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PROtect: The leading Enhanced Accident Tolerant Fuel Program

Taking fuel to the next level by developing advanced fuel systems for nuclear reactors worldwide.

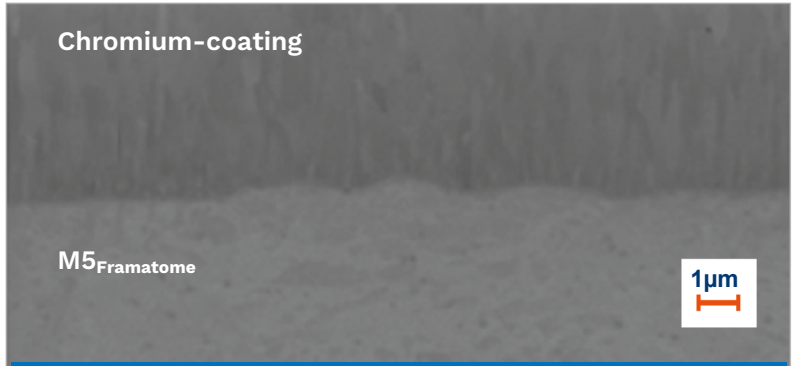
Your performance
is **our** everyday **commitment**

Chromium-coated rods

The Challenge

Framatome initiated its enhanced accident tolerant fuel program as a response to the Fukushima incident in 2011 to improve safety for nuclear plant operators.

Since then, we continue to develop technologies and solutions to make a more resilient nuclear power industry. As a result, we continually exceeded our targets and have implemented our solutions to reactors around the world.



Metallographic cross-section of chromium-coated $M5_{Framatome}$ cladding tube, before irradiation, showing excellent adherence of the two materials.

Adding an optimized chromium coating to our existing $M5_{Framatome}$ cladding offers an advanced and mature cladding solution

The coating consists of a dense layer of chromium on the surface of the cladding tube.

We have a dense and adherent coating thanks to a proprietary Physical Vapor Deposition (PVD) process.

This solution shows greatly improved high-temperature steam oxidation resistance with reduced cladding creep and ballooning

PROtect chromium-coating technology is optimized regarding the cladding behavior. The development of this technology was initiated by the French Alternative Energies and Atomic Energy Commission (CEA) and is supported by its French partners Framatome and EDF in the frame of the French Three Partite Institute in addition to the U.S. Department of Energy and BPI France.

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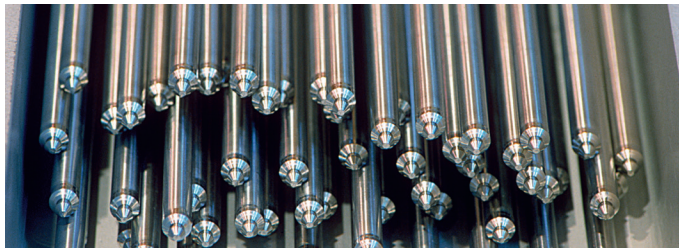
Utility Benefits

Today, the PROtect Cr-coated cladding solution provides beneficial margin gains concerning Design Basis Accident and coping time under severe accidents.

Cr-coated cladding technical benefits value adders for customers combined with minimal over-cost of coating thanks to Framatome exclusive coating process lead to a very competitive product and are levers to maximize benefits of LEU+ fuel



- Chromium-coated cladding contributes to significant safety margin gain
- PROtect improves fuel cycle economics

PROtect milestones and timeline

We developed an aggressive schedule to deploy the PROtect advanced fuel technologies to all Light Water Reactors of the current fleet, plus a dded fl exibility for use in the next generation of advanced reactors.

Since 2016 material test rods have been under irradiation and are confirming the positive results from out-of-pile tests: chromium-coated $M5_{Framatome}$ cladding material test rods were successfully irradiated and operated in a commercial reactor in Europe for a complete five-year lifecycle.

In 2019 in-pile irradiation of the PROtect full length Cr-coated rods began in a PWR in the U.S. with full length coated rods containing chromium-doped fuel pellets. This is the world-wide first complete full scale Enhanced Accident Tolerant Fuel (E-ATF) concept to be irradiated in a commercial reactor, quickly followed by an European and another American utility.

In 2021, the **first worldwide complete PROtect E-ATF Cr-coated assembly** was inserted for irradiation in a U.S. commercial reactor. This is a gain a worldwide first insertion of a full Fuel Assembly equiped with E-ATF rods.

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2026
First PROtect reloads capabilities.

2023
GAIA PROtect full length fuel rods completed their first 3 18-month lifecycle in a U.S. PWR demonstrating excellent performance results and operated as expected.

2021
First LFA fully loaded with PROtect chromium-coated fuel rods put into operation in a U.S PWR reactor.

PROtect fuel segments completed their first 5-year lifecycle in a Swiss PWR and demonstrating excellent performance and visual results.

2019
First in-pile irradiation of full length PROtect Cr-coated rods in commercial PWRs in Europe (HTP Design) and in the U.S. (GAIA and HTP Design).

2018
Fully qualified process for manufacturing of full length Cr-coated claddings

2016
First irradiation of chromium-coated material test rods in a commercial reactor

2011
Start of PROtect development