Barium Titanate/Aluminum Oxide Ceramic Composites

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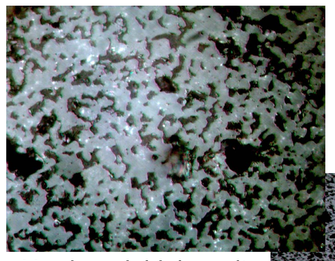
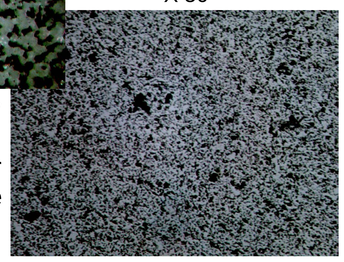
Background and Significance

Barium titanate ($BaTiO_3$) is a ferroelectric ceramic with piezoelectric properties. Like most ceramics, barium titanate is brittle and it develops cracks during mechanical and electrical loading that can cause device failure. This research develops an inexpensive mixed oxide, powder compaction and sintering method to make the $BaTiO_3/Al_2O_3$ composite. The effect of percentage Al_2O_3 addition and sintering temperature on density, porosity, hardness, and strength of barium titanate will be evaluated and compared with control samples.

X 500

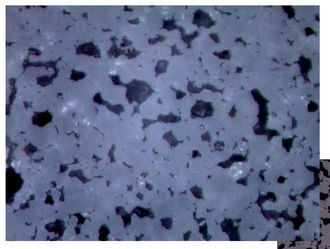


X 50

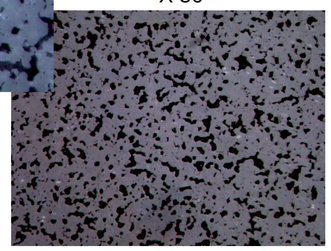


Un-doped, high-purity barium titanate sintered at 1200°C for 2 hours had extensive porosity

X 500

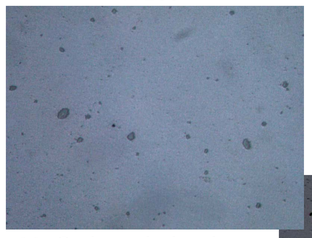


X 50



Porosity decreased upon sintering at 1300°C for 2 hours

X 200



X 50

MgO-doped aluminum oxide had much less porosity than barium titanate. Higher temperature (1350°C), longer sintering time (4 hours) and MgO doping aided densification.

Plan of Work

Powders of $BaTiO_3/xAl_2O_3$ (x = 0, 5, 10 and 15 weight%) were ball-milled for 24 hours using zirconia milling media and uniaxially pressed on a hydraulic press into disks that were subsequently sintered for 1 hour and 4 hours at 1250°C and 1300°C. The sintered composites were characterized for density, porosity, hardness and flexural strength as a function of processing conditions. A total of 42 samples were prepared and tested.

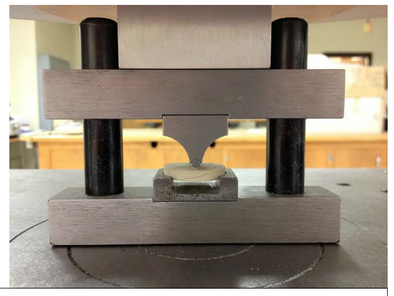
Ball Mill

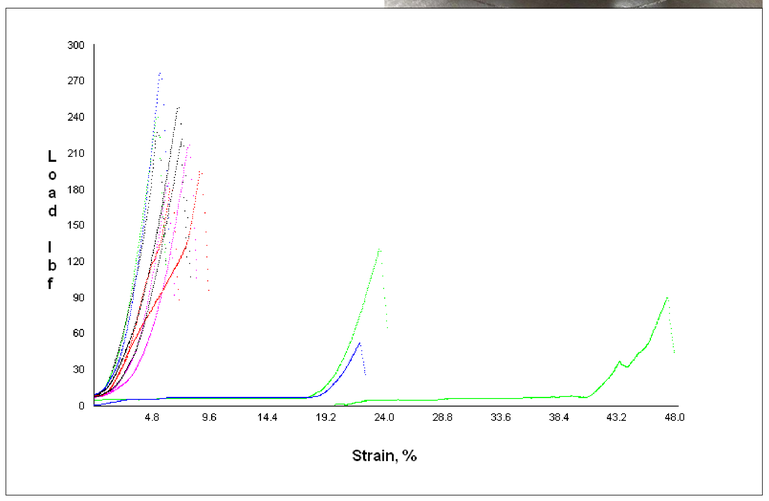
Die

Hydraulic Press

Sintering Furnace

The bend test used in this experiment followed the ASTM Standard C1161, “Standard Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperatures”, except non-standard test specimens were used.





Results of 3 point bend test for various samples

Un-sintered Samples

Sintered Samples

Warped Sample

Results

0% Al_2O_3

Temperature	Time (h)	Density (kg/m³)	MOR (MPa)	MOR (MPa)	Porosity
1250°C	4	5119.3	410.8	45.6	17.6%
1300°C	1	4535.4	328.8	35.3	24.7%
1300°C	4	4962.7	370.7	36.2	15.0%

5% Al_2O_3

Temperature	Time (h)	Density (kg/m³)	MOR (MPa)	MOR (MPa)	Porosity
1250°C	4	5194.5	371.7	37.2	11.6%
1300°C	1	4563.3	336.1	36.6	22.4%
1300°C	4	4865.8	215.0	21.8	17.2%

10% Al_2O_3

Temperature	Time (h)	Density (kg/m³)	MOR (MPa)	MOR (MPa)	Porosity
1250°C	4	4568.4	269.7	28.3	20.6%
1300°C	1	4317.4	306.5	33.8	25.0%
1300°C	4	4570.0	132.9	14.2	20.6%

15% Al_2O_3

Temperature	Time (h)	Density (kg/m³)	MOR (MPa)	MOR (MPa)	Porosity
1250°C	4	4230.9	249.4	25.1	25.1%
1300°C	1	3850.2	144.5	15.4	31.8%
1300°C	4	3991.9	236.8	22.8	29.3%

*MOR numbers were calculated using equations for round and rectangular samples.

Conclusions

- The density of the samples decreases as the amount of Al_2O_3 in the sample increases which was expected because the density of aluminum oxide (4000 kg/m³) is lower than the density of barium titanate (6020 kg/m³).
- The porosity increases as the amount of Al_2O_3 in the sample increases. This may be due to the higher melting temperature of aluminum oxide which is 2072°C, compared to 1625°C for barium titanate.
- The Modulus of Rupture (MOR) was the highest for the 0% Al_2O_3 samples which means that with the parameters used in this research, aluminum oxide was not able to strengthen barium titanate.
- There was not a consistent trend to show that sintering temperature and sintering time had an effect on the density or the modulus of rupture.