Westinghouse Advanced Doped Pellet – Characteristics and Irradiation behaviour

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Contents

ADOPT overview

Properties that will be discussed

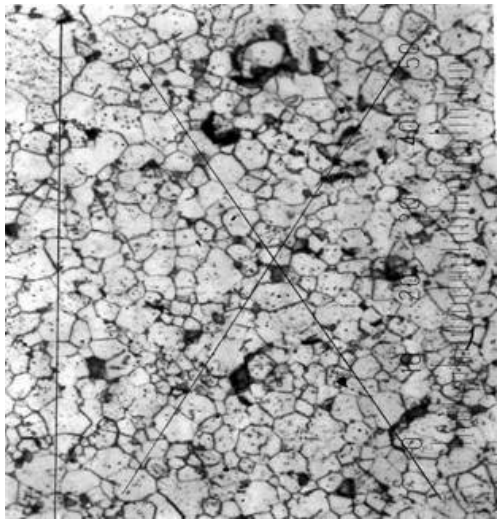
- Density
- Fission gas release
- PCI performance
- Secondary degradation behavior

Conclusion

ADOPT = Advanced Doped Pellet Technology

ADOPT Overview

- High density UO_2 pellets with enlarged grain size. ADOPT contains additives of Cr- and Al-oxide less than 1000 ppm total
- Improved quality: the additives facilitate pellet densification during sintering and are experienced to give a lower rejection rate in the visual inspection after grinding

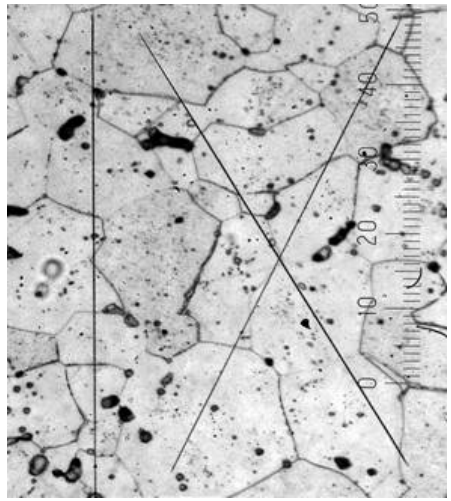


Standard pellet

Grain size 9 μm

Density 10.60g/cm^3

96.7% of TD



ADOPT pellet

Grain size 31 μm

Density 10.67g/cm^3

97.4% of TD

ADOPT Overview

Verification

- An extensive test program performed
- High BU irradiation on-going

Experience

- 10 years of experience from irradiation
- Two full reloads in operation

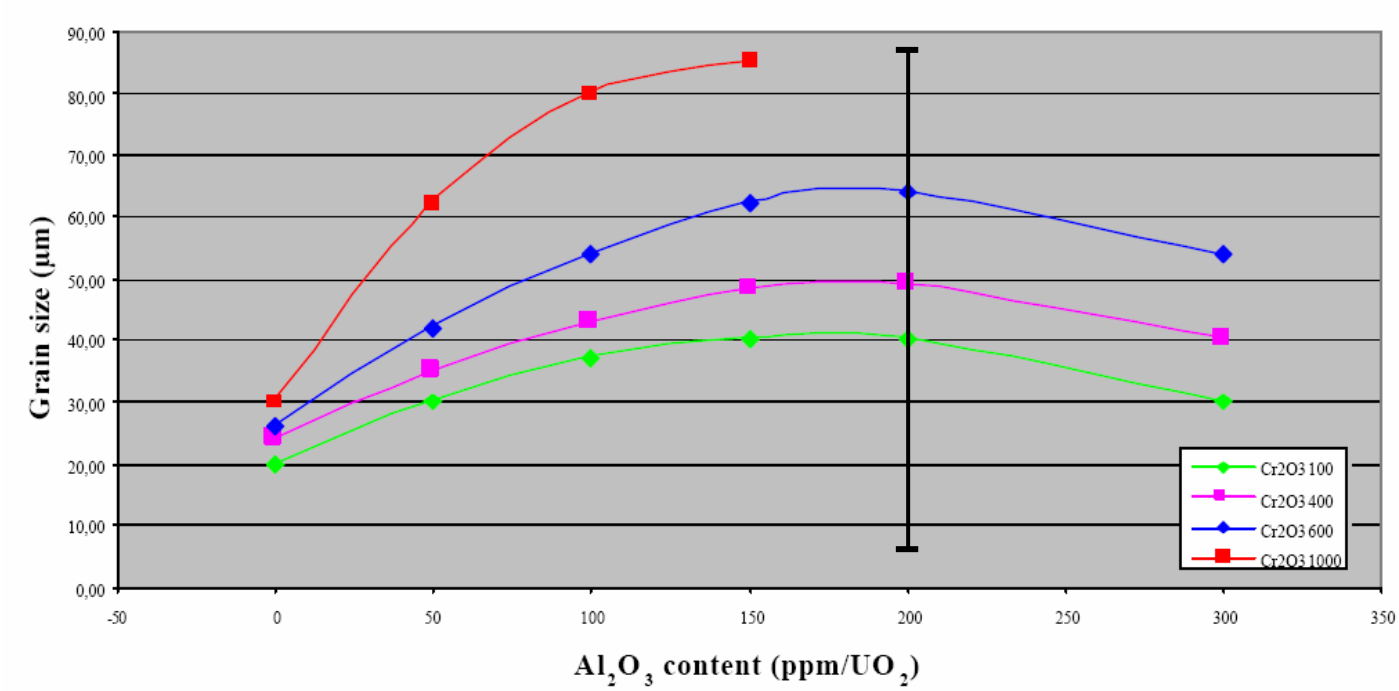
ADOPT Overview

Density

- Manufactured density mainly influenced by Cr_2O_3 content.

Grain size

- Strongly influenced by both Al_2O_3 and Cr_2O_3 content



Physical Properties

Properties characterized

- Thermal Diffusivity
- Specific Heat
- Thermal Expansion
- Melting Temperature

The difference between ADOPT and Standard UO_2 is negligible (within the uncertainty of accurate measurements)

Densification and swelling behaviour

Densification and swelling – Resinter tests

- **ADOPT, density 10.67g/cm3**

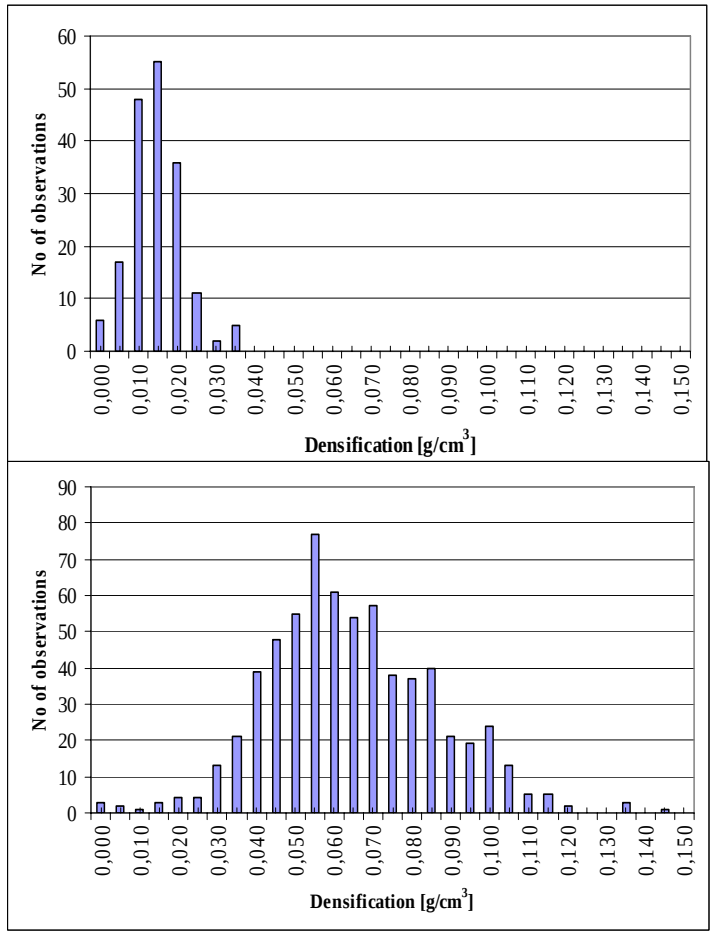
  0.13% ±0.13%,

  From 18 pellet lots

- **Standard UO_2, density 10.60g/cm3**

  0.60% ±0.40%,

  From 65 pellet lots



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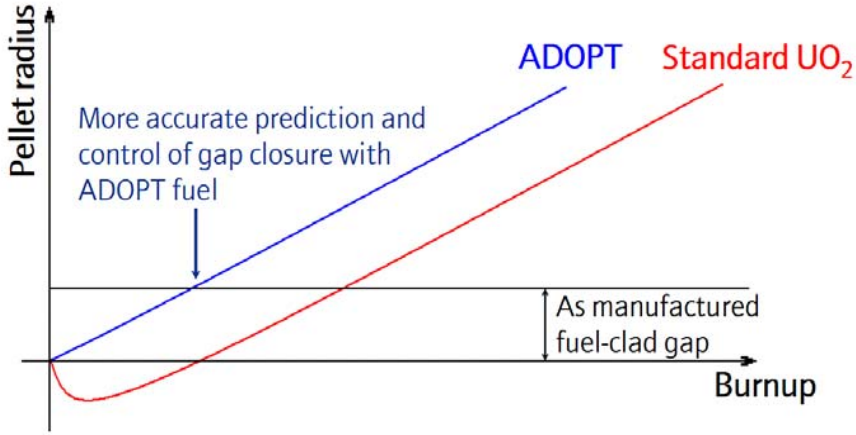
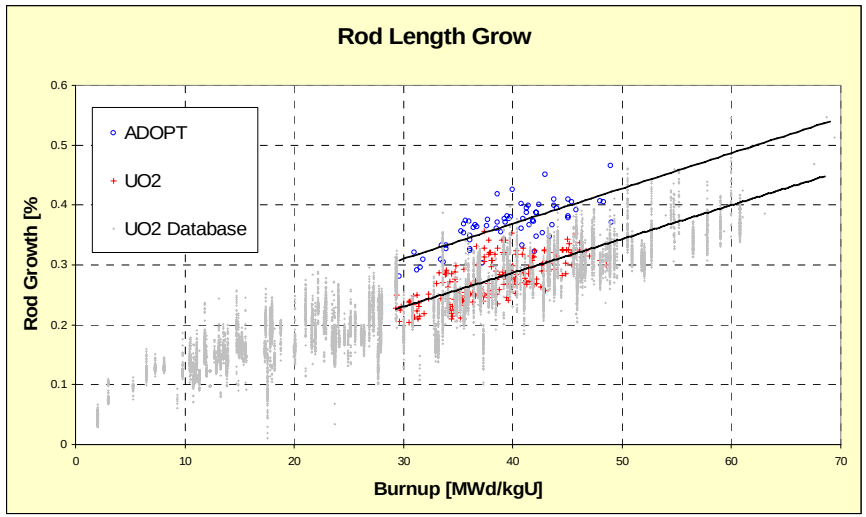
Fuel rod growth

- Less fuel densification of ADOPT pellets implies earlier pellet cladding contact resulting in a higher rod length increase.
- Same swell rate after densification
- After pellet cladding contact occurs the rod length growth rate is the same.





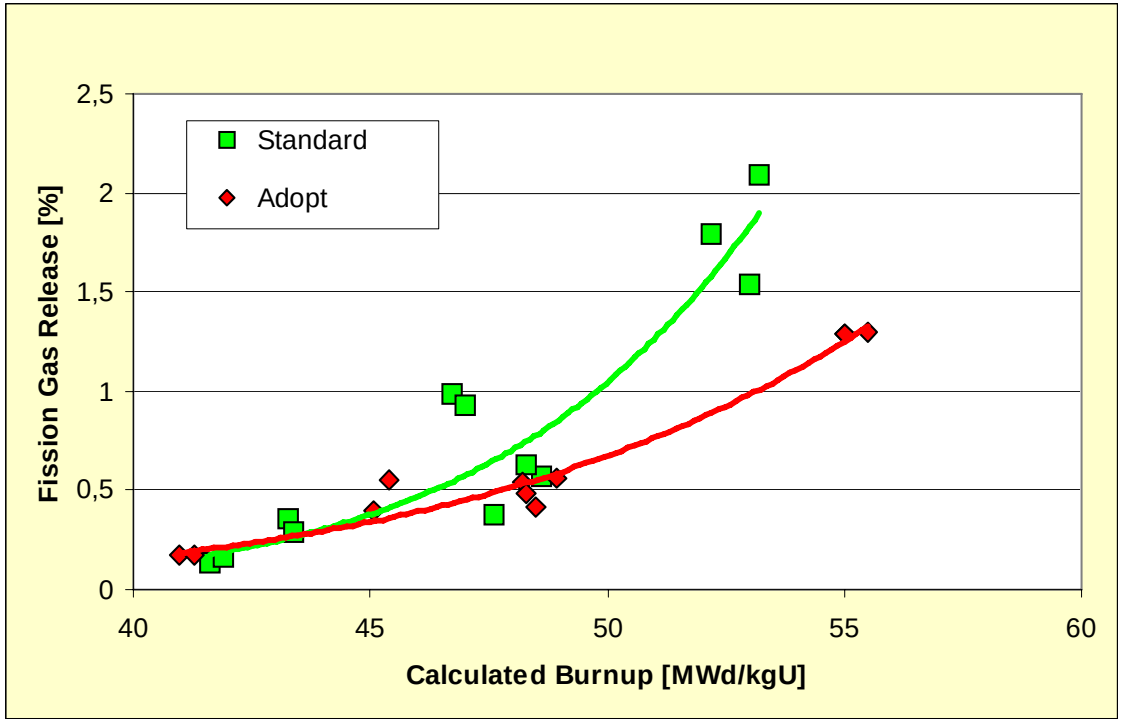
Fission Gas Release

FGR – Gamma measurements at Oskarshamn

Measurements on 22 fuel rods from 2 FA

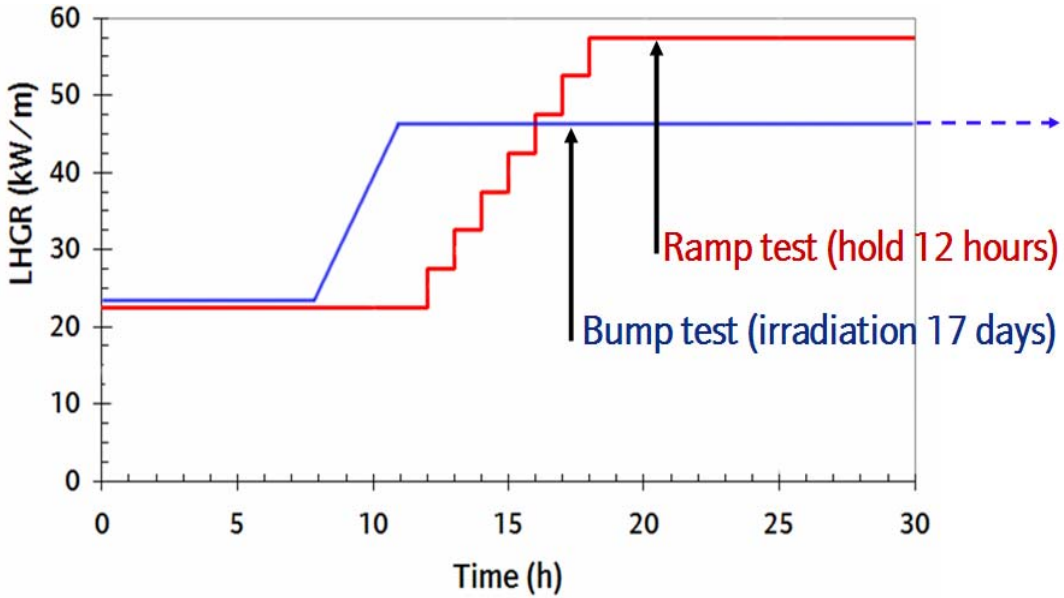
10 with ADOPT-pellets

12 with standard pellets



Around 30 % benefit of ADOPT – consistent with Studsvik enhanced power data

FGR – Studsvik data

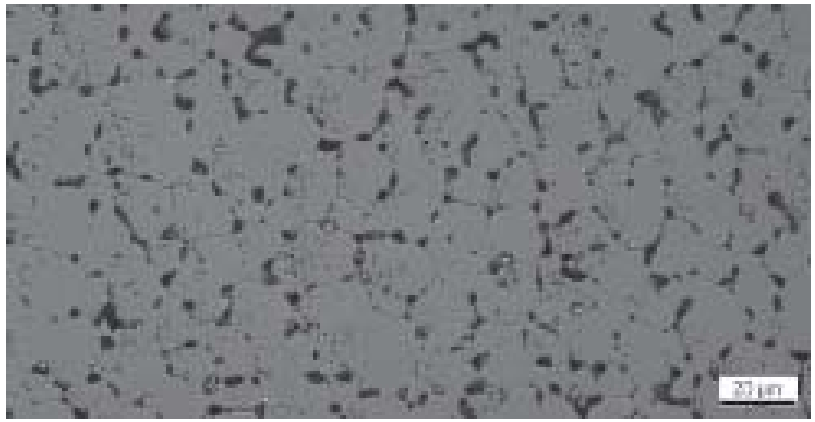


Relative FGR (%)	Standard UO_2	ADOPT
RAMP TEST 57kW/m	30.2%	17.2%
BUMP TEST 45kW/m	29.7%	20.5%

- Significantly less gas release from the ADOPT fuel

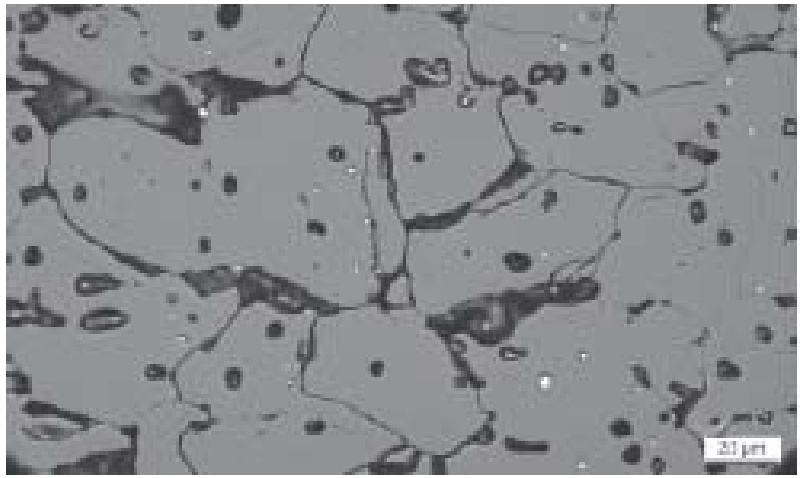
FGR – PIE after ramp test

Standard pellets have pores precipitated mainly in the grain boundary.



Standard segment (r = 2,2mm from center)

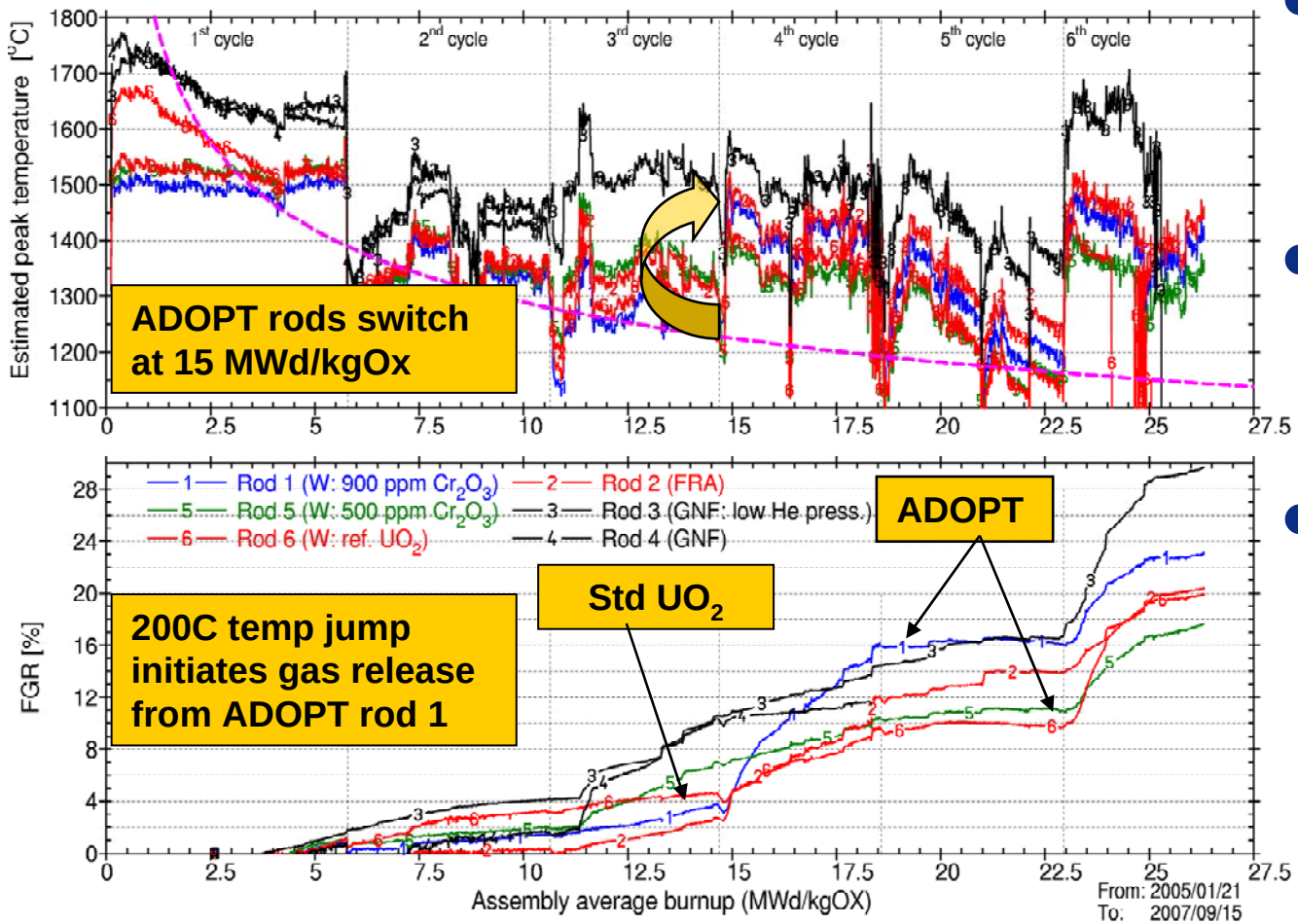
The doped pellet have the pores precipitated mainly inside the grain. This is beneficial to FGR.



Doped segment (r = 2,0mm from center)

Halden Test

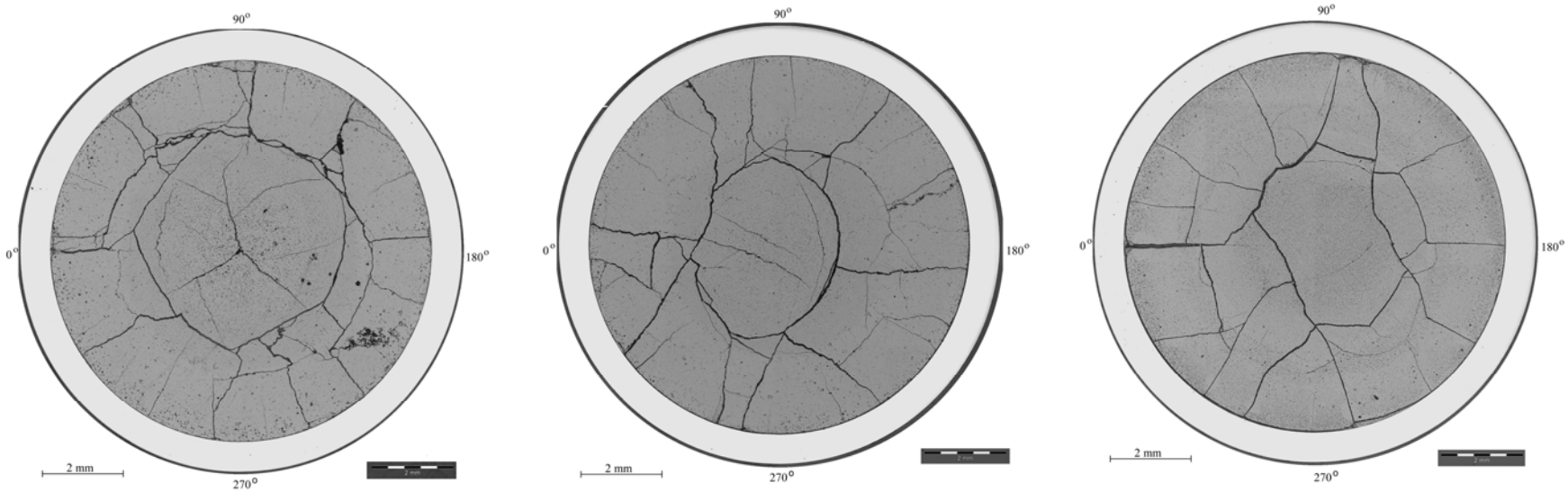
FGR Estimates from Normalized Rod Pressures



- The rods were operated above the Vitanza FGR threshold
- The timing of the FGR release are linked to big steps in temperature
- The FGR release from the different rods are not comparable due to the completely different power histories they have experienced

Halden test
Results from PIE

Rod 1 ADOPT	Rod 5 ADOPT	Rod 6 Standard UO_2



The PIE examinations show results which is consistent with earlier ADOPT experience

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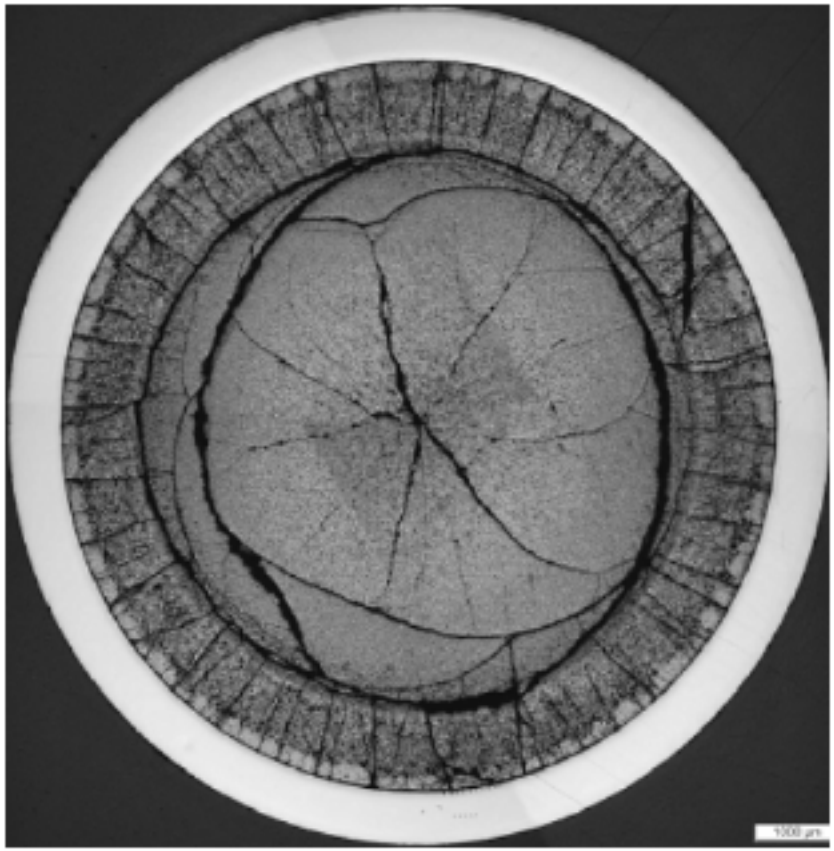
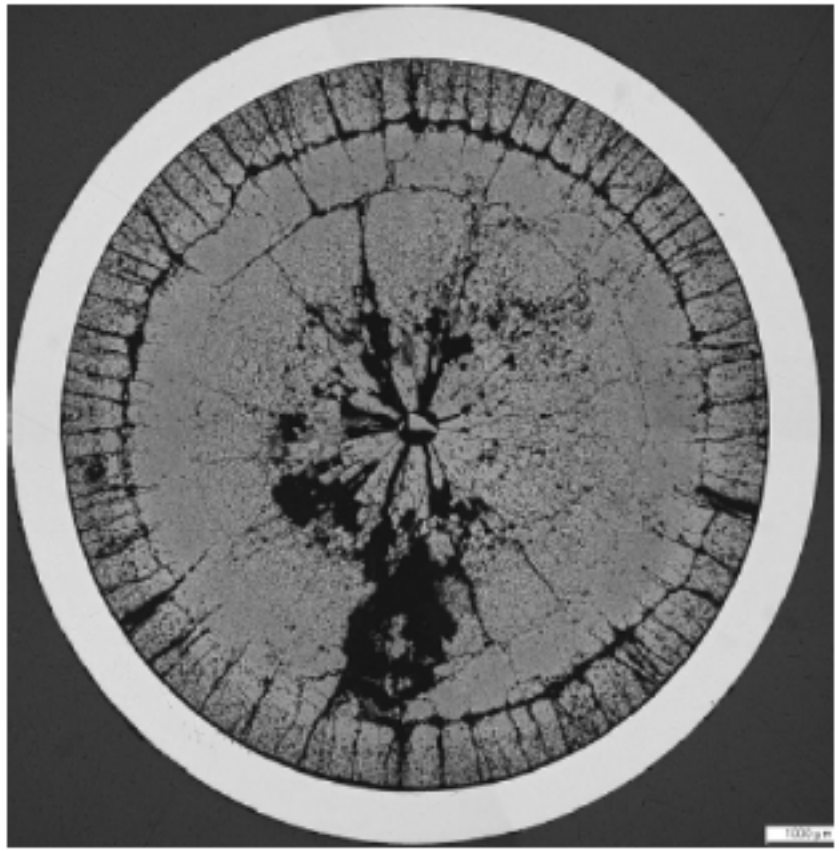
PCI performance

PCI performance – PIE following ramp tests



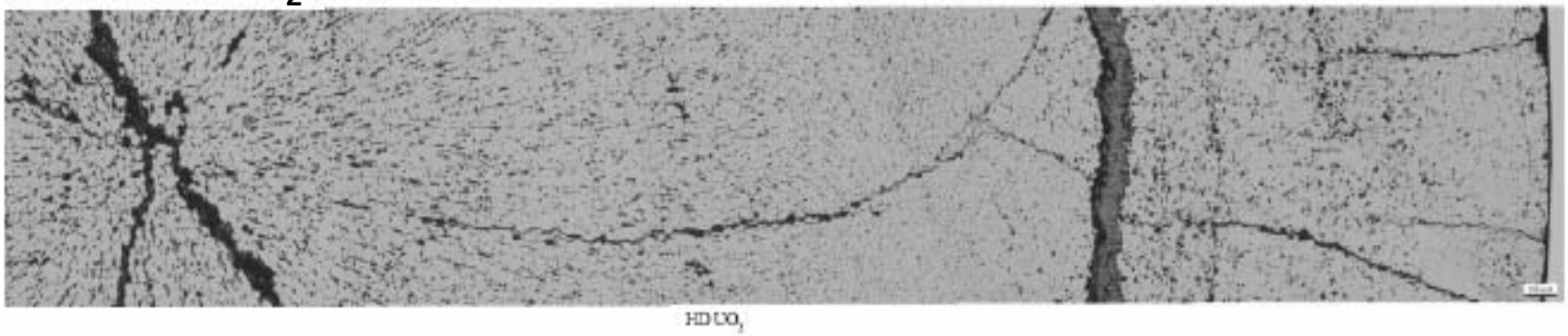
Standard



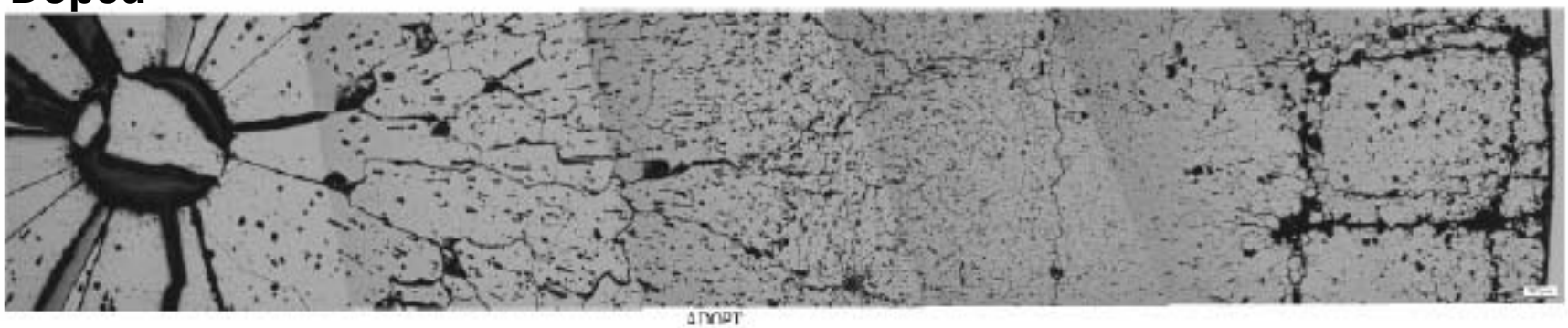
Doped

PCI performance – PIE following ramp tests

Standard UO_2

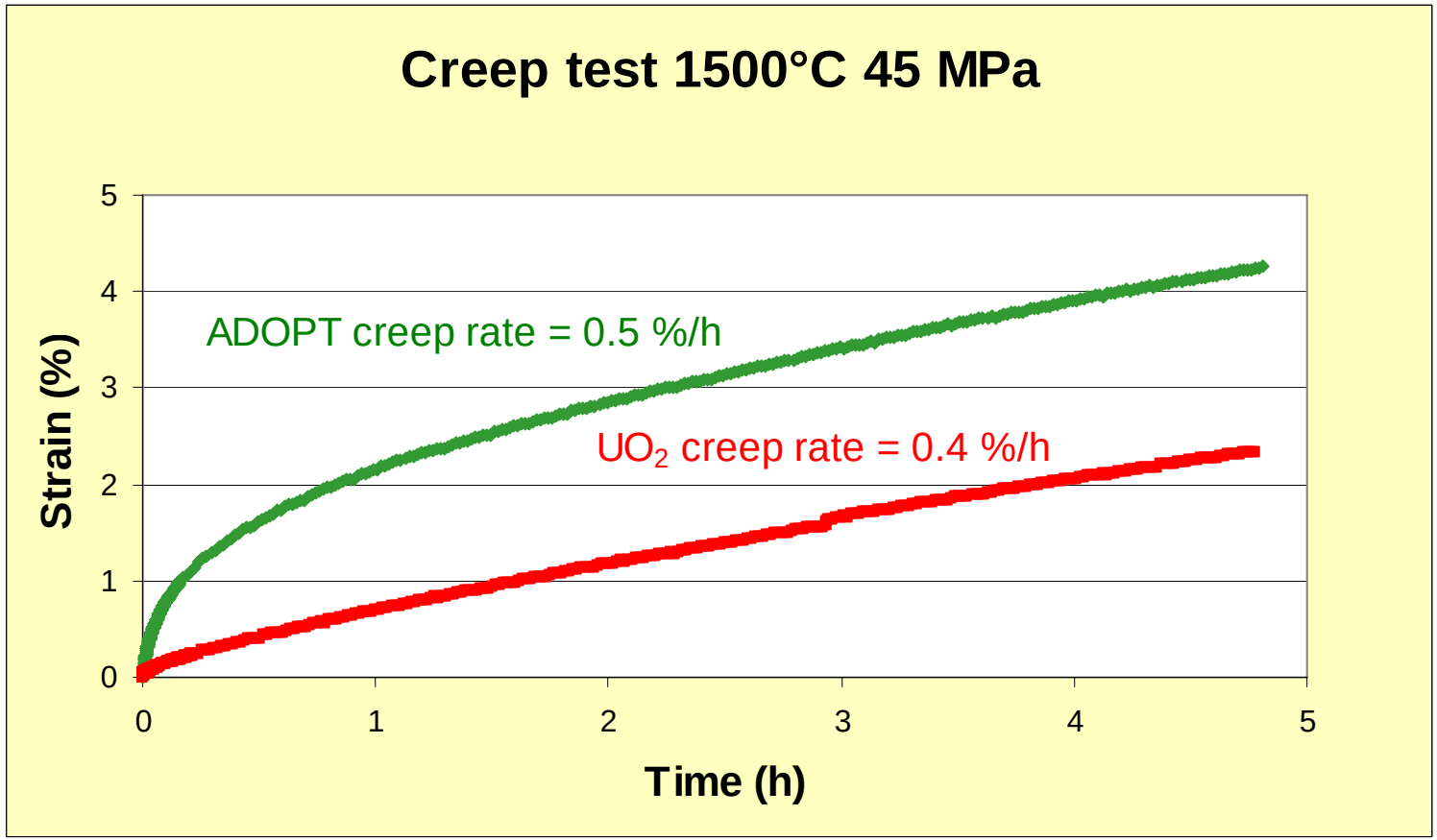


Doped



- Formation of central hole and filling of pellets dishes indicates enhanced viscoplasticity

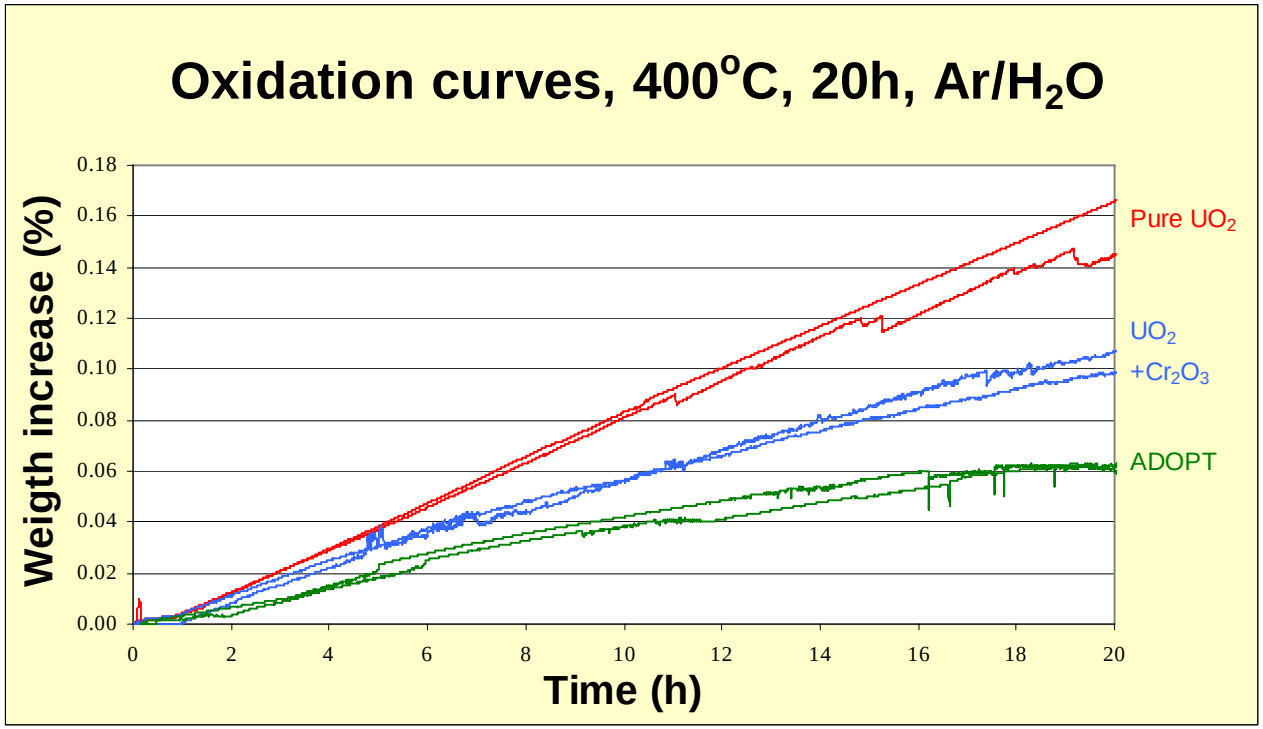
Pellet creep
Constant Stress



- A higher creep rate indicate a more viscoplastic behavior of the ADOPT pellet compared to the standard pellet

Resistance to secondary degradation

Secondary degradation – Oxidation resistance test



- Thermal microbalance test shows that ADOPT has improved resistance to fuel oxidation

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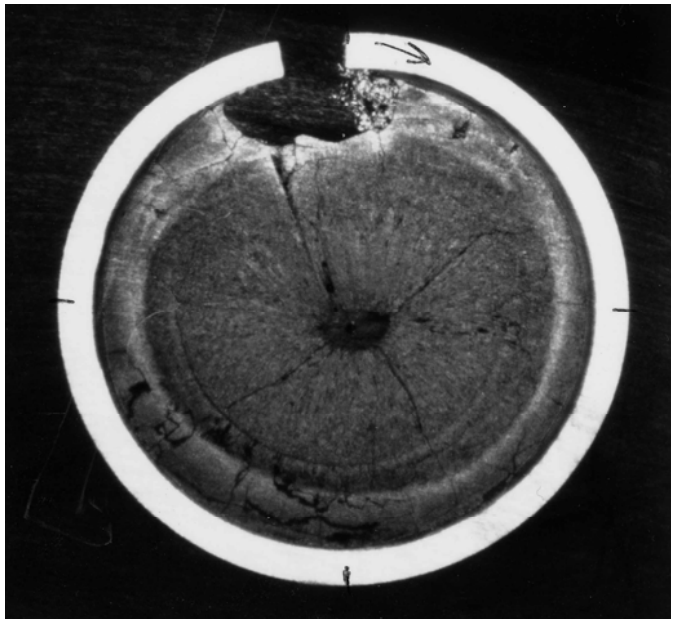
Secondary degradation – Inreactor washout test

BWR rod with a large secondary defect



Standard UO_2 pellet after inreactor washout test

- Studsvik inreactor test show less washout caused by erosion and or surface boiling of higher density pellets i.e. ADOPT

Conclusions

Experience with ADOPT

- 10 years of experience including two full reloads
- An extensive test program

Improved properties

- Higher density
- Reduced FGR
- Improved creep – (PCI performance)
- Secondary degradation behavior – in and out of pile test

Thank You!