DART-THERMAL Analysis of Irradiation Behavior of U-Mo/Al Dispersion Fuels

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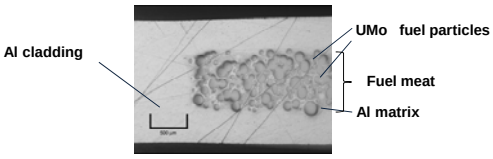
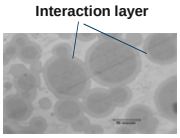
U-Mo/Al Dispersion Fuel

- U-Mo/Al dispersion fuel is being developed for advanced research reactors to replace the high-enriched uranium fuel (^{235}U enrichment > 20%) with low-enriched uranium fuel (^{235}U enrichment < 20%).
- U-Mo/Al dispersion fuel elements are plates/rods with U-Mo fuel particles distributed in Al matrix.



Irradiation-induced Microstructural Changes



- An amorphous layer of **U-Mo-Al interaction product**, which has low density and thermal-conductivity, forms around the fuel particle.

- **Fission-gas-filled pores** are observed in-between the fuel particles.

- **Fission gas bubbles** distribute inside and on the boundaries of U-Mo grains.

Description of DART-THERMAL

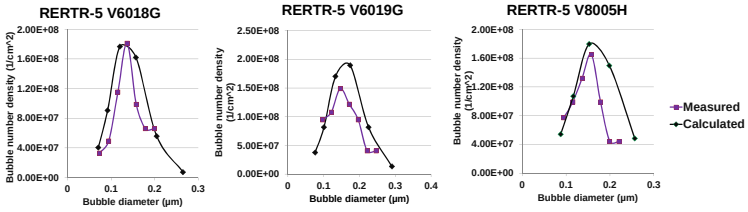
- DART-THERMAL is a **mechanistic model for predicting fission-product-induced swelling** of U-Mo/Al dispersion fuels from a fundamental, theoretical approach.
- DART-THERMAL integrates multiple mechanisms such as:
  - **Rate-theory model** simulating fission gas behavior
  - **Thermal degradation model** for fuel meat thermal conductivity calculation
  - **1-D heat transfer thermal model** to calculate fuel meat temperatures
  - **Interaction layer growth correlation** based on experimental data

U-Mo/Al Fuel Irradiation Tests

- U-Mo fuel has been extensively irradiation-tested in the Advanced Test Reactor (ATR) at the Idaho National Laboratory (INL).

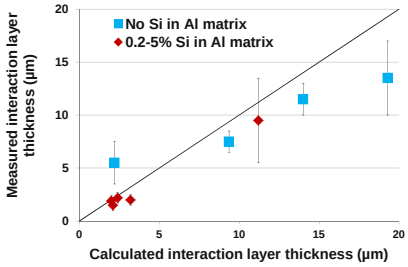
Test	RERTR-5, 6, 7, and 9	AFIP-1
Fuel plate type	Dispersion mini-plate	Dispersion full-sized plate
Fuel plate dimensions (cm)	10(L) x 2.5(W) x 0.14(T)	54.6(L) x 5.75(W) x 0.13(T)
Fuel meat composition	U-10 wt% Mo/Al U-7 wt% Mo/Al U-7 wt% Mo/Al-Si	U-7 wt% Mo/Al-Si

Intergranular Bubble Size Distributions



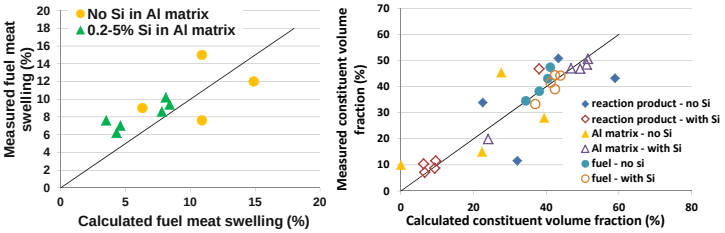
- The values of materials properties related to fission gas behavior for all plates were calibrated with the experimental measurement from RERTR-5 V6018G.

Interaction Layer Thickness



- The interaction layer thickness is a function of fission density, fuel meat temperature, irradiation time, and Si contents in the matrix.

Fuel Meat Swelling and Constituent Volume Fractions



- The model slightly underpredicts the fuel meat swelling in the plates with Si addition. This discrepancy might be related to uncertainties associated with the fuel swelling contributed from pores which are not simulated in the current model.

Conclusions

- **DART-THERMAL can calculate fission gas bubble size distributions and fission-product-induced fuel swelling as functions of microstructures and morphology.**
- **Validations against post-irradiation examination data obtained from the RERTR mini-plate tests and AFIP-1 test show good overall agreement between the calculated and measured data.**
- **The DART-THERMAL code is a comprehensive and powerful tool for dispersion fuel performance analyses.**