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Review Article

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Lead Zirconate Titanate: A Piezo electric material

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ABSTRACT

Lead Zirconate Titanate [Pb $Zr_xTi_{1-x}]O_3$ ((0≤x≤1) - is an intermetallic inorganic piezoelectric material have been the subject of active research in recent years because of its remarkable applications in many field like micro-electromechanical (MEMS) and nano-electromechanical (NEMS) devices. PZT is a metallic oxide based piezoelectric material developed by scientists at the Tokyo Institute of Technology around 1952. In comparison to the previously discovered metallic oxide based piezoelectric material Barium Titanate (BaTiO3), PZT materials exhibit greater sensitivity and have a higher operating temperature. PZT based materials are components of ultrasound transducers and ceramic capactitors. Ceramics also exhibit certain extremely useful magnetic and electronic properties that provide for a very wide range of possible applications.

INTRODUCTION

PZT is also used in the manufacture of ceramic resonators for reference timing in electronic circuitry. In gas heaters, cooking stoves and cigarette lighters, piezo-electric ceramic devices produce sparks and share many common features with ferroelectric ceramics. Piezo-electric ceramics find their applications in quartz watches, medical instruments such as ultrasonic scanners, SONAR devices etc. Since piezoelectric materials develop a potential difference across its two faces during compression and changes in dimension when electric field is applied it has been used in sensor and actuator applications. PZT is also ferroelectric which means it has a spontaneous electric polarization can be reversed in the presence of an electric field. The dielectric constant of PZT can range from 300 to 3850, depending upon orientation and doping. Physical properties of the PZT ceramics depend on technology, especially on temperature and time of densification because during the densification process evaporation of lead can be observed, which causes disturbance in the initial chemical composition. In practice, PZT is rarely used in a pure chemical form. The dielectric, piezoelectric and pyroelectric properties of PZT can be modified by adding dopants [1,2]. Appropriate choice of a type and a quantity of dopant ions is important. PZT is generally available with either acceptor or donor doped form thus by creates hard PZT and soft PZT. Piezoelectric constants are proportional to the polarization or to the electrical field generated per unit of mechanical stress, or alternatively is the mechanical strain produced by per unit of electric field applied. In general, soft PZT has higher piezoelectric constant, but larger losses in the material due to internal friction. In hard PZT, domain wall motion is pinned by the impurities thereby lowering the losses in the material, but at the expense of a reduced piezoelectric constant. One of the commonly studied chemical composition is $PbZr_{0.52}Ti_{0.48}O_3$. The increased piezoelectric response and poling efficiency near to $x = 0.52$ is due to the increased number of allowable domain states at the MPB. At this boundary, the 6 possible domain states from the tetragonal phase <100> and the 8 possible domain states from the rhombohedral phase <111> are equally favorable energetically, thereby allowing a maximum 14 possible domain states. This review is focused on the Dielectric properties of piezo electric lead zirconate titanate.

Arun Chamola et al reported the structural, dielectric and electrical properties of Lead zirconate titanate and $CaCu_3Ti_4O_{12}$ ceramic composite. It is observed that there is a decrease in the dielectric constant with increase in CaCu3Ti4O12 percentage. The prepared ceramic composites have high dielectric constant and low dielectric loss. The temperature dependence of the ac conductivity indicated that the conduction process is due to singly ionized (in ferroelectric region) and doubly ionized (in para electric region). [3]

Suo Baia et al synthesized ultra-long and flexible single-crystalline lead zirconate titanate Pb(Zr0.52Ti0.48)O3 (PZT) nano/ micro-wires (N/MWs)were by hydrothermal method [4].

Many researchers have investigated the thickness effects on dielectric and leakage current properties of ferroelectric thin films for barium-strontium-titanate and lead-based titanates. The interfacial layer between electrode and ferroelectric bulk could cause the deterioration of the dielectric properties due to its low dielectric constant and high trap density. Thin films of erbium doped lead zirconate titanate (PZT) of different thickness were deposited by sol–gel technique on PtyTiO 2ySiO2ySi substrates. Capacitance–voltage measurements show that the dielectric constant continuously increases with the thickness. The leakage current properties also depend on thickness and temperature. It is observed that the calculated interfacial potential barrier height amounts to 0.81 and 0.74 eV, respectively for erbium doped and pure PZT thin films [5].

PZT thin films with Zr/Ti ratio of 52/48 deposited on to platinized silicon wafers using sol-gel techniques were studied. The thickness and crystallographic orientation dependence of the film properties are attributed to several factors. The most important factor is the residual stress in the film which depends on film thickness and processing conditions. Interfacial layers between the film and the electrodes may also contribute to the thickness effects [6]. The dependence of the dielectric and piezoelectric characteristics of the composite on the volume fraction of PZT has been established by Banerjee et al [7]. Addition of Al inclusions and increase of PZT volume fraction has enhanced the dielectric and piezoelectric properties.

Yimnirun et al [8] prepared PZT and PMN powders by a mixed-oxide method and studied the dielectric properties as a function of both temperature and frequency. The results indicate that the dielectric properties of the pure phase PZT and PMN follow that of normal and relaxor ferroelectric behaviors, respectively. The dielectric behaviors of the 0.9PZT - 0.1PMN and 0.7PZT - 0.3PMN ceramics are more those of normal ferroelectrics, while the other compositions are obviously those of relaxor ferroelectrics. It is also observed that the transition temperature decreases and the maximum dielectric constant increases with increasing amount of PMN in the system. Most importantly, this study shows that the dielectric properties of the PZT-PMN ceramics are not linearly dependent of the amount of the end members over the whole compositional range of PZT-PMN as a result of the composite nature of the materials. These results clearly show the significance of PMN in controlling the dielectric behavior of the PZT-PMN system. The development of new endoscopic applications of ultrasound imaging is critically dependent on the availability of efficient broadband transducers with areas of 2 mm^2 or less. The material properties of PZT ceramics for operation in the thickness mode at frequencies >80 MHz are reported [9]. Each of the ceramics tested showed a reduction in k, with increasing frequency. In a fine grained PZT, values of k, as high as 0.44 were measured at 80 MHz. The effects of grain size were also evident in the measurement of frequency dependent mechanical losses. Experimental and theoretical analysis of I mm2 45-kIHz PZT transducer verified the validity of the properties measurements and demonstrated excellent insertion loss and bandwidth characteristics. The minimum insertion loss of -17.5 dB is in good agreement with theory and is a marked improvement over the performance of polymer devices. Details on the fabrication and testing of high frequency ceramic transducers are described. The results suggest that ceramic transducers may offer improved performance over polymer devices in the 25-80 MHz range, particularly when the area of the device is small (< 2 mm’). The results of the materials properties of the three test ceramics indicated that these materials were well suited for use in high frequency transducers.

Graphene oxide is a highly orderly compound has piezoelectric responses and investigated by Zhenyue Chang et al. via first-principles density functional calculations [10]. Graphene oxide found its potential applications in actuation material for designing. Due to the excellent piezoelectric properties, the robust molecular structures, and an atomic thickness, GO crystals are promising two-dimensional piezoelectric materials for MEMS/NEMS actuators and sensors. Recently, Ong et al. 11] used density functional theory (DFT) calculations to study the piezoelectric properties of graphene-based materials. It is well known that the piezoelectric effect only exists in crystalline materials with no inversion symmetry. Pengtao Xu et al studied the structural and electronic properties of graphene-

ZnO interfaces. The computations provide a theoretical explanation for the good performance of graphene/ZnO hybrid materials in photo catalysts and solar cells [12].

CONCLUSION

PZT ceramics, in spite of their relatively large grain size (up to 10 pm) are well adapted to ultrasound transducer applications at frequencies as high as 80 MHz. Their high dielectric and coupling constants provide a significant advantage over other materials in the fabrication of miniature devices. PZT is currently the primary material used in naval sonar devices, and it has also been investigated for possible use in FRAM memory modules. The ferroelectric, dielectric and piezoelectric properties of a dense and crack-free lead zirconate titanate ($Pb(Zr_{0.52}Ti_{0.48})O_3$, PZT) thick film containing micro- and nano-crystalline particles results show that these electrical properties are dependent strongly on the annealing temperature and film thickness. The dielectric results show that relative dielectric constant achieves the largest value at annealing temperature of 700°C, and increases with the increasing film thickness. Therefore, the PZT thick films present good electric properties and enlarged potential in MEMS applications.

REFERENCES

[1] R. Z a c h a r i a s z, D. B o c h e n e k, *Archives of Metallurgy and Materials* 54, 895 (**2009**).
[2] E. Nogas-Cwikel, *Archives of metallurgy and materials*, 56, **2011**, 1065-1069.
[3] Arun Chamola, Hemant Singh, U.C. Naithani, Shubhash Sharma, Uday Prabhat, Pratiksha Devi, Anuradha Malik, Alok Srivastava, R.K. Sharma, *Adv. Mat. Lett*. **2011**, 2(1), 26-31]
[4] Suo Bai, QiXu, LongGu, FeiMa, YongQina, ZhongLinWang, Single crystalline lead zirconate titanate (PZT) nano/micro-wire based self-powered UV sensor, http://dx.doi.org/10.1016/j.nanoen.2012.09.001]
[5] M. Es-Souni, N. Zhang, S. Iakovlev, C.-H. Solterbeck, A. Piorra, *Thin Solid Films* 440 (**2003**) 26–34.
[6] L. Lian and N. R. Sottos, *Journal of Applied Physics*, 87 (8) **2000**, 3941-3949.
[7] S. Banerjee, K. A. Cook-Chennault, *Journal of Engineering Materials and Technology*, Vol. 133 / 041016-11.
[8] Yimnirun, R., Ananta, S. and Laoratakul, P. *J. Sci. Technol*., **2004**, 26(4) : 529-536
[9] Characterization of Lead Zirconate Titanate Ceramics for Use in Miniature High-Frequency (20-80 MHz) Transducers , F. Stuart Foster, Member, IEEE, Linda K. Ryan and Daniel H. Turnbull, **1991**.
[10] Piezoelectric properties of graphene oxide: A first-principles computational study Zhenyue Chang, Wenyi Yan, Jin Shang, and Jefferson Zhe Liu, *Applied Physics Letters*, 105, 023103 (**2014**)
[11] Ong, M. T. & Reed, E. J. *ACS Nano* 6, 1387–1394 (**2012**).
[12] Pengtau Zu, Qing Tang, Zhen Zhou, *Nano Technology* **2013** , 305401-305407.