A single crystalline (Ytrium stabilized) Zirconia was extensively studied in order to get insight into the charge transport process in Zirconia as compared to other crystalline samples. One thing we examined was the effect of crystalline-orientation charge retention on the electret formation discs. We did not find any significant difference in the electret formation or retention on cutting the crystal in different orientations. We did, however, notice and collected data on the increase of the charge density and the half life when the sample thickness was increased. We are trying to correlate this with our theory developed for the charge retention and relaxation for the two different mechanisms of monocharge and bipolar charge retention. We did also examine the increase in the relaxation time by storage at colder temperature and drier atmosphere. The result was an exponential increase of the half life with the fall of temperature as expected.

We started investigating different new materials, all obtained from single crystalline structure. Some new materials like deuterated triglycine fluoroberylliate, (TGS) etc, were found to have much lower insulation property to be able to retain the charges. On the other hand the single crystalline samples of Lithium Niobate and Lead Zirconium Titanate were found to be much better than the single crystal-Zirconia.
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These are the main aspects of electret formation and retention which have been investigated.

(a) The difference in the mechanism of mono-charge and predominate bipolar charge retention and relaxation of discharge. We have attempted to charge our crystalline samples in three different ways: A single surface positive only, negative only, and both faces oppositely charged.

(b) We have also investigated the effect of the crystalline axial orientation on the charged disc.

(c) We also examined the difference between the electret-forming crystalline samples and the uncharged (without electret formation) crystalline samples of the materials. We could not detect any difference between the charged electret and non-charged samples of the single crystalline Zirconia.

The Analysis and its Importance

The alternating current and high-frequency properties of insulating dielectric materials have been investigated for a very long time. The instrumentation for the study of the complex dielectric constant with alternating current at different frequencies, though novel fifty years ago, is almost routine today. To get data on transport properties with very large retention times (of hours and days rather than in microseconds or picoseconds), the most successful recent method is the study of thermally stimulated currents giving information on energies involved in the ionic diffusion or hopping mechanisms. The newest and the most direct
method of microscopic analysis of (direct current) charge transport or storage property is the stress-wave probing method invented, developed and perfected during the past ten years. Two effective techniques in this method are the Laser Induced Pressure Pulse Technique and Thermally Stimulated Discharge Current Measurement. Basically the equipment needed for both techniques in studying the charging or decaying process mechanism and the activation energies involved in the process are the same. A programmed temperature controller, an X-Y plotter and a sensitive electrometer with matched amplifier to connect it to the plotter are the essential tools needed for this set-up. Except for the programmable temperature controller, we do have some essential parts of the equipment, e.g., Keithley (Model 616) electrometer and an X-Y plotter. However, because of the sensitivity of the equipment to electronic load matching etc, it would be desirable to have an entirely new and isolated set-up.

Other Support

No other support of this project or any other related project that involves research investigation is pending before any Federal State or local agency.

RECENT ACCOMPLISHMENTS

(a) Graduate Students

Two graduate students have completed their dissertation and received their Master's Degree in Physics. These students, Mr. Terry Harrington and Mr. Gerald Payton, were supported by DOE Funds.
(b) Undergraduate Student

One undergraduate student, Mr. S. Christopher Thedford who was supported under the DOE grant received, in 1989, a full three year ONR fellowship to complete his Ph.D. in Materials Science. He is currently pursuing his Ph.D. degree at North Carolina State University, Raleigh.

(c) Publications


Tests are now in progress studying polarization in Lead Zirconium Titantate. Results have shown that zirconia exhibits behavior that is characteristic of electrets. Studies are in progress and special attention is being focused on altering the sample thickness, changing the temperatures and other variables.

Recent Accomplishments

Two graduate students and three undergraduate students were actively involved in this project. They are

1. Terry Myers - graduate student
2. Patricia Lee - graduate student
3. Curtis Evans - undergraduate student
4. Christopher Thedford - undergraduate student
5. Paul Brown - undergraduate student

At the end of August 1989 Steven Thedford won an ONR Fellowship to do his Ph.D. in Materials Science. He has been replaced by Roy Williams, an undergraduate student, Paul Brown was terminated due to his poor GPA and replaced by Jacqueline Fernandez. Patricia Lee was dropped because of her poor performance, irregular attendance, and unsatisfactory results. Currently, we have a team of four (4) students working under this project.

1. Terry Myers - graduate student
2. Roy Williams - undergraduate student
3. Jacqueline Fernandez - undergraduate student
4. Curtis Evans - undergraduate student

We are making preparations to present a paper at the 1990 Spring meeting of the Materials Research Society, April 14-18, 1990 in San Francisco, California. We applied and made every effort to attend the Gordon Research Conference on Solid State Studies in Ceramics held August 14-18, 1989 in New Hampshire, however, we were unsuccessful.

Thermally stimulated charge decay investigations are in progress. Decay measurements and x-ray analysis techniques are in use for such investigations in our laboratory. We now have an active team that includes graduate and undergraduate students. The preliminary progress reports prepared by our students as a result of their efforts on this research project were transmitted to you in our earlier report.
Recent Results

1. The samples exhibit anisotropic properties as well as piezoelectric properties. Furthermore, there is evidence that a relationship between the thermal conditions that this material experiences and its magnetic anisotropic properties. The errors in calculations, and procedures are attributable to both random and systematic errors. The random errors could occur because of how the measurements were taken by this researcher when using the electrometer, or any of the other computational devices used in this process. In spite of these marginal errors, we have confidence in the quality of the results obtained.

2. Various procedures such as the plate-induced method and the analysis of the surface charge density provide essential information to the effects of the polarization of the material. From the graphs of density and intensity, it is quite obvious the ceramic material lead zirconium titanate (PZT) when exposed to relatively high electric fields (3kV) tend to discharge rapidly over a short period of time.

We expect progress in the consistent and precise analysis of peaks due to the motion of space charges. The crucial advance would be to extend the analysis to multiple traps, so that it agrees better with the actual situation.

Much more investigations are needed since the results so far have been inconclusive.

\[\text{Signature} \quad 2/21/87\]

Om P. Purti, Professor of Physics