

1-1-1999

Measurement of the Dielectric Strength of Titanium Dioxide Ceramics

Wayne Huebner

Missouri University of Science and Technology, huebner@mst.edu

J. M. Lundstrom

L. F. Rinehart

R. C. Pate

et. al. For a complete list of authors, see https://scholarsmine.mst.edu/matsci_eng_facwork/1445

Follow this and additional works at: https://scholarsmine.mst.edu/matsci_eng_facwork



Part of the [Materials Science and Engineering Commons](#)

Recommended Citation

W. Huebner et al., "Measurement of the Dielectric Strength of Titanium Dioxide Ceramics," *Proceedings of the 12th IEEE International Pulsed Power Conference, 1999*, Institute of Electrical and Electronics Engineers (IEEE), Jan 1999.

The definitive version is available at <https://doi.org/10.1109/PPC.1999.823813>

This Article - Conference proceedings is brought to you for free and open access by Scholars' Mine. It has been accepted for inclusion in Materials Science and Engineering Faculty Research & Creative Works by an authorized administrator of Scholars' Mine. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.

MEASUREMENT OF THE DIELECTRIC STRENGTH OF TITANIUM DIOXIDE CERAMICS

Lundstrom, J.M. (Ktech Corp.)[†]; Rinehart, L.F.; Pate, R.C.; Smith, T.L. (Ktech Corp.)
Sandia National Laboratories[‡], PO Box 5800, MS 1153
Albuquerque, New Mexico, USA, 87185-1153

Krogh, M.L.
Allied Signal FM&T, 2000 East 95th St., PO Box 419159
Kansas City, Missouri, USA, 64141-6159

Huebner, W
University of Missouri at Rolla, 222 McNutt Hall, 1870 Miner circle
Rolla, Missouri, USA, 65409-0330

Abstract

Titanium dioxide ceramics (TiO₂) are candidate materials for high energy density pulsed power devices [1]. Experiments to quantify the dielectric strength of TiO₂ have been performed on a limited number of unoptimized samples. A high voltage test set was constructed to test the TiO₂. All samples had a relative dielectric constant of 100, all samples were of 3mm nominal thickness, and all tests were performed in water dielectric to reduce the effect of the triple point field enhancement at the electrode edge. Both single layer and laminated samples were tested and the breakdown field strengths were recorded.

Voltage risetimes varied slightly around 400 ns depending upon the size of the test sample area. Areas varied from <0.2 cm² to >100 cm². Both single layer and laminated material showed a strong area effect where the dielectric strength dropped off as area to the -0.17 and -0.1 power respectively. Effective areas of the electrodes were calculated using a field solver program. Breakdown field strengths varied from 469 kV/cm to 124 kV/cm in the single layer specimens, and from 556 kV/cm to 261 kV/cm in the laminates over an increasing area range. Energy density calculations for the material show that at areas of approximately 100 cm² the laminates can store nearly 3 times more energy than single layers.

I. INTRODUCTION

Advances in pulsed power frequently depend on the ability to find better dielectric materials. Titanium dioxide ceramics (TiO₂) show promise for pulsed power devices requiring high energy density componentry because of their high dielectric constant provided the dielectric strength of the material is adequate. To quantify its dielectric strength a test set was built that was capable of output voltages > 200.0 kV. The 10% to 90% risetime varied with the load but centered around 400 ns with little deviation over the four electrode sizes used.

II. THE TEST SETUP

The test set consisted of a tube switched modulator submersed in a transformer oil bath. A second container within the oil bath held the electrodes and test sample submersed in deionized, deaerated water. A capacitance to control the risetime was connected in parallel with the test sample whenever the low area (small capacitance) electrodes were used. Deaeration of the water was performed with the TiO₂ samples submersed to remove air bubbles from the electrode and TiO₂ surfaces. Stangenes model CVD-350 [2] capacitive voltage dividers were used to measure the breakdown voltage of the test sample. The monitors were connected at the high voltage feedthrough points on the sample container.

Because the electrodes had large radiused edges, the effective area was larger than the electrode contact area. The effective area was calculated using a commercially available field solver. The edge was arbitrarily defined as the point where the E-field dropped to 85% of the peak field. The intersection of the E-field line of this value with the surface of the test material was used as the effective diameter and used to calculate the effective area. The discrepancy between the contact area and the effective area is most obvious when you consider the 1.27 cm diameter hemispherical electrodes. Although the contact is a single point, the effective area was calculated to be 0.168 cm².

Submersion of the test sample in water reduced the field enhancement at the triple point, but not enough to ignore it completely. The field solving software also enabled the calculation of a field enhancement factor (FEF). For example, the same 1.27 cm diameter hemispherical electrodes were calculated to have an FEF of 1.078.

III. THE TEST

A limited number of test samples were available. All samples were 3 mm nominal thickness. The dielectric

constant of TiO2 can be varied at production but all of the samples tested had a relative dielectric constant of 100. Some samples were a single layer of ceramic while others were laminated. The data have been separated accordingly. TiO2 is not a self-healing dielectric. When the dielectric strength of a particular piece was found by a high voltage breakdown through the material a permanent defect remained. This limited the number of tests that could be performed with the larger electrodes. As noted on the graph in Figure 3, one of the large area data points is a single event.

IV. THE DATA

Figure 1 and Figure 2 show all the data points for single layer and laminated samples of various areas. Figure 3 is a comparison of the average breakdown strength as a function of area.

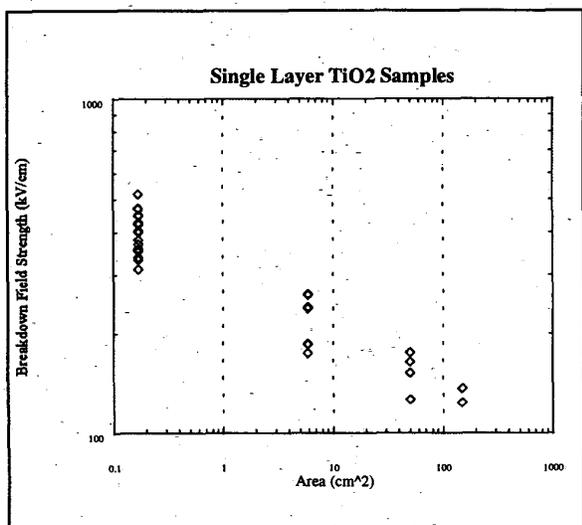


Figure 1. All data points for single layer TiO2 samples

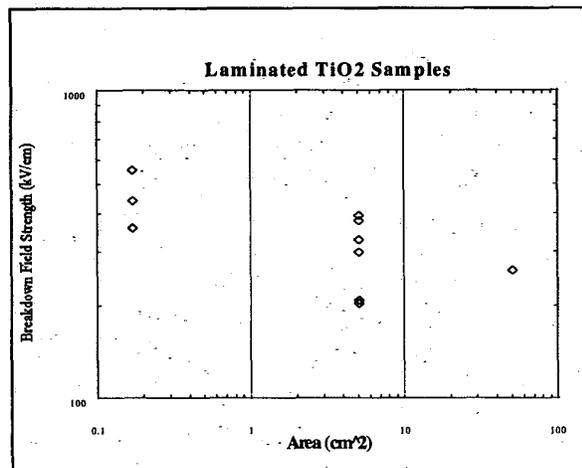


Figure 2. All data points for laminated TiO2 samples

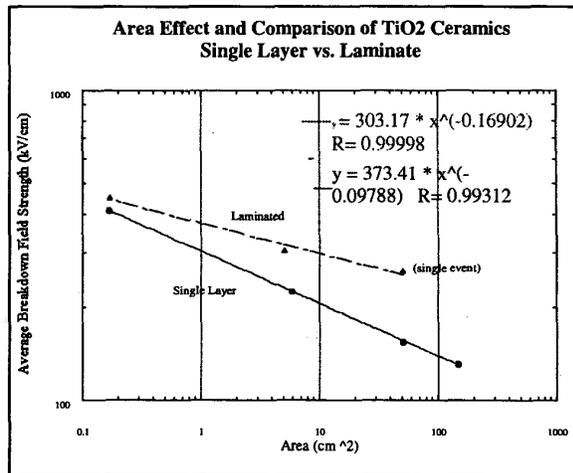


Figure 3. Average breakdown strength comparison

Energy density, the amount of energy that can be stored per unit volume, is an important figure of merit for dielectrics. Figure 4 compares energy density calculated at average breakdown field strength for single layer and laminated TiO2 test samples. The data show that laminates out perform single layers over the entire range of areas tested. At approximately 100 cm² area, the laminates can store nearly 3 times as much energy as single layers.

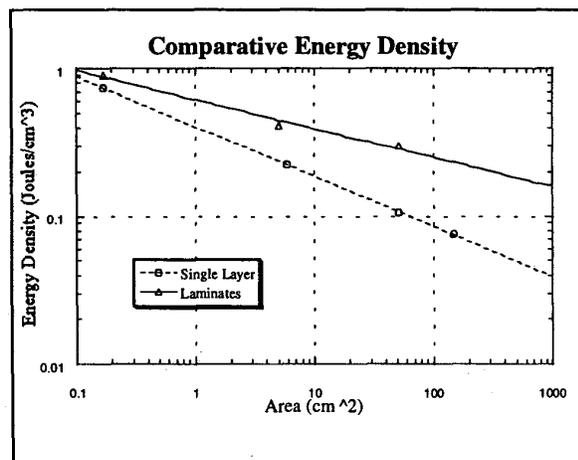


Figure 4. Energy Density Comparison

V. CONCLUSION

An area effect was found to exist in both single layer and laminated samples of unoptimized TiO2. Test samples of laminated construction perform with higher dielectric strength than a single layer. The performance of the single layer TiO2 followed the expression,

$$E_{Bs} = 303.2 \times A^{-0.17} \quad (1)$$

and the laminated TiO₂ followed the expression,

$$E_{Bl} = 373.4 \times A^{-0.1} \quad (2)$$

where E_{Bs} and E_{Bl} are breakdown field strength in kV/cm and A is area in square centimeters. In energy density laminated samples outperformed single layer samples by nearly a factor of 3 at areas of approximately 100 cm².

† Ktech Corporation, 2201 Buena Vista S.E.,
Albuquerque, New Mexico 87106-4265

‡ Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000

VI. REFERENCES

- [1] Krogh, M.L., et. al, "High Breakdown Strength, Multilayer Ceramics for Compact Pulsed Power Applications," to be published in Proceedings of 12th IEEE Pulsed Power Conference, 1999
- [2] Stangenes Industries Inc., 1052 East Meadow Circle, Palo Alto, California, 94303