Current Research and Research Interests

Prof. Rodney Trice
Purdue School of Materials Engineering
February 8, 2018

Videos and publications available at triceceramics.com

Prof. Trice's Background and Education

1983-1987 BS in Mechanical Engineering – UT Arlington
1988-1989 MS in Materials Science – UT Arlington

1989-1991 Lockheed Martin Aerospace (Formerly General Dynamics)
1991-1995 Northrup Grumman Aerospace (Formerly LTV Aerospace)

1995-1997 Ph.D. in Materials Science and Engineering - University Of Michigan

1998-2000 Post Doctoral Research Associate - Northwestern University

2000 - 2006 Assistant Professor - Purdue University
2006 - 2013 Associate Professor - Purdue University
2013 - Present Professor – Purdue University

Low-cost processing of ceramics, additive manufacturing and injection molding of ceramics, high temperature mechanical properties, optical properties of ceramics

Active Research in These Specific Programs

1. PHASE II: DESIGN AND ASSESSMENT OF MULTIFUNCTIONAL COATINGS FOR ABLATION AND EMISSIVITY PERFORMANCE

Air Force Office of Scientific Research, Program Manager: Dr. Ali Sayir

2. NAVY NEPTUNE: EFFECT OF BIOFUELS ON GAS TURBINE MATERIALS

Office of Naval Research, Program Manager: Dr. Rich Carlin and Dr. Maria Medeiros

With Profs. Hilkka Kenttämaa and Gozdem Kilaz

3. FORMING TRANSPARENT CERAMICS VIA ALIGNMENT OF A-AL_2O_3 PLATELETS: A FUNDAMENTAL INVESTIGATION AND FORMING STUDY

Army Research Office, Program Managers: Dr. Michael Bakas

with Prof. Jeffrey Youngblood

4. INJECTION MOLDING AND ADDITIVE LAYER MANUFACTURING OF B_4C FOR BALLISTIC TESTING

Office of Naval Research, Program Managers: Rodney Peterson, and Troy Hendricks

with Prof. Jeffrey Youngblood

What follows is a 1 page description of each project

1. Phase II: Design and Assessment of Multifunctional Coatings for Ablation and Emissivity Performance

Air Force Office of Scientific Research, Program Manager: Dr. Ali Sayir

Goal: Professor Trice's research group at Purdue University are developing high emissivity coatings capable of increasing radiation heat transfer from the leading edges of hypersonic aircraft.

Approach: Certain rare-earth oxides have been identified as having the requisite electronic structure to provide high emittance from visible to near IR wavelengths. To date, coatings with an emittance of 0.9 at 1600°C and superior ablation performance have been developed. These coatings could reduce leading edge temperatures by 200°C. In collaboration with subject matter experts in the Materials and Manufacturing Directorate of AFRL, the program is also leveraging funds and evaluation capabilities, enabling the characterization and development of coatings with tailored spectral emittance.

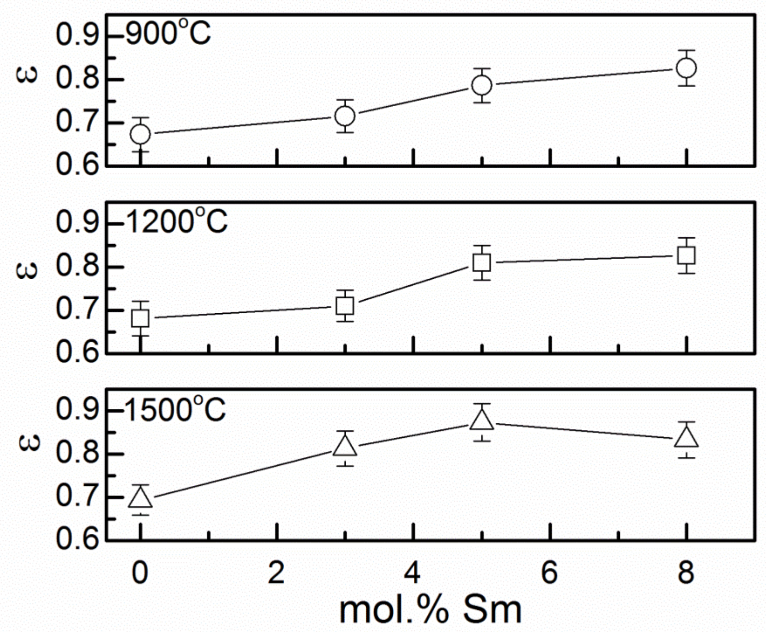


Figure shows the emittance of coatings developed as a function of samarium concentration and temperature. At 1500°C, a coating with 5 mol.% Sm demonstrates an emittance of 0.9.

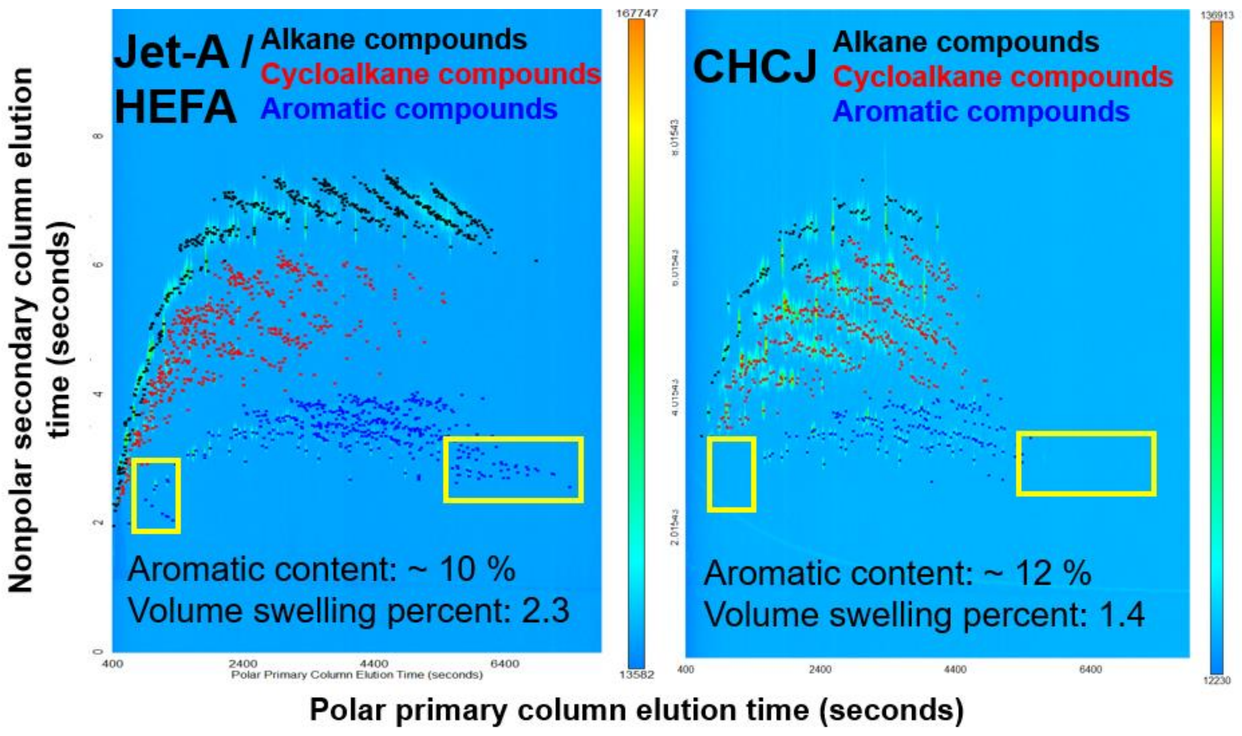
2. NAVY Neptune: Design of Next Generation Renewable Fuels

Office of Naval Research, Program Manager: Dr. Rich Carlin and Dr. Maria Medeiros

With Professors Hilkka Kenttämaa and Gozdem Kilaz

Goal: Aviation fuels are vastly complex mixtures, including many different types of hydrocarbons, additives, and impurities. The goal of the funded work is to facilitate renewable aviation fuel implementation in Navy's aircraft by establishing guidelines for the desirable composition of aviation fuels, determining concentration limits for biomass-derived impurities, and developing cheaper and faster tests for approval of an aviation fuel. The ultimate goal of our project is to begin to design custom fuels, possibly generated from renewable biomass, with more desirable and fewer undesirable properties than current petroleum derived jet fuels.

Approach: As an example of our team's efforts, we have used specialized analytical chemistry tools to determine the key constituents in Jet A that cause necessary o-ring swelling. As biofuels do not typically have these aromatic compounds, we are evaluating many different possible additives to blend with these fuels. Mechanical tests of the o-rings complement the chemistry evaluations.

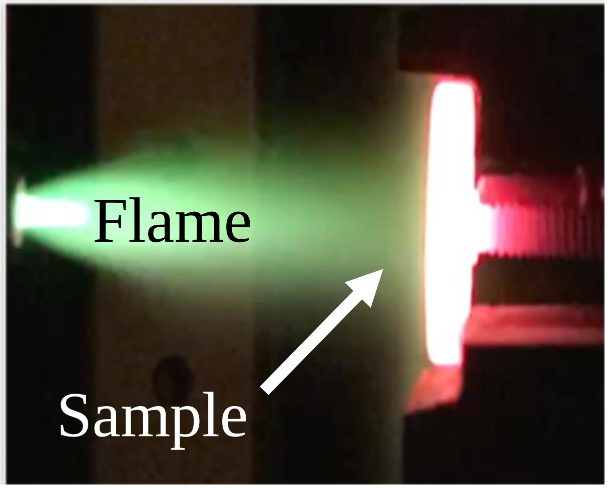


The chemical composition of Jet A / HEFA differs from CHCJ. Importantly, alkylbenzenes with a molar mass of 106 Da are absent in CHCJ. These are the compounds most efficient in swelling o-ring seals. Hence, CHCJ may not swell o-rings sufficiently to prevent fuel leaks.

2. NAVY NEPTUNE: DESIGN OF NEXT GENERATION RENEWABLE FUELS

Office of Naval Research, Program Manager: Dr. Rich Carlin and Dr. Maria Medeiros

With Professors Hilkka Kenttämaa and Gozdem Kilaz



Research Equipment Available in the Aviation Fuels Testing Laboratory:

Qualitative and quantitative fuel chemical compositional analysis via two LECO two-dimensional gas chromatography instruments equipped with an electron ionization time of flight mass spectrometer [GCxGC/(EI) TOF MS] and a flame ionization detector [GCxGC FID].

We can execute the following tests:

- D2386 - Freezing Point of Aviation Fuels
- D3343 - Estimation of Hydrogen Content of Aviation Fuels
- D4809 - Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
- D6379 - Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method
- D7042 - Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
- D86 - Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
- D56 - Standard Test Method for Flash Point by Tag Closed Cup Tester
- D976 - Calculated Cetane Index of Distillate Fuels
- D637 - HPLC with Refractive Index Detection

Furthermore, we have an ablation rig capable of simulating the rapid temperature extremes in a gas turbine, mechanical load frames, and have developed methods to incorporate impurities into our gas turbine materials (e.g. thermal barrier coatings, etc).

Top image shows a sample being ablated at 1400^{o}C in an oxyacetylene torch; bottom image shows a ceramic thermal barrier delaminating from the metallic substrate due to biofuel contaminates. Sample is 25.4 mm in diameter.

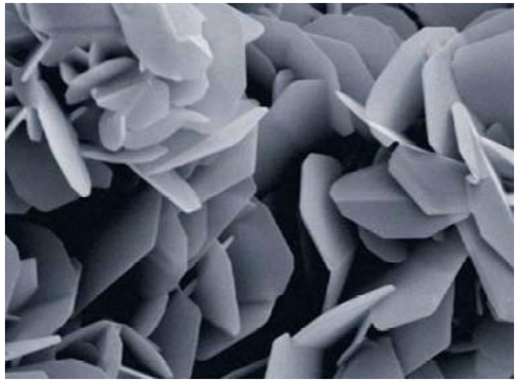
3. Forming Transparent Ceramics via Alignment of a-Al_2O_3 Platelets: A Fundamental Investigation and Forming Study

Army Research Office, Program Managers: Dr. Michael Bakas with Prof. Jeffrey Youngblood

Goal: To improve transparency of polycrystalline alumina ceramics by limiting birefringence induced scattering.

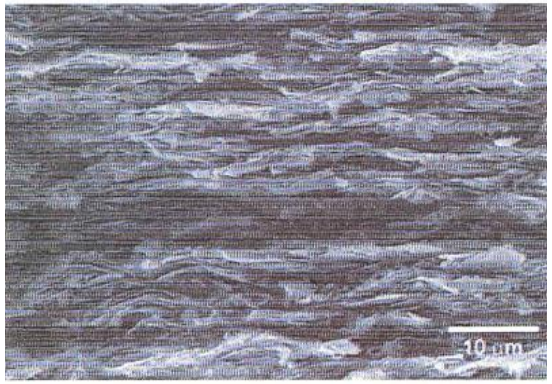
Approach: To use shear and elongational flows of particle slurries and polymer melts to orient platelet alumina to limit grain boundary refractive index mismatch. The goal is to make large sections of polycrystalline transparent alumina.

Turn this…



Unaligned alumina platelets

Into this….



Aligned platelets via polymer flow

And get this:

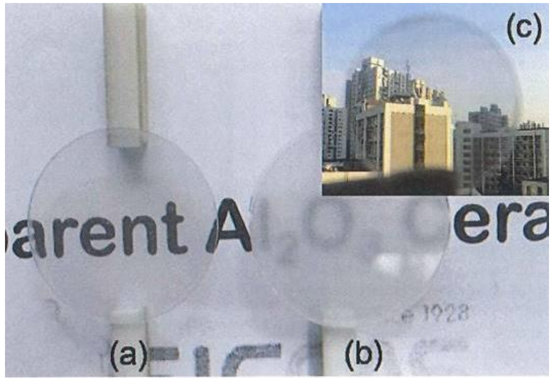


Image from H. Yi, X. Mao, et. al, *Ceram. Int.*, **38** [7] 5557–5561 (2012).

Magnetically aligned alumina showing enhanced transparency (image a versus image b)

4. Injection Molding and Additive Layer Manufacturing of B_4C for Ballistic Testing

Office of Naval Research, Program Managers: Rodney Peterson, and Troy Hendricks with Prof. Jeffrey Youngblood

Goal: To prepare boron carbide (B_4C) ballistic testing specimens via injection molding and 3D printing followed by pressureless sintering as a low cost alternative to the production of B_4C via hot pressing.

Approach: Professors Youngblood and Trice have developed a method of making aqueous ceramic-loaded suspensions with shear-thinning rheological properties that can be used for injection molding and additive layer manufacturing of direct ink writing using Y_2O_3 as a sintering aid.

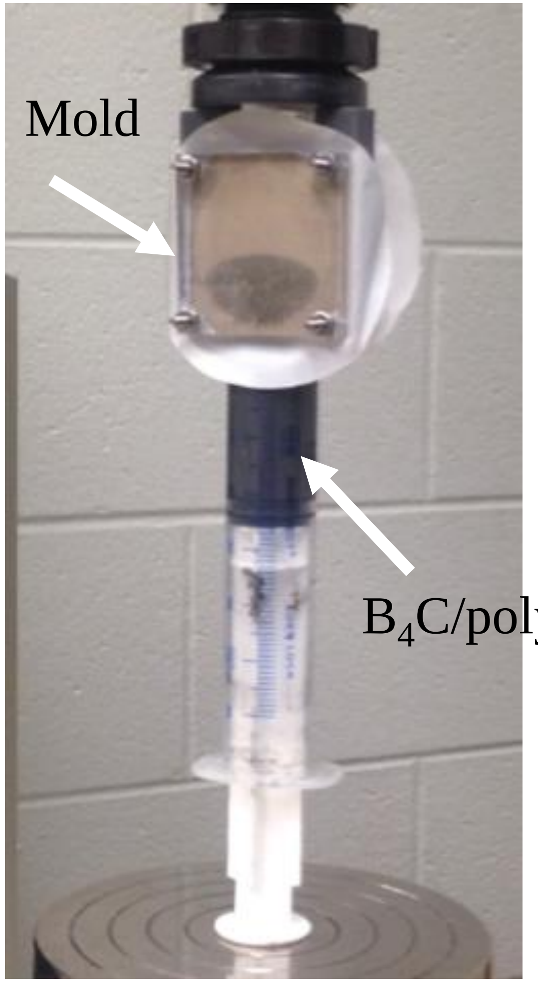
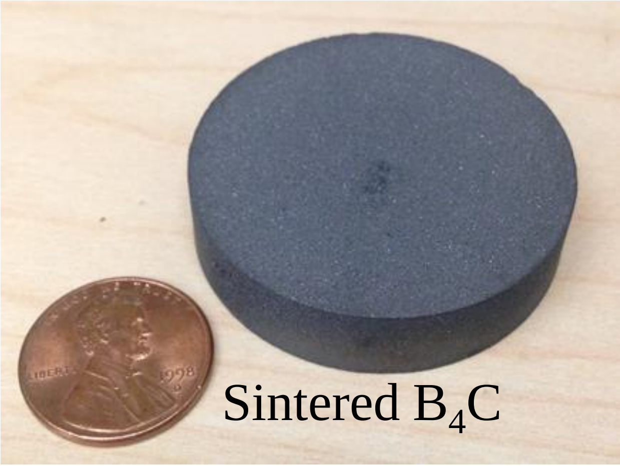


Image shows B_4C/polymer being injection molded into die at room temperature. Video on triceceramics.com



B_4C sample sintered to greater than 95% density using Y_2O_3 sintering aid/2100°C