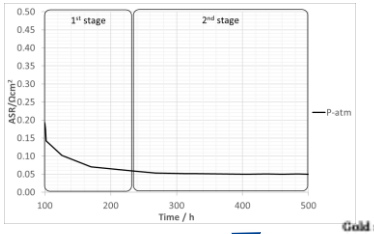

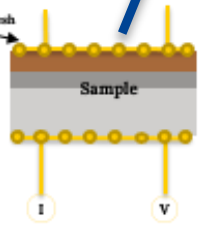

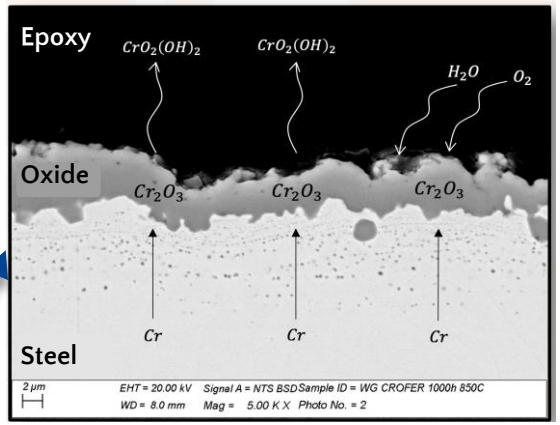

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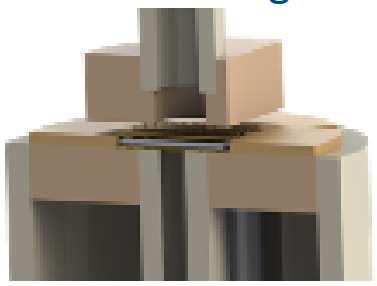
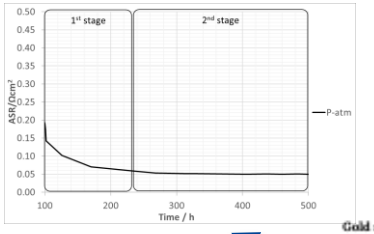
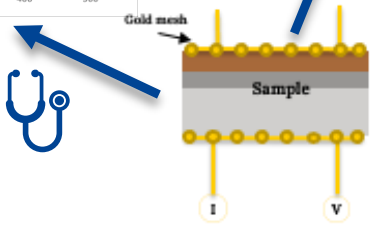
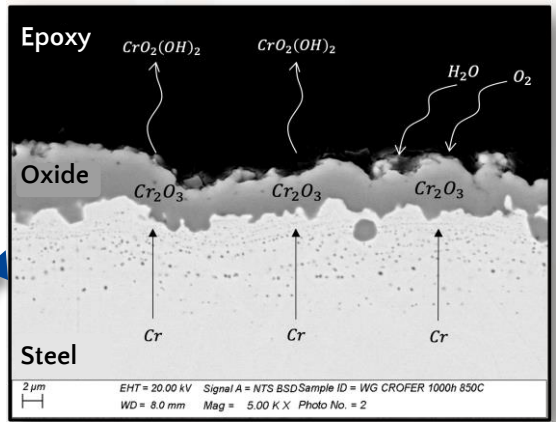






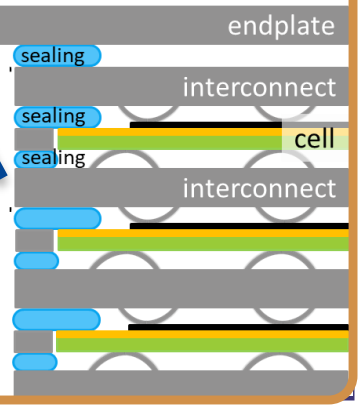


composition

morphology

thickness

Aging in stacks



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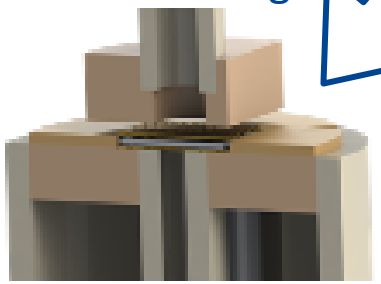
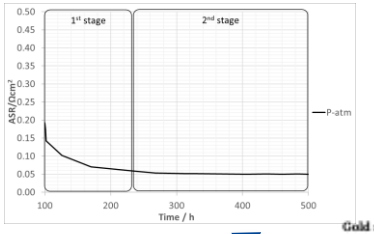
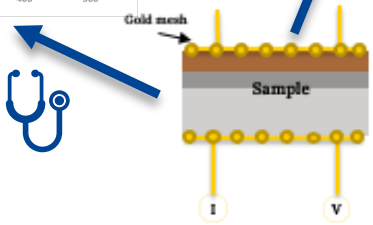
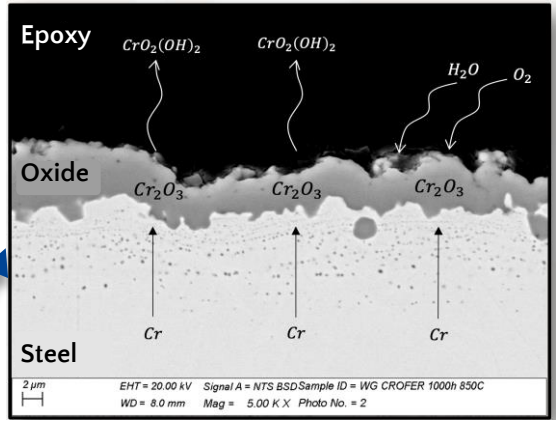








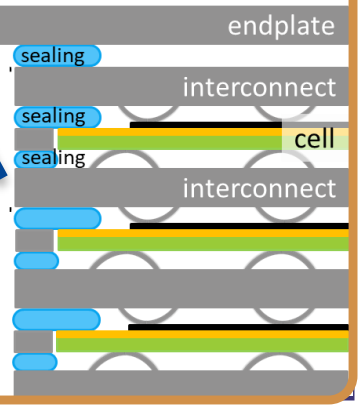
composition

morphology

thickness

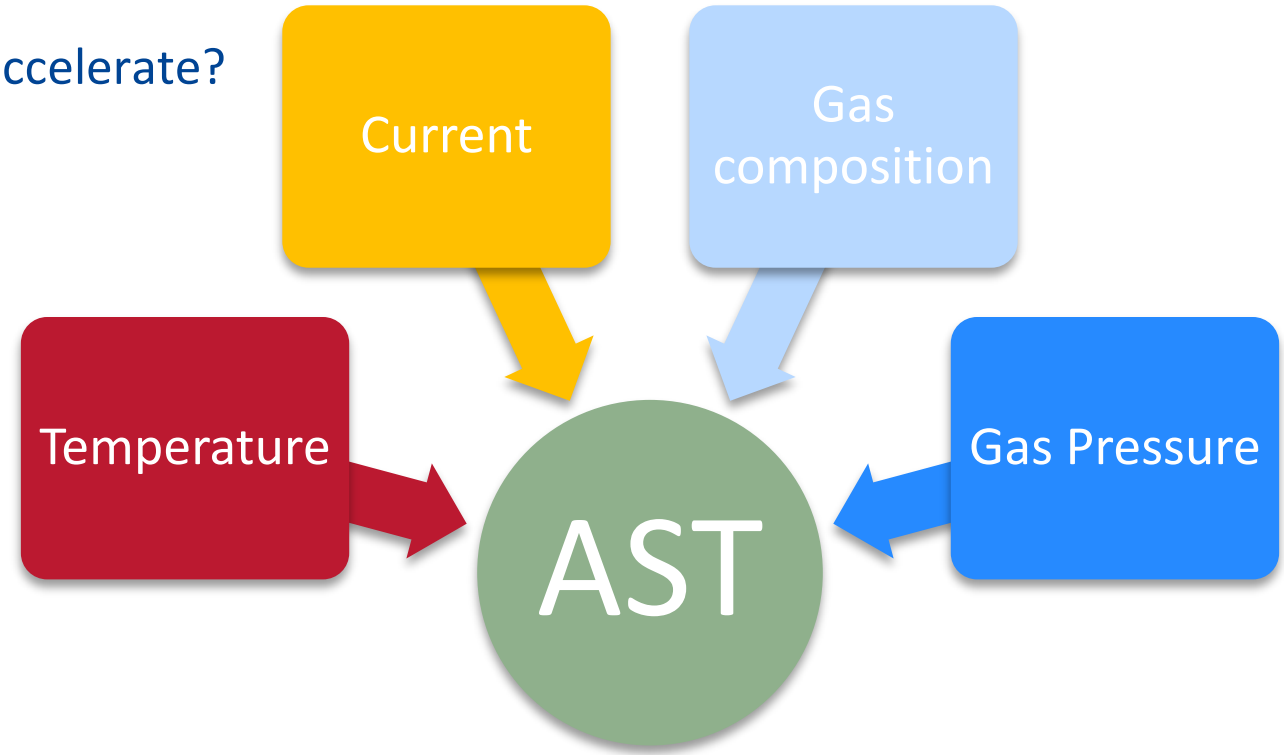
electrical properties

Aging in stacks



ACCELERATED STRESS TESTS

- Interconnect oxidation, interface reactions, internal resistance
- How to accelerate?

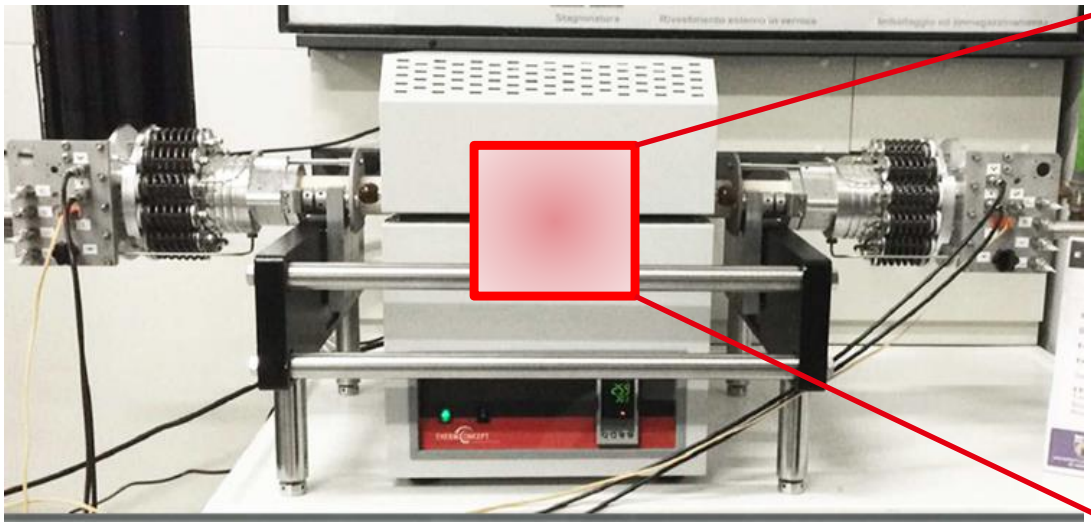


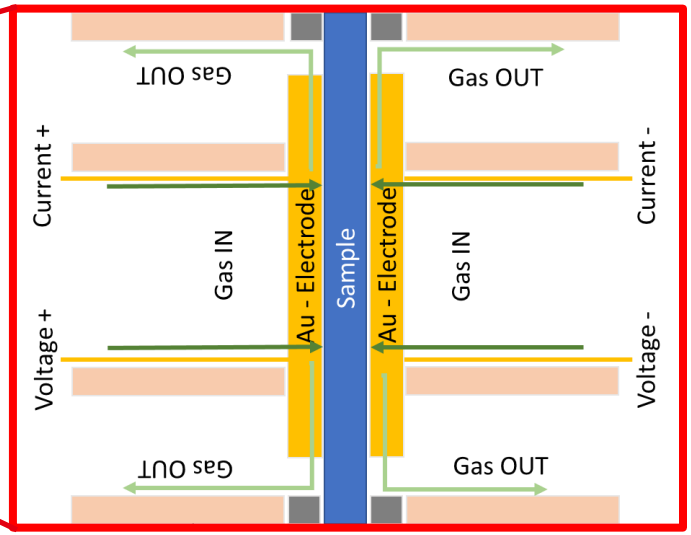
Thermodynamic | **Reliability** | **Kinetic**

MATERIALS AND METHODS

- Interconnect materials: AISI 441; Crofer 22 APU
- Preparation: cut, cleaning in water and acetone
- Coating materials: Cu-Mn; Co-Mn spinels
- Aged interconnect from stacks (to compare ASR and oxide thickness)

ASR measurement setup (Temperature range RT-900°C; Pressure range 1-5bar)

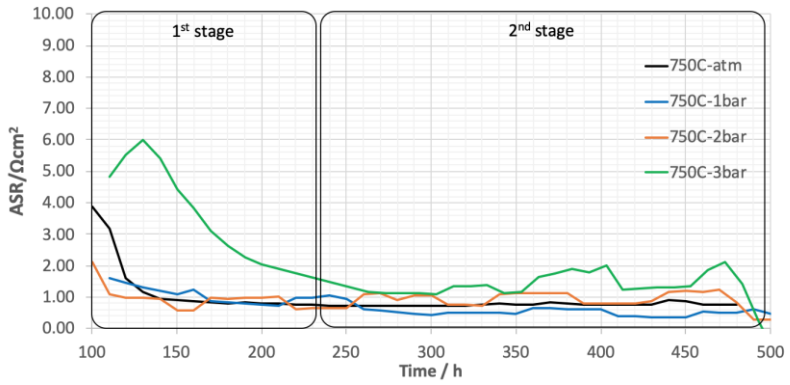




FEASIBILITY STUDY AND DEFINITION OF PARAMETERS: TESTS ON BARE STEELS

TESTS ON BARE STEEL – EFFECT OF TEMPERATURE AND PRESSURE

750°C



Identified 2 steps of ASR evolution:

1. Decrease, possibly due to electric contact improvement
2. Stable values or noise (possibly due to cracks and delamination)

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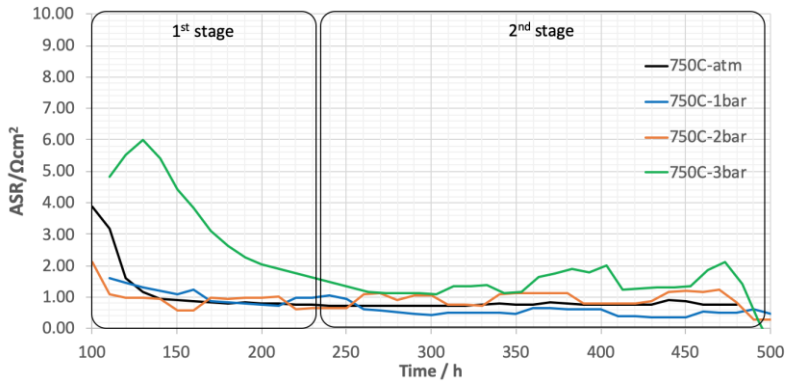

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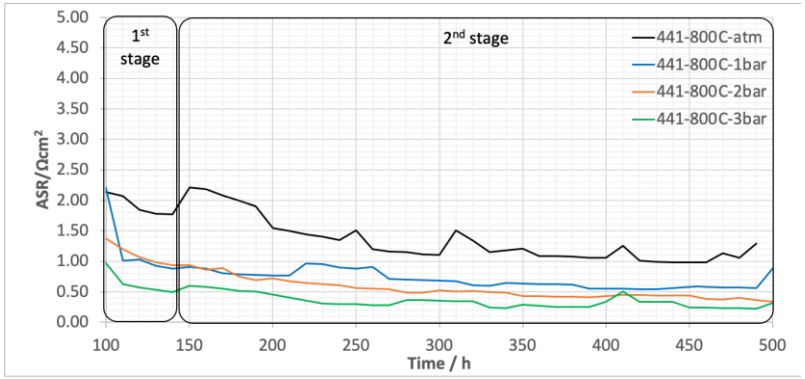

Identified 2 steps of ASR evolution:

1. First step shorter compared to measurements at 750°C, possibly due to faster improvement of the contact promoted by higher temperature
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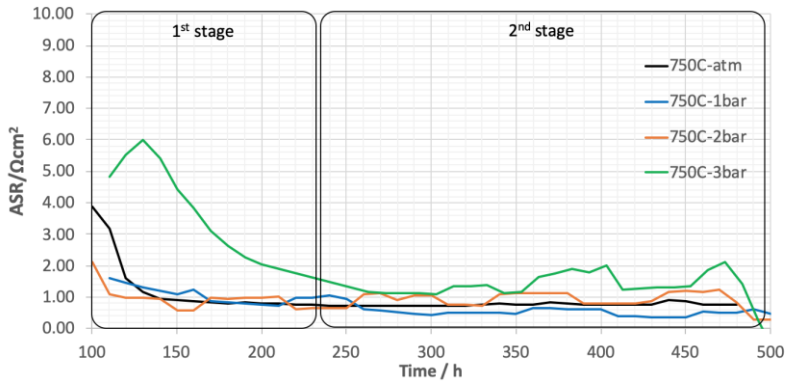

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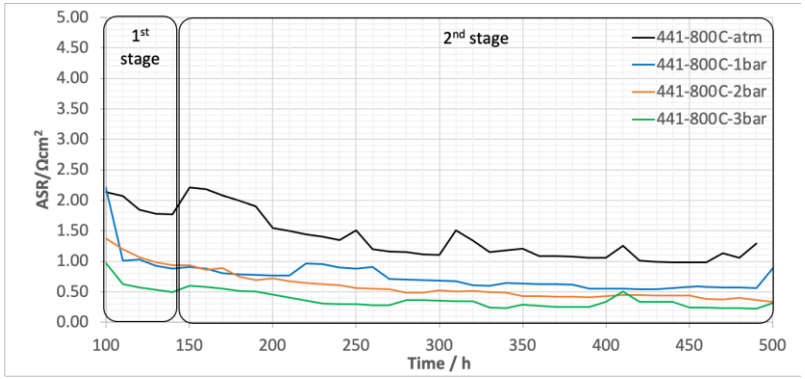

Identified 2 steps of ASR evolution:

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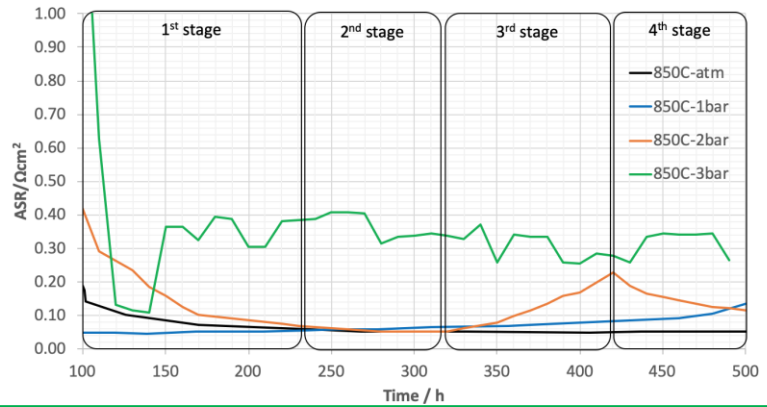
850°C

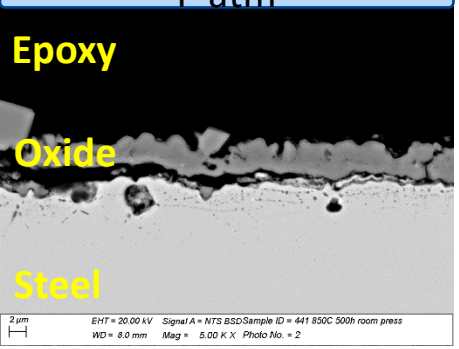


Identified up to 4 steps of ASR evolution, influenced by pressure:

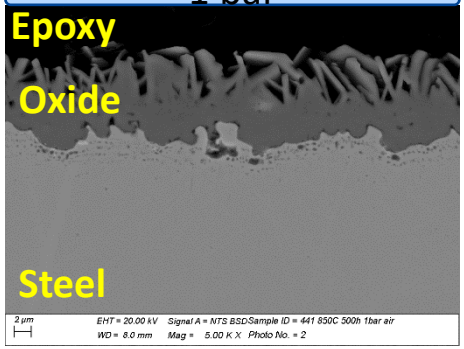
1. Decrease, due to electric contact improvement
2. Stable values
3. Incrase, influenced by pressure
4. Decrease, or noise, due to welding or delamination, respectively

TESTS ON BARE STEEL – COMPARISON WITH STACKS

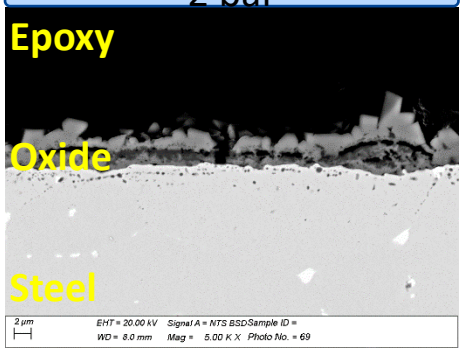
P atm



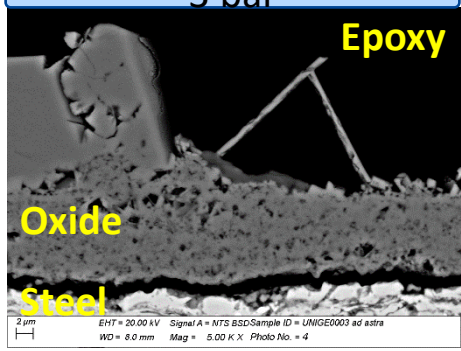
1 bar



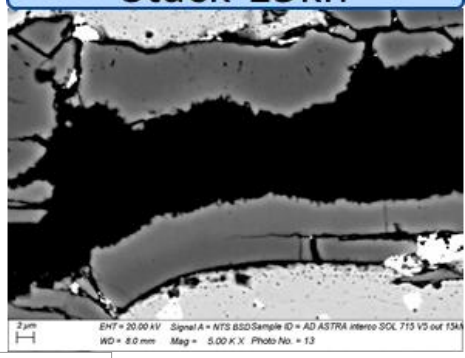
2 bar



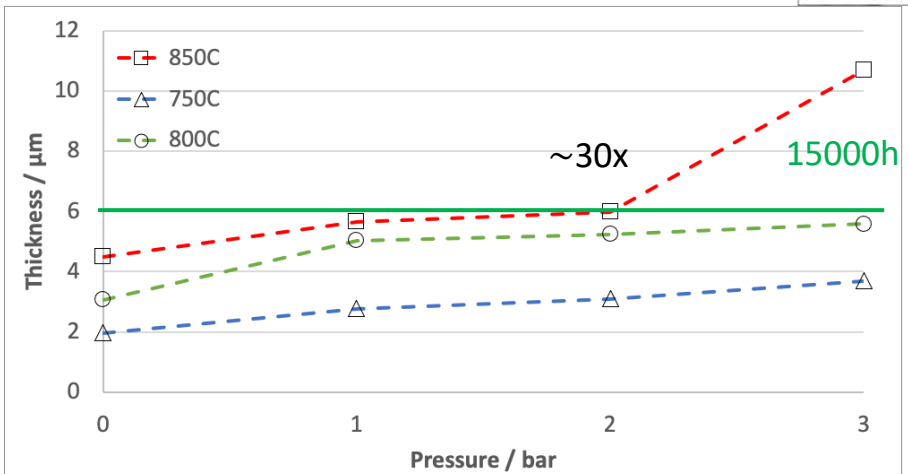
3 bar



Stack-15kh



- Changes in thickness and morphology, influenced by pressure
- Formation of plates on top of a dense oxide layer at 1 bar
- Growth of two different layers at 2 bar, possible delamination
- Growth of plates on top of a porous layer at 3 bar
- Comparison with sample aged for 15kh
  - Same composition up to 1 bar
  - same thickness at 2 bar

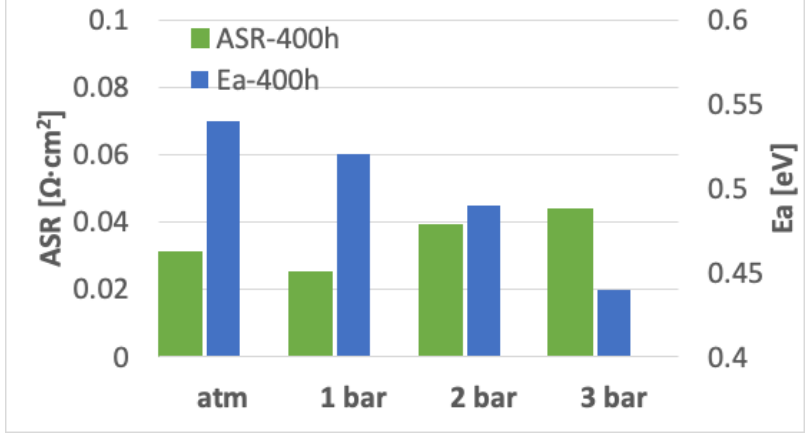


AST AND COMPARISON WITH STACKS: TESTS ON COATED STEELS

TESTS ON COATED STEEL – 750°C; ATM→+3BAR

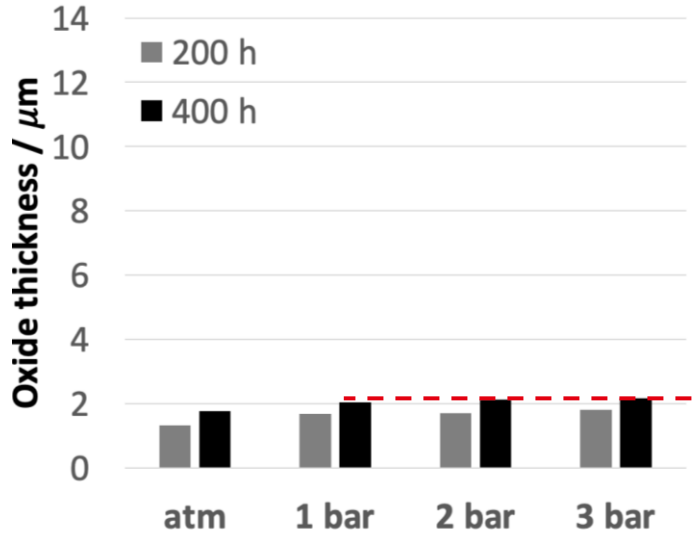
Tests on **Cu-Mn-coated** interconnects - comparison with stack samples

ASR and Ea at 750°C (lab)

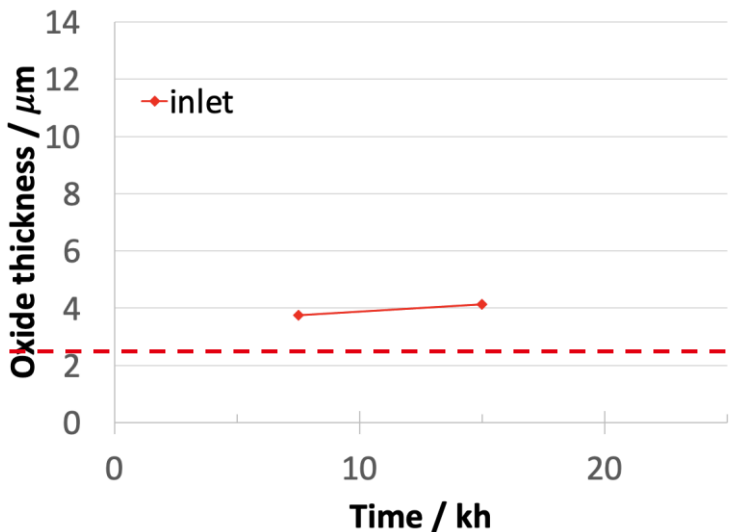


- Influence of pressure on **ASR** and **Ea**
- **Increase of ASR, decrease of Ea**: effect of thickness and composition
- **Oxide thickness increased** over time for both, lab and stack samples
- **No significant acceleration** was observed (confirmed observations on bare steels)

Thickness (lab)



Thickness (stack)



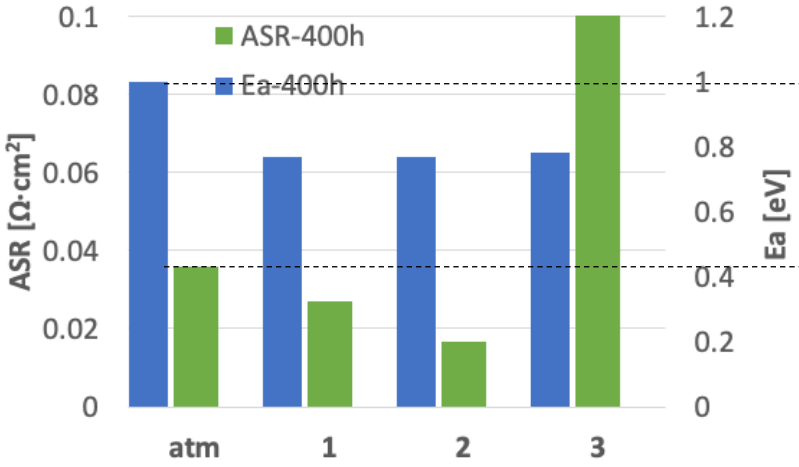
TESTS ON COATED STEEL – 850°C; ATM→+3BAR

Tests on **Co-Mn-coated** interconnects – comparison with stack samples

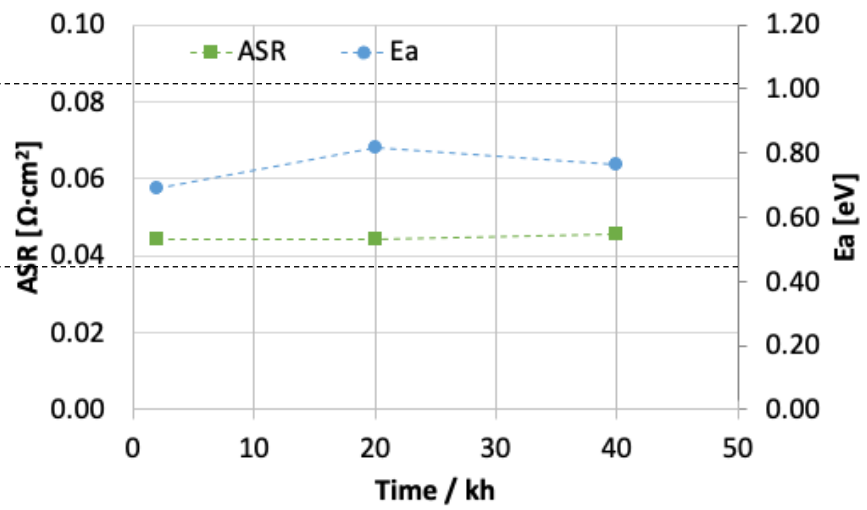
- Influence of pressure on **ASR** and **Ea**
- **Decrease** of both: promoted by pressure
- Highest ASR values after aging at 3 bar, possibly due to delamination of layers

- **Stable** ASR and Ea values after aging in stacks up to 40 kh
- **Comparable** values to those obtained on lab samples

ASR and Ea 850°C (Lab)



ASR and Ea meaured 850°C (Stack)

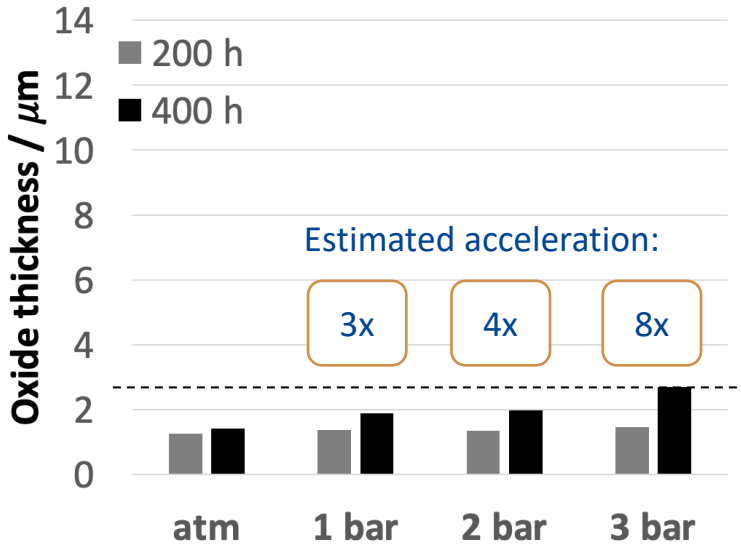


TESTS ON COATED STEEL – 850°C; ATM→+3BAR

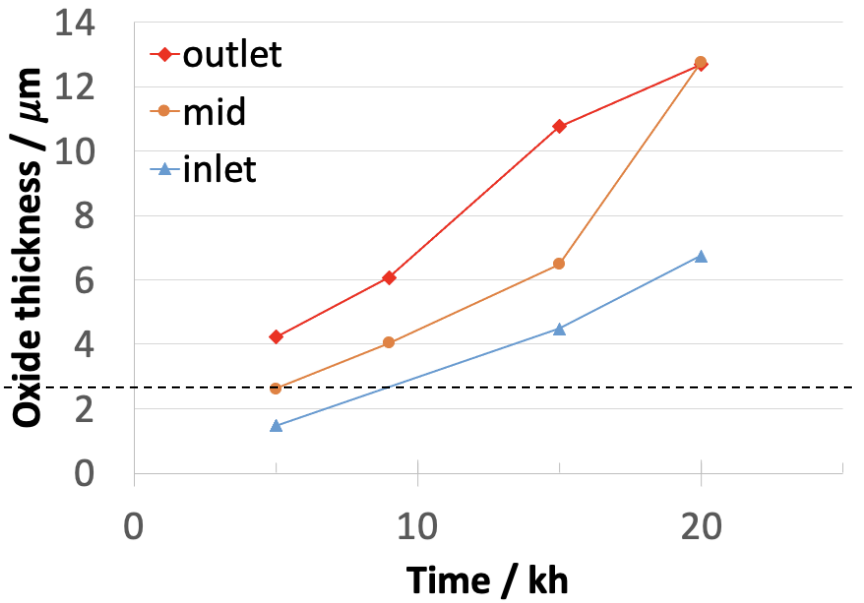
Tests on **Co-Mn-coated** interconnects – comparison with stack samples

- **Oxide thickness increased** over time for both, lab and stack samples
- Higher temperatures promoted **faster growth**
- Growth rate estimated with additional measurements at 200 h
- Thickness increase **accelerated by 8 times** when aging at 3 bar

Thickness (lab)



Thickness (stack)



CONCLUSIONS

- ✓ Pressure influences the oxidation kinetics affecting the **ASR** evolution, oxide **thickness** and **composition**
- ✓ The **effectiveness of AST** was found to be at higher temperatures
- ✓ The **feasibility** study proved an acceleration by **30x on bare steel**, when exposed to 2 bar at 850°C
- ✓ AST on coated samples **accelerated** the **interconnect degradation** only at 850°C, by **3x, 4x and 8x** at 1, 2, 3 bar respectively
- ✓ Electrical and microstructural characterizations were **validated** by comparison with samples extracted from **stacks**

ACKNOWLEDGEMENTS

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