LA-UR- 10-01955

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Intended for: American Nuclear Society Annual Meeting, 6/13-17 San Diego

Los Alamos NATIONAL LABORATORY EST. 1943

Resonant Ultrasound Spectroscopy Measurements of the Elastic Properties of Uranium and Plutonium Based Oxide Fuels

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INTRODUCTION

Los Alamos National Laboratory is engaged in producing mixed actinide (i.e., U, Np, Pu, and Am) oxides to study candidates for nuclear fuels. Correlation of composition and processing technique with initial morphology and crystallographic structure is critical to understanding and predicting the performance of these fuels. In this presentation, I will communicate the results of characterization of fuels ranging in actinide composition from UO_2, $U_{0.8}Pu_{0.2}$ to $U_{0.75}Np_{0.02}Pu_{0.2}Am_{0.03}$ via Resonant Ultrasound Spectroscopy (RUS) for recently fabricated fuel candidates.

EXPERIMENTAL SUMMARY

Oxide fuel pellets were fabricated by pressing and sintering oxide powders into pellets at a variety of processing conditions. Powder milling, pressing pressure and sintering temperature were varied for different samples and compositions. Final pellet dimensions were approximately 5 mm in diameter by 5 mm tall. Compositions measured ranged from depleted uranium oxide to mixtures of plutonium and depleted uranium oxide (MOX) and mixed oxides with small percentages of minor actinide oxide added (MA-MOX).

Densities were calculated from geometry and weight for the urania samples and measured with precision immersion techniques for the mixed oxide samples.

The elastic properties of finished pellets were measured using R~~esonant Ultrasound Spectroscopy~~ (RUS). By iterating the actual experimentally measured specimen resonances vs. predicted spectra for a sample, accurate calculations of bulk (G) and shear (K) modulus can be obtained. The resonance spectra were also analyzed for data quality (Q) via full-width-half-max measurements of primary resonance peaks. This Q factor is a useful measure of quality control in small scale sample processing. Internal cracks, inhomogeneity, incomplete sintering, networked voids and other imperfections can manifest in lower Q factors. Higher quality samples can be selected for use in future experiments and measurements using this method.

RESULTS

Measurements of select fuels are presented in Table I. Notably the depleted urania fuels had much higher data quality than the MOX fuels, even on lower density samples. Many samples had extremely low Q, thus elastic constants were not able to be calculated due to low poor resonance.

Table I. Elastic moduli and Q of oxide fuels

Nominal composition	r	Q	K	G
	% theo.		GPa	GPa
UO_2	93.2	**535**	161.1	70.5
UO_2	61.6	**788**	30	13
UO_2	91.9	**1670**	156.7	70.33
$U_{0.8}Pu_{0.2}$	92	**121**	152.6	63.3

DISCUSSION AND CONCLUSIONS

Moduli presented in Table I compare well to literature values of samples of urania and MOX at similar densities. The UO2 sample at 62% density is unusual due to its high Q despite low density. Ceramography has not been completed on all samples, but initial results show a high degree of heterogeneity in grain size and actinide concentration (Figure I). This, coupled with low density and a corresponding high void percentage, may impede resonance and measurement. RUS has proved to be a useful technique to nondestructively measure sample quality in oxide fuel pellets.

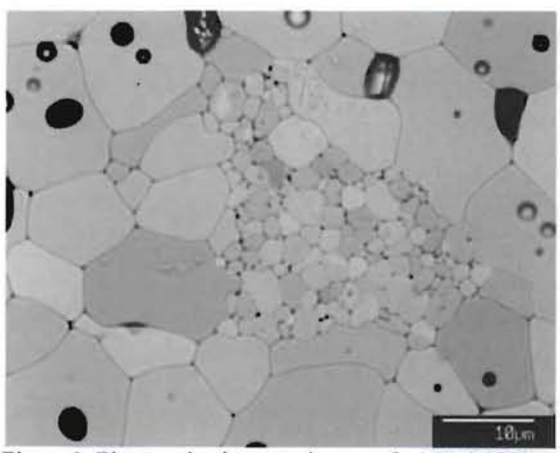

Figure I. Electron backscatter image of a MA-MOX pellet showing clusters of small grains rich in NpO_2 in the center. Nominal composition: $U_{0.75}Np_{0.02}Pu_{0.2}Am_{0.03}$.