Composites of 'Ferroelectric Ceramics' and Polymers - a Potential Source of Non-Volatile Memory

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Abstract— *The term memory in context of 'Computer' is usually taken as random access memory (RAM). Static RAM (SRAM) and Dynamic RAM (DRAM) are its two main forms and both are considered volatile, as their state is lost or reset when power is removed from the system. Non-volatile memory is the computer memory that can retain the stored information even when power is switched off. Flash memory is the best-known form of NVRAM memory today, which uses NAND and NOR logic gates but it has the drawback of high power requirement which places another drawback making it slow in operation as high power requires more time to attain its high level. The system with very low power consumption and faster in operation is given by Ferroelectric-RAM. 'Ferroelectric-Ceramic'-polymer composites which are considered as potential source of Non-Volatile memory are discussed in this paper.*

Keywords— *Polarization, Dielectrics, Ferroelectrics, Polymers, composites,* ***Memory, Switching time, Volatile and non-Volatile memory,*** *Fe-RAM,*

I. Introduction

The positive and negative charge in atomic or molecular entities constituting the dielectric materials form a bound system when seen in the presence of an external electric field. These charge centres of constituting entities separate out (but less than the atomic diameter) in the presence of external electric field and thus every individual entity start behaving like an electric dipole giving a net dipole moment to the dielectric medium. The dipole moment represents a state of polarization which may or may not be retained by the entities when applied electric field is withdrawn. It is this state of polarization that is used to store digital information. As the digital information is stored in binary system so the material entities must have two polarization states and, further, system must be capable of switching from one state to another. To keep the stored information intact in the absence of applied field the material must have the characteristic of spontaneous polarization i.e. a polarization acquired/retained by the material even in the absence of electric field. This type of behaviour is manifested by a class of dielectric materials known as ferroelectric materials and the system of memory provided by these materials is of Non-volatile type. As ferroelectric materials by their nature are spontaneously polarised and all the dipoles could be aligned to attain one saturated state of polarization (say binary state 1) with application of electric field and the material can be brought in symmetrically opposite saturated state of polarization (say binary state 0) by application of reverse field. These types of materials have become a scope for non-volatile memories. The further research in this area could further lower the switching time between the two states of polarizations thus giving more speed to the data processing.

II. Why Composites of 'Ferroelectric Ceramics' and Polymers are Preferred?

. Ferroelectric materials are characterised by spontaneous polarization and the factor which makes them peculiar suitable for memory devices is that their polarization state can be reversed by the application of external field in the direction opposite to previously applied field which had brought the material in initial polarization state. This characterises the material with two states of polarizations out of which one can be used to store binary digit 1 and the second to store binary digit 0. In simple way, the attainment of initial polarization state can be regarded equivalent as storage of binary digit 1 and reversal of polarization state is regarded equivalent as storage of binary digit 0 or vice-versa. Likewise the stored information could be recalled back by bringing the material in the required state of polarization, of course, with the application of suitable external field which is measured in terms of coercive field. This discussion is sufficient to convince ourselves how ferroelectric materials have a scope in memory devices as in these types of materials

-every unit cell has a permanent dipole

-each dipole will couple with others to form groups called domains, and

-the domains can be forced to switch directions.

Making a gross simplification, the cumulative direction of all of the dipoles in a ferroelectric material defines its total memory.

But the microelectronic devices need low voltage operation where the traditional ferroelectrics like PZT, $(NH_2CH_2COOH)_3H_2SO_4$, BST, LiTaO3, BaTiO3, NaNbO3, KNO3 etc have high coercive field and high density on one side and they are brittle on the other side making them unsuitable in the form of thin film.

Pure polymers (ferroelectric) have limited applications due to their low polarization value although due to their flexibility, low density they provide the ease in processing them in a desired shape.

By considering the limitations of traditional ferroelectrics and that of pure polymers, the composite of the two known as ferroelectric-polymer composites have emerged as a new class of materials and are being widely investigated all over.

As these composites can be fabricated in the form of thin films it has paved the way work with low operating voltage as high coercive field over the specimen can be generated with comparatively low operating voltage.

III. Ferroelectric Loop and Non-Volatile Memory

The characteristic ferroelectric loop also known as hysteresis loop of a ferroelectric specimen is shown as loop ABCDEFA in fig1. It is the loop traced by measurement of polarization state of the specimen as a function of applied electric field. The points A and D are the mutually opposite saturated states of polarizations of the specimen attained by the specimen with application of electric field E_+ and E_- respectively. The points B and E are other important points clearly showing that once polarised, the specimen retains polarization $P_r(+)$ or $P_r(-)$ even in the absence of applied electric field as can be seen the field value corresponding to these two points.

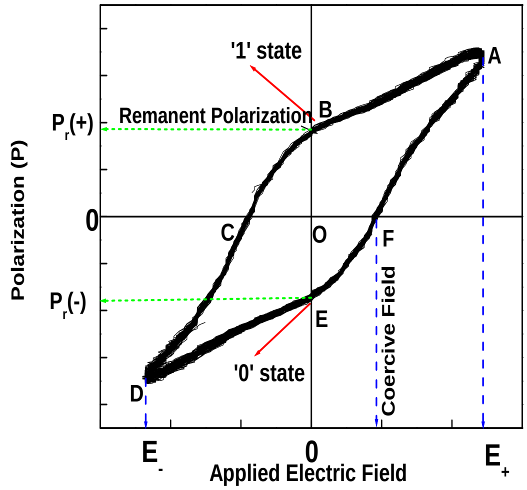

Fig1: Labelled Ferroelectric Loop

From non-volatility point of view, the points B and E referring to states '1' and '0' are very significant. It is these states of the ferroelectric specimen which attributes it the characteristic of non-volatility means the stored information would not be lost even if the electric power is switched off. The corresponding states act as a storage location of digital information in the binary system as earlier said that the attainment of initial polarization state can be regarded equivalent as storing binary digit 1 and reversal of polarization state is regarded equivalent as storing binary digit 0 or vice-versa.

The points C and F refer to the coercive field with which the specimen may be depolarized i.e. it is made to loose the stored information. The required high coercive field relatively at low operating voltage can be made feasible by reducing the thickness of the ferroelectric specimens which can be done by fabricating flexible thin ferroelectric films. This goal is realised in the form of composites prepared by embedding otherwise brittle and high density ceramic like ferroelectric materials into the matrix provided by flexible, low density polymers. In this way ferroelectric-polymer composite films become viable for the microelectronic industry to form ferroelectric capacitors to be used in the memory cells as a source of non-volatile memory store house.

IV. Reported Research Work in This Area

To investigate the various properties and to improve their behaviour as ferroelectric various researchers have reported their work on different Ferroelectric-Polymer composites in different conditions and adopting different techniques for fabrication. Some of such studies are referred here.

In the composite films containing equal proportion by weight of KNO3:PVA system studied by Hundal J.S, Dabra N. et.al, and reported improvement of remnant polarization [1]. The nanocomposites consisting of the PVA matrix, reinforced with the fabricated Fe_2O_3 nanoparticles were fabricated and effects of nanoparticles on the PVA, both on the nanoparticles surface and on the bulk polymer, were investigated. In the study Physico-chemical property changes were observed with PVA attached to the nanoparticles surface where the nanoparticles were found not only to increase the PVA cross-linking with an increase in melting temperature but also enhanced the thermal stability of the PVA [2]. The switching properties of spray deposited CsNO3: PVA composite films were found to have improved as compared to the pure CsNO3 [3]. Structural, optical, and magnetic properties of (Co, Cu) co-doped $Zn_{0.99-x}Co_xCu_{0.01}O$ films ($0<x<0.20$) synthesized by a sol-gel method were investigated. The surface uniformity and crystal quality of the films reported to have improved by introducing a moderate concentration of Co ions [4].The effect of thermal treatment influences the properties of the material to a great extent. In the studies related with the influence of annealing time on structural and electrical properties of Sb doped SnO2 films it has been reported that the size of the grains varies with annealing temperature [5].The change in dielectric properties has been reported to be due to major changes in the microstructure of the barium strontium titanate powders during the heat treatments, that led to increase of the grain size, as well as the reduction of the porosity [6]. In the studies related to dependence upon annealing parameters of crystallinity and surface morphology of RF sputtered zinc oxide nano films it is reported that the structure and morphology of RF sputtered zinc oxide nano films were dependent on temperature, gas flow rate and time of annealing [7]. Sekher et al studied the ferroelectric and switching properties of $NaNO_2$: PVA composites prepared by 'spray deposited technique' on brass substrate at different temperatures [8]. Thus a lot of research work is being carried on in this field all over.

V. Conclusions

A lot of research work in this field speaks volumes of importance of research in the field of composites of 'ferroelectric ceramics' and polymers. The non-volatile Fe-RAM involves low operating voltage; further new fabricating techniques should be worked upon so that operating voltage could be further lowered as this factor would make the system faster to more extent. To enhance the 'storage density' further, the particle size of the specimen could be reduced as each particle acts as an independent dipole capable of storing two bits '1' and '0'. So, it is another area of research. The kind of matrix provided by a given polymer might have bearing on the particle size of the filler i.e. ceramic like ferroelectric material.

Thus, the composites of 'ferroelectric ceramics' and polymers a potential source of Non-Volatile memory store house on the one hand and simultaneously have the potential to enhance the 'storage density' further by making devices miniature to next extent.

Acknowledgment

The authors acknowledge the Department of Applied Physics GZS-PTU Campus Bathinda for the facilities provided in its Research Lab to carry on the research work. The corresponding author acknowledge his parent organization Punjabi University Patiala for permission to proceed on study leave for PhD research work, Punjab Technical University Kapurthala-Jalandhar Highway Kapurthala for providing an institutional research platform for accomplishing PhD degree for professional growth.

REFERENCES

1. Navneet Dabra, Jasbir S. Hundal, Ferroelectric Phase Stability Studies in Spray Deposited KNO3: PVA Composite Films, J. Am. Ceram. Soc., 92 [4] 834–838 (2009).
2. Zhanhu Guo • Di Zhang • Suying Wei et al, J Nanopart Effects of iron oxide nanoparticles on polyvinyl alcohol: interfacial layer and bulk nanocomposites thin film Res (2010) 12:2415–2426, Springer Science+Business Media B.V. 2009
3. Arvind Nautiyal ·K.C. Sekhar · N.P. Pathak ·Navneet Dabra · Jasbir S. Hundal · R. Nath;' Polarization switching properties of spray deposited CsNO3:PVA composite films', © Springer-Verlag 2010 Appl Phys A,(DOI 10.1007/s00339-010-5699-8)
4. M. Xu, 1,a) H. Yuan,1,b) B. You,2 P. F. Zhou,1 C. J. Dong,1 and M. Y. Duan3 Structural, optical, and magnetic properties of (Co, Cu)-co doped ZnO films with different Co concentrations' Journal Of Applied Physics 115, 093503 (2014)

5. M. Hemissi 1, H. Amardjia - Adnani 1* , J.C. Plenet 2, B. Canut 2 and J.M. Pelletier 3'Influence of annealing time on structural and electrical properties of Sb doped SnO2 films'Revue des Energies Renouvelables Vol. 10 N°2 (2007) 273 – 279

6. Gabriel Caruntu,* Randy Rarig Jr, Ioan Dumitru and Charles J. O'Connor 'Annealing effects on the crystallite size and dielectric properties of ultrafine $Ba_{1-x}Sr_xTiO_3$ (0<x<1) powders synthesized through an oxalate-complex precursor' Department of Chemistry, Chemistry Faculty Publications University of New Orleans; 2-1-2006ScholarWorks@UNO

7. J. Karamdel, C.F. Dee* & B. Yeop Majlis 'Effects of Annealing Conditions on the Surface Morphology and Crystallinity of Sputtered ZnO Nano Films' . Sains Malaysiana 40(3)(2011): 209–213

8. K. C. Sekhar, A. Nautiyal and R. Nath "Structural and Ferroelectric Properties of Spray Deposited Sodium Nitrite: Poly(vinyl alcohol) Composite Films", J.Appl. Phys., Vol. 105, pp. 024109(1) – (5) (2009).