# HOT EXTRUSION OF ALPHA PHASE URANIUM-ZIRCONIUM ALLOYS FOR TRU BURNING FAST REACTORS

A Thesis

by

JEFFREY STEPHEN HAUSAMAN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2011

Major Subject: Nuclear Engineering

Hot Extrusion of Alpha Phase Uranium-Zirconium Alloys for TRU Burning Fast Reactors

HOT EXTRUSION OF ALPHA PHASE URNIUM-ZIRCONIUM ALLOYS

FOR TRU BURNING FAST REACTORS

A Thesis

by

JEFFREY STEPHEN HAUSAMAN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

| | |
|---|---|
| Chair of Committee, | Sean M. McDeavitt |
| Committee Members, | William S. Charlton |
| | Jaime C. Grunlan |
| | Lin Shao |
| Head of Department, | Raymond J. Juzaitis |

December 2011

Major Subject: Nuclear Engineering

# ABSTRACT

Hot Extrusion of Alpha Phase Uranium-Zirconium Alloys for TRU Burning Fast Reactors. (December 2011)

Jeffrey Stephen Hausaman, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Sean M. McDeavitt

The development of fast reactor systems capable of burning recycled transuranic (TRU) isotopes has been underway for decades at various levels of activity. These systems could significantly alleviate nuclear waste storage liabilities by consuming the long-lived isotopes of plutonium (Pu), neptunium (Np), americium (Am), and curium (Cm). The fabrication of metal fuel alloys by melt casting pins containing the volatile elements Am and Np has been a major challenge due to their low vapor pressures; initial trials demonstrated significant losses during the casting process.

A low temperature hot extrusion process was explored as a potential method to fabricate uranium-zirconium fuel alloys containing the TRU isotopes. The advantage of extrusion is that metal powders may be mixed and enclosed in process canisters to produce the desired composition and contain volatile components. Uranium powder was produced for the extrusion process by utilizing a hydride-dehydride process that was developed in conjunction with uranium alloy sintering studies. The extrusions occurred at 600ºC and utilized a hydraulic press capable of 450,000 N (50 tons) of force.

Magnesium (Mg) metal was used as a surrogate metal for Pu and Am because of its low melting point (648°C) and relatively high vapor pressure (0.2 atm at 725°C). Samples containing U, Zr, and Mg powder were prepared in an inert atmosphere glovebox using copper canisters and extruded at 600°C. The successful products of the extrusion method were characterized using thermal analysis with a differential scanning calorimeter as well as image and x-ray analysis utilizing an electron microprobe. The analysis showed that upon fabrication the matrix of the extruded metal alloy is completely heterogeneous with no mixing of the metal particle constituents. Further heat treating upon this alloy allows these different materials to interdiffuse and form mixed uranium-zirconium phases with varying types of microstructures. Image and x-ray analysis showed that the magnesium surrogate present in a sample was retained with little evidence of losses due to vaporization.

# DEDICATION

I'd like to dedicate this thesis to my family and friends, for always believing in my ability and encouraging me to succeed in my graduate studies.

# ACKNOWLEDGEMENTS

I would like to acknowledge the wisdom and guidance of Dr. McDeavitt, my committee chair, throughout my undergraduate and graduate studies. Also, I would like to acknowledge the rest of my committee; Dr. Charlton, Dr. Grunlan and Dr. Shao for their contributions to this thesis, as well as their collective roles in my undergraduate and graduate education.

I would like to acknowledge the members of staff of the Fuel Cycle and Materials Laboratory for their invaluable assistance in helping me complete this work. This includes, but is not limited to (in no particular order): Aaron Totemier, Adam Parkison, David Garnetti, Grant Helmreich, Carissa Humrickhouse, Micheal Naramore, Jeffrey Clemens, Brandon Blamer, Daniel Eichel, Julie Borgmeyer, and Allison Cosgrove. I would also like to acknowledge the support and exceptional learning environment provided by the entire Texas A&M University Department of Nuclear Engineering.

I would also like to acknowledge Dr. Guillemette of the Department of Geology for exceptional assistance in teaching and training me to utilize the electron microprobe, which was an indispensable component to this research.

I would also like to acknowledge Braden Goddard and Alice Dale for being exceptional friends and colleagues.

# TABLE OF CONTENTS

Page