INL/RPT-23-73672-Revision-0

Quantitative Insight to Fission Gas Bubble Distribution in Irradiated Annular U-10Zr Metallic Fuel Using Deep Learning

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Idaho National Laboratory

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Final Edge of Poster

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Mission

U-10Zr metal fuel is a promising nuclear fuel candidate for next-generation sodium-cooled fast spectrum reactors. Understanding of the mechanism governing the evolution behavior of fission gas bubbles helps the commercial qualification of U-10Zr fuel.

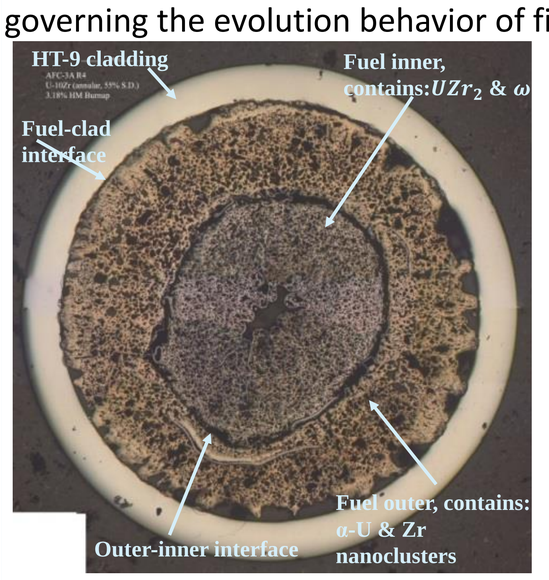


Fig. 1. The optical micrography of a U-10Zr irradiated to 3.4% fission per initial metal atom (FIMA) burnup[1] .

Porosity Analysis

1. Bubble Size

2. Bubble Morphology

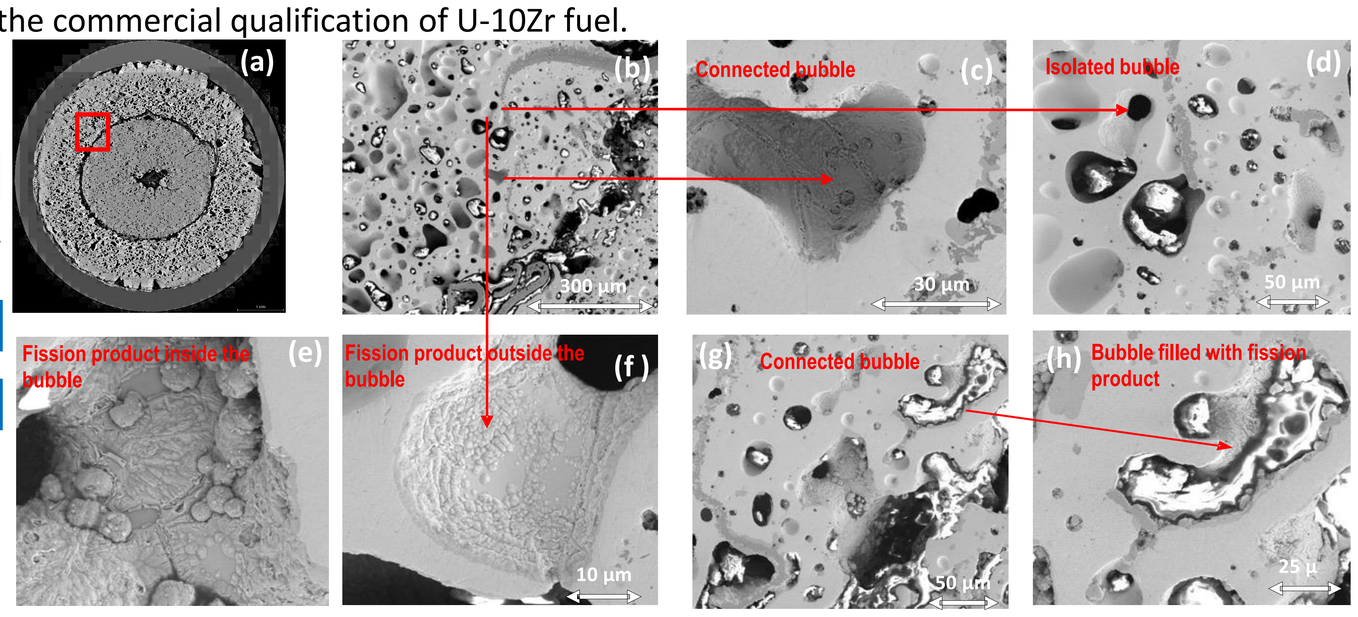


Fig. 2. The Scanning Electron Microscope images of bubbles in U-10Zr fuel[1] .

Analysis and Results

Image Segmentation

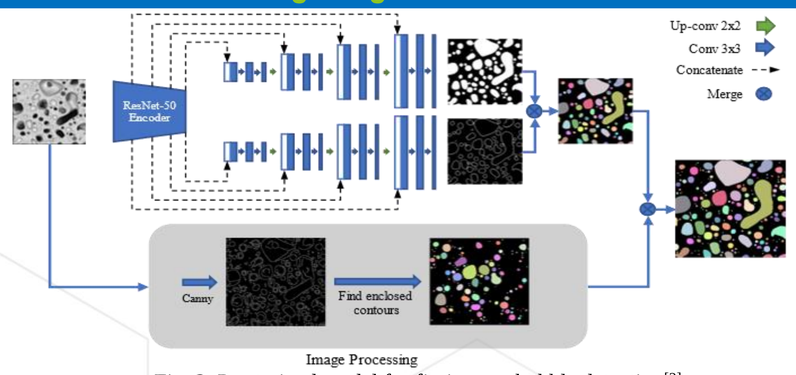
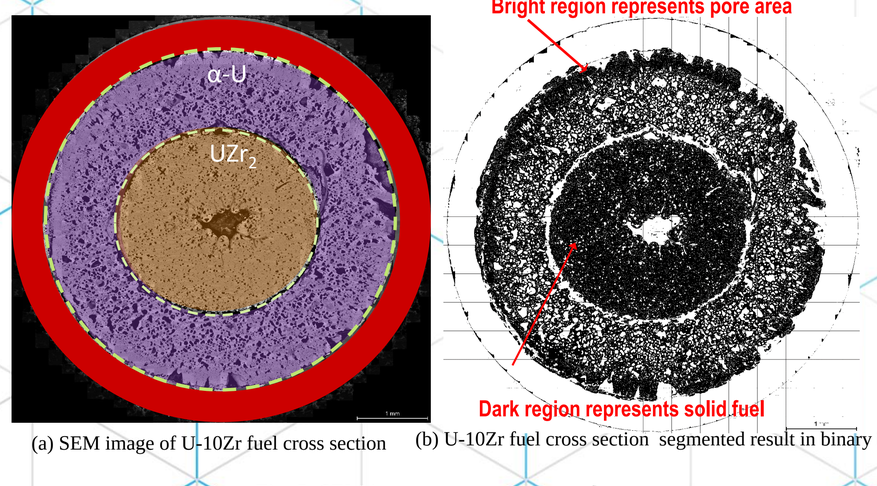


Fig. 3. Pre-trained model for fission gas bubble detection[2] .

(a) Original SEM image (b) Bubbles detected using simple threshold method (c) Bubbles detected using machine learning

Fig. 4. Comparison between SEM image segmentation using simple threshold method and machine learning method[2] .



(a) SEM image of U-10Zr fuel cross section (b) U-10Zr fuel cross section segmented result in binary image

Fig. 5. SEM image segmentation results.

Bubble Size/ Morphology Classification

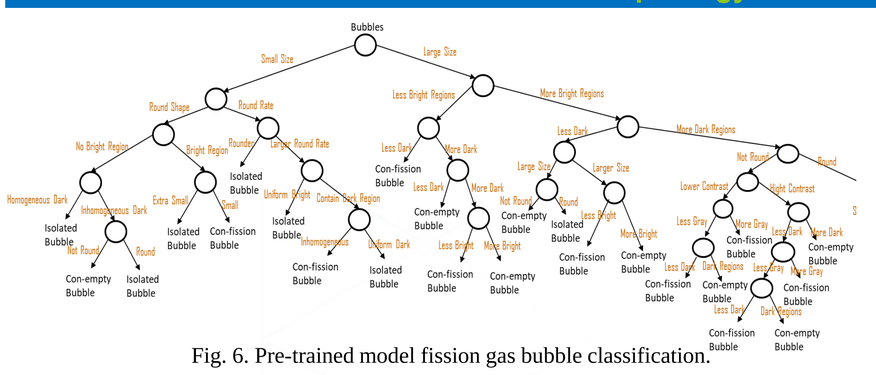


Fig. 6. Pre-trained model fission gas bubble classification.

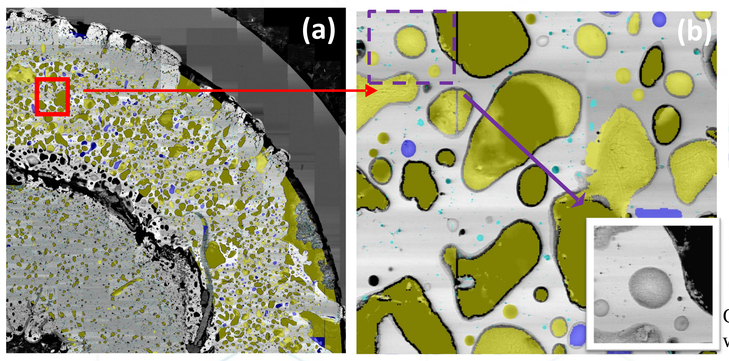


Fig. 7. (a) Pore category labeled on top of original SEM image of U-10Zr, (b) detailed image of interested area.

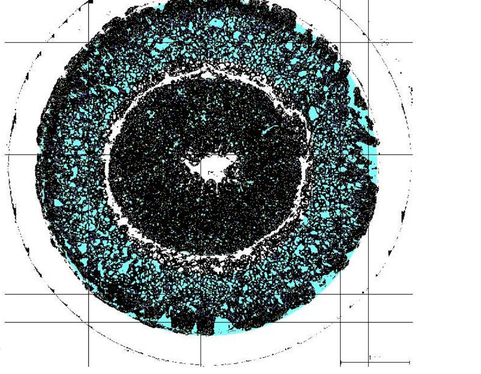


Fig. 8. (a) Pore size labeled on top of original SEM image of U-10Zr, (b) detailed image of interested area.

Bubble Distribution Statistics

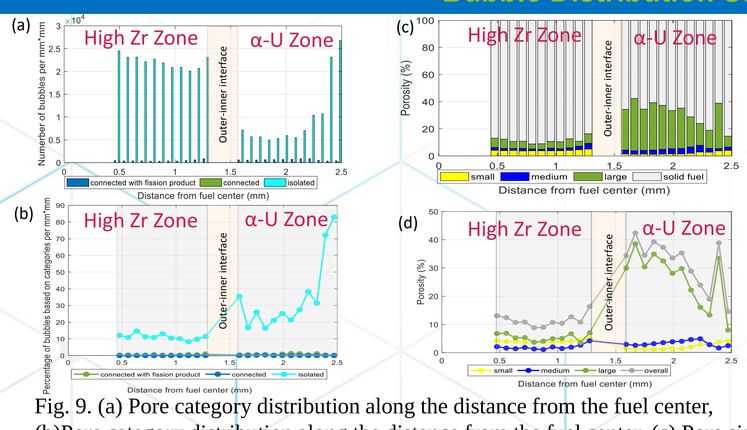


Fig. 9. (a) Pore category distribution along the distance from the fuel center, (b)Pore category distribution along the distance from the fuel center, (c) Pore size distribution along the distance from the fuel center, (d) Pore size distribution along the distance from the fuel center.

Fig. 10. Pore size distribution on the U-10Zr cross section.

Discussion and Future Work

- Further investigation is needed to understand how pore characteristics affect the thermal conductivity.
- Pore orientation analysis is needed to provide insights into the distribution of fission products along the thermal gradient.

References:

1. Cai, L., Xu, F., Di Lemma, F. G., Giglio, J. J., Benson, M. T., Murray, D. J., ... & Yao, T. (2022). Understanding fission gas bubble distribution, lanthanide transportation, and thermal conductivity degradation in neutron-irradiated α-U using machine learning. Materials Characterization, 184, 111657.
2. Sun, S., Xu, F., Cai, L., Salvato, D., Capriotti, L., Xian, M., & Yao, T. (2023). An Efficient Instance Segmentation Approach for Studying Fission Gas Bubbles in Irradiated Metallic Nuclear Fuel.

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