Toughness Determination of Y+Ta Co-doped Stabilized Zirconia for Thermal Barrier Coating Applications

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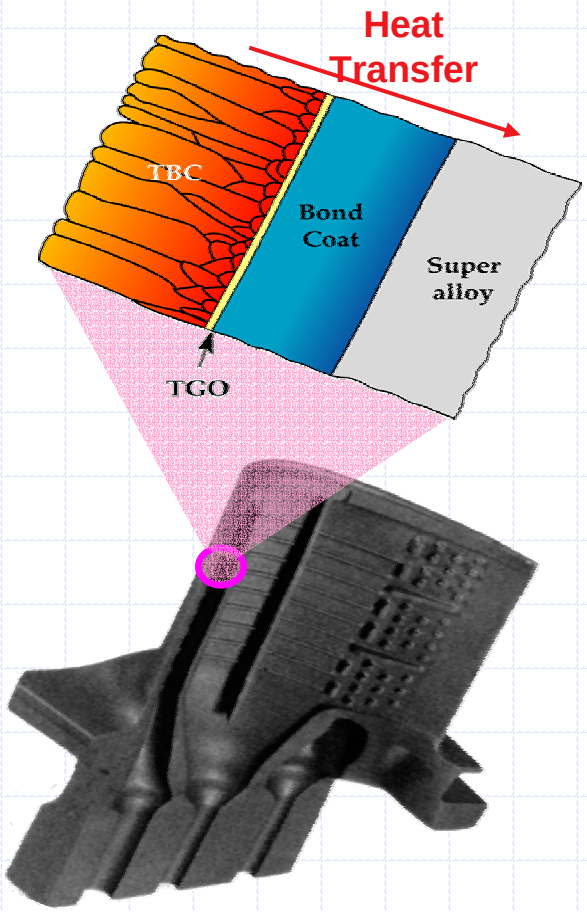
Thermal Barrier Coating System



Turbine Blade
Courtesy of Levi Group

Thermal Barrier Coating (TBC)

Ceramic coatings thermally insulate metallic substrate.

Thermally Grown Oxide (TGO)

Prevents oxidation of the Bond Coat

Bond Coat

Adherence of TBC to supper alloy

Provides Aluminum for TGO

Superalloy

Material of turbine components

State-of-the-Art TBCs

Consist of yttria-stabilized-zirconia (7YSZ) applied by electron beam physical vapor deposition or plasma spraying.

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Applications of Thermal Barrier Coatings

- Used in Gas Turbine Engines
  - Insulate metal alloy components from high operating temperatures of 1100ºC.
- Funding by the Office of Naval Research
  - Develop TBC material with increased resistance to corrosion by impurities in fuel.
  - Increase the operating temperature at which TBC materials can operate to increase efficiency.

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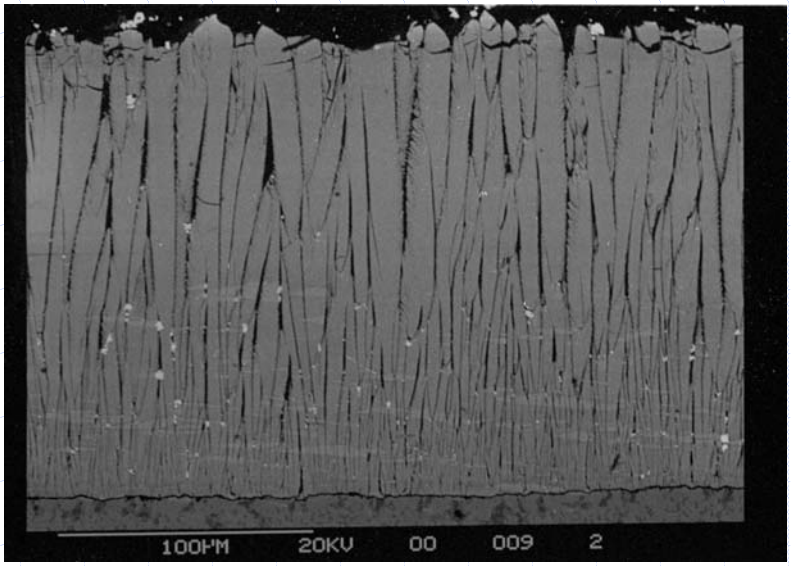
Purpose of Research

Erosion

- Causes TBCs to lose small to large layers which may expose the underlying metallic substrate to high engine temperatures.
- Higher toughness leads to an increased resistance to erosion.
- New Y+Ta co-doped compositions must meet or exceed current TBC material toughness values.



Small particle erosion.

Exposure of turbine blade by erosion.

Courtesy of J. Nicholls, Cranfield University

Toughness

- Measure of resistance to crack propagation.
- Tetragonal bonding of yttria + tantala co-doped system theorized to increase toughness, the resistance to erosion, of TBC materials.
- Multiple compositions of varying percentages of yttria and tantala must be tested.
- Results compared to toughness characteristics of the yttria-stabilized-zirconia TBCs in use.

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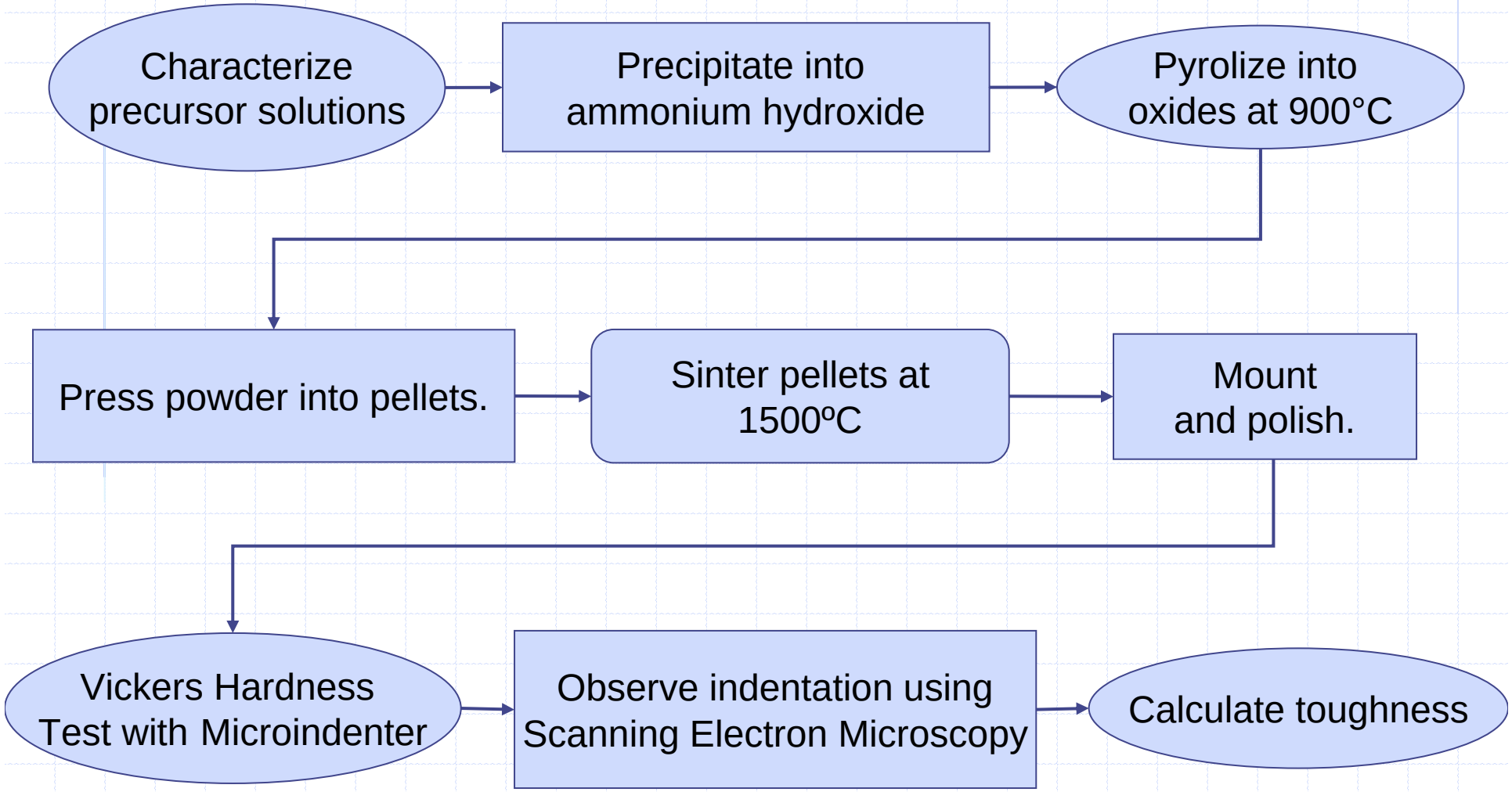

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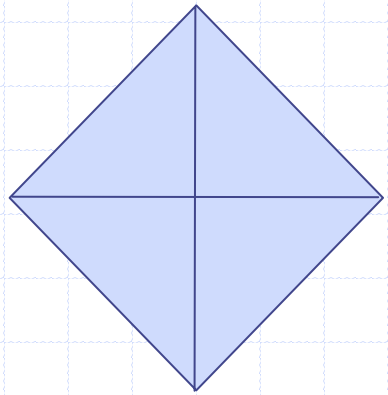
Indentation

- Vickers Hardness Test
  - Microhardness test with a pyramidal diamond indenter.
  - Indentation forces crack propagation from corners.
  - Cracks measured and used to calculate toughness.



Indentation

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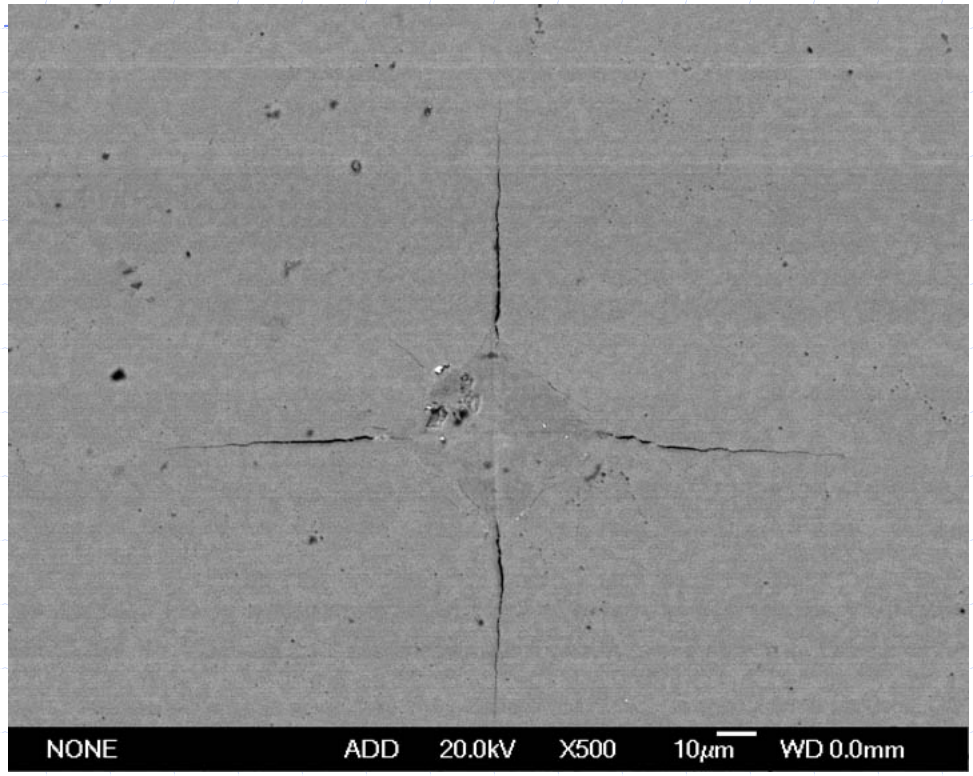
Measuring



$(22YO_{1.5}+12TaO_{2.5})$ Stabilized ZrO

- Crack length is measured in the SEM.
- Length crack along with force applied to cause fracture used to calculate toughness.
- All corners should have uniform crack length.
- Ideal indentation lacks cracking from sides.

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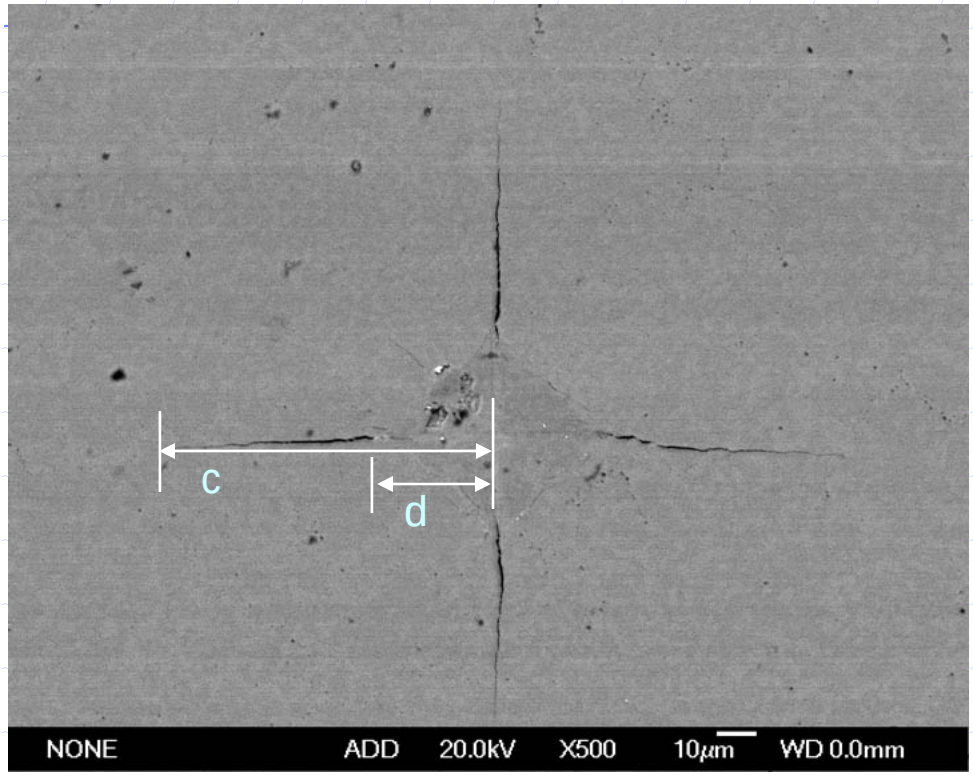
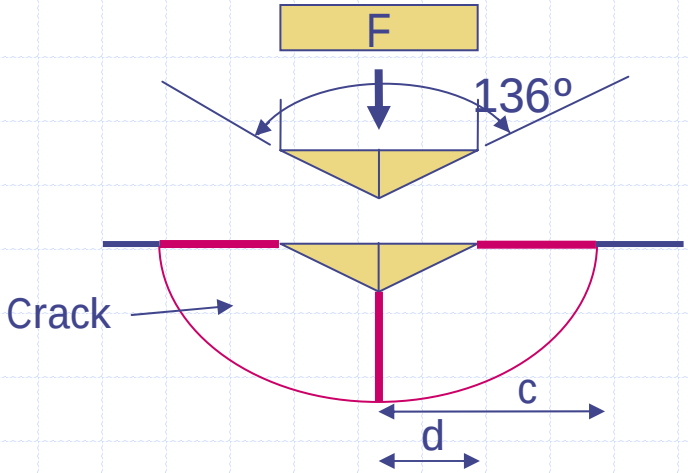
Measuring



$(22YO_{1.5}+12TaO_{2.5})$ Stabilized ZrO



$$H = P/2d^2$$

$$K_c = \xi(E/H)^{1/2}(P/c^{3/2})$$

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Kc: toughness

H: Hardness

P: load

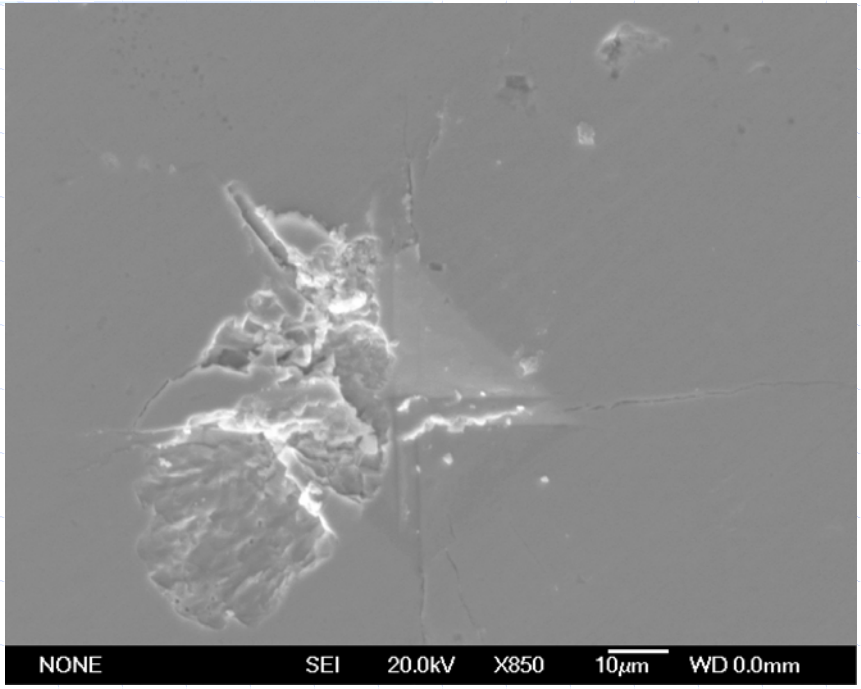
c: crack length from a center of impression to a crack tip

d: the half diagonal length of vickers impression

E: Young's modulus

xi: constant (0.016)

Problems with Present Materials

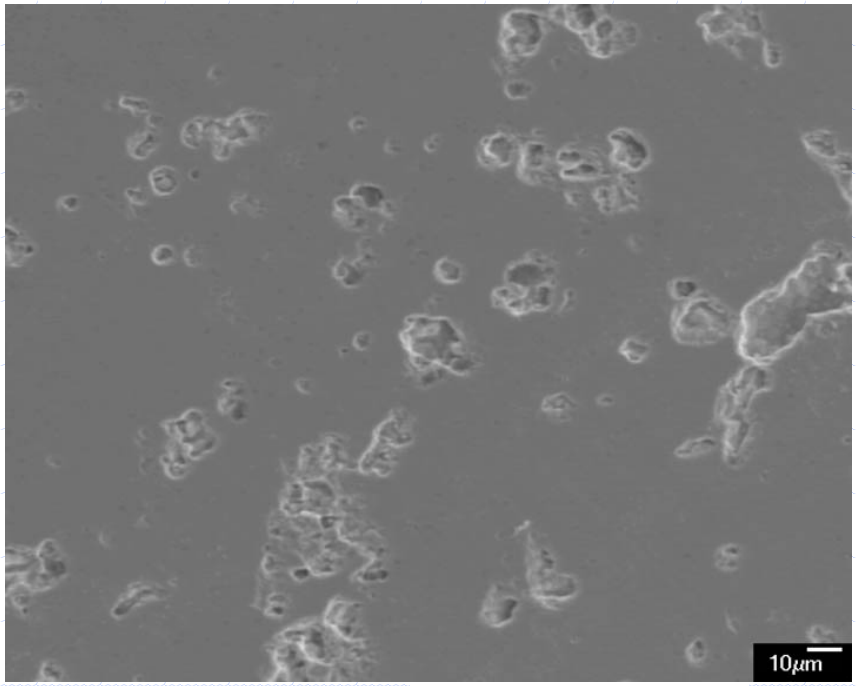


$(22YO_{1.5}+12TaO_{2.5})$ Stabilized ZrO_2

Subsurface pores cause collapse.

Sintered pellets not dense enough for indentation.

$(17YO_{1.5}+17TaO_{2.5})$ Stabilized ZrO_2



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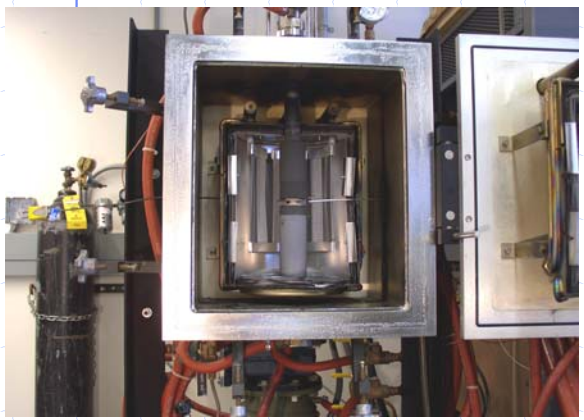
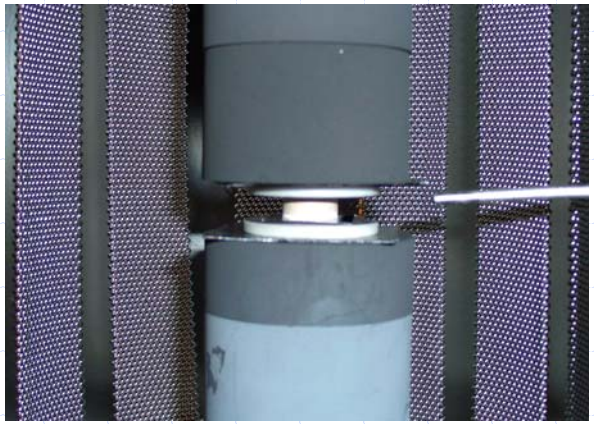
New Direction

- Sinter Forge
  - Pressure and high temperatures of around 1300°C.
  - Forces material to move, thereby filling pores.
  - Increases density of pellet.

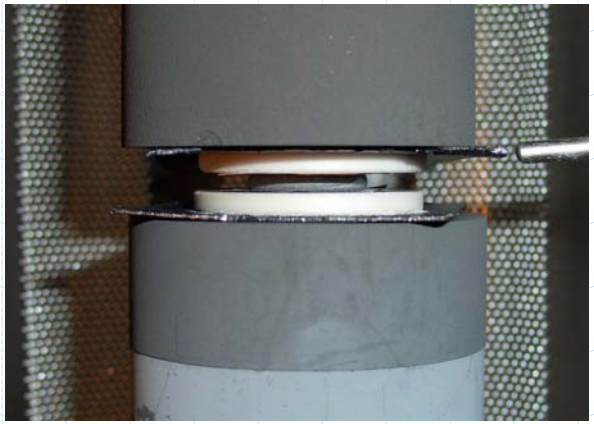
Courtesy of Rafael Leckie, UCSB



Hot Press



Pellet before



Pellet after

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Summary

- Progress
  - Sintered pellets of co-doped TBC material.
  - Indentation of pellets.
  - Samples determined too porous for toughness testing.
- Continued Research
  - Reduce porosity of pellets.
  - Employ sinter forging process.
  - Check constants for accuracy in toughness calculation.

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