We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,300

Open access books available

172,000

International authors and editors

190M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Introductory Chapter: Ferroelectrics Material and Their Applications

Irzaman Husein and Renan Prasta Jenie

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/intechopen.80643>

1. Ferroelectrics material

Ferroelectricity is a symptom of inevitable electrical polarisation changes in materials without external electric field interference. Ferroelectricity is a phenomenon exhibited by crystals with a spontaneous polarisation and hysteresis effects associated with dielectric changes when an electric field is given. Our fascination with ferroelectricity is thanks to a beautiful article by Itskovsky, in which he explains about kinetics of a ferroelectric phase transition in thin ferroelectric layer (film) [1]. We have been researching about ferroelectrics materials since 2001 [2, 3].

There are several materials known for its ferroelectric properties. Barium titanate and barium strontium titanate are the most well known [2–4]. Several others include tantalum oxide, lead zirconium titanate, gallium nitride, lithium tantalate, aluminium, copper oxide and lithium niobate [5–14].

Researchers often introduce dopant to enhance material's ferroelectric characteristics. Lanthanum is one of the most well-known materials to be used as dopant [10, 13, 15–18]. Ferric oxide is also most often used as dopant [8, 19–21]. Other dopants include gallium oxide, tantalum oxide, niobium oxide and manganese [9, 14, 19, 22–24]. Furthermore, we are currently trying to enhance the ferroelectric effects using photonic crystals [25].

When researchers are growing ferroelectric thin films, they have used various concentrations, starting from 0.25 to 2.5 mole [7, 23, 25–28]. Researchers applied the chemical solutions of various substrates: the most often is p-type silicone [3, 11]. n-Type silicone, transparent conductive oxide substrate and corning glass are also known to be used as ferroelectric substrates [2, 24–26]. We ourselves have prepared our ferroelectric materials mostly using chemical solution deposition methods and coupled with spin-coating methods, usually for 30 s, with rotational speed of 2000–8000 rpm [3, 4, 6, 7, 11, 18, 19, 23, 27, 29]. Other preparation methods researchers have

used include pulsed laser ablation deposition (PLAD), DC magnetron unbalanced magnetron sputtering (DC UBMS), solid solution methods, plasma-assisted metal-organic chemical vapour deposition (PAMOCVD) and sol-gel method [2, 9, 14, 27, 30, 31].

Researchers usually anneal or heat the ferroelectric samples in furnace. We have tried low temperature in rich oxygen chamber, at 200–280°C [23]. We mostly anneal our ferroelectric samples in atmospheric chamber, at various temperatures from 350 to 950°C [5, 20, 24, 28, 32, 33]. We also have varied the holding duration from 1 to 29 h [3, 7–9, 11, 17, 18, 20, 27, 29, 30, 34, 35]. The resultant ferroelectric crystal shape is either hexagonal, tetragonal, or orthorhombic [6, 9, 12, 13, 36].

To learn more about the nature of our ferroelectrics, researchers have utilised several characterisation devices. They usually start with IV meter or current-voltage photovoltaic measurement and LCR meter [3, 27, 33, 37]. They are also heavily utilising spectrophotometric devices, in an ultraviolet to visible range, visible to near-infrared range and Fourier transformed infrared (FTIR) spectrophotometry [2, 4, 10, 15, 18, 37]. To assess deep inside the ferroelectric crystal structure, researchers have utilised particle size analyser, scanning electron microscopy, atomic force microscopy, dispersive energy X-ray and X-ray diffraction device (XRD) [3, 10, 14, 16, 23]. We are currently working on an implementation of ARIMA methods to enhance FTIR and XRD results [15, 16].

With those measurement devices, researchers could observe the ferroelectric electrical characteristics such as voltage responsivity, electrical insulation/conductivity, energy gap, ellipsometric measurement, value range, accuracy level, sensitivity, hysteresis, dielectric constant, time constant and dielectric loss [2, 3, 6, 7, 10, 11, 18, 20, 36]. The researchers have also measure physical characteristics such as gravimetric calculation, depth measurement, resolution, surface roughness, structural properties and functional groups [4, 10, 23, 36]. Other than those parameters, researchers also have measured spectral and applied characteristics such as refractive index, photonic absorption, pyroelectric characteristics and solar cell efficiency [6, 9, 17, 25, 27, 30, 35].

2. Ferroelectrics material and their applications

Researchers have been developing various forms of sensors with various working principles. The sensor is a simple device, which can measure how much and produce some form of the output of mechanical, electrical and optical output. Today, developmental sensors use computing, communications and connectivity to the web, mobile smart devices and integration clouds added to the sensor capabilities [38]. The development of censorship in the healthcare world was initially widely used in hospitals, but now censorship is widely used by many patients both in public places, individual homes that support their health management. Clarke and Lyons first developed the concept of biosensing in 1962. The concept of glucose biosensor was successfully commercialised in 1975 by the instrument companies Yellow Springs and the American National Standards Institute. Currently, medical industries are massively developing the biosensor as a tool for AIDS testing and home pregnancy, allergy detection. Besides, biosensors are now widely developed for environmental applications such as detection of bacteria, pesticides and heavy metals in water samples [39]. The next sensor development is a MEMS-based sensor. This sensor has a small size accurate, and industries can integrate this sensor into the device ranging from sports hours, electronics, to cars. The U.S Government initiated an accelerated

program in the development of MEMS-based sensors in 1990. The technique used was the manufacture of semiconductors, accelerometers (ADXL50) was the first sensor to be sold commercially in 1992 [40]. Currently, the evolution of sensors is strongly influenced by ICT technology, with integration with the microcontroller, wireless communications module and data storage permanently. Industries have supported this technology by the development of sensor systems with a standard architecture. Computing, storage and communication features are used to present multiple sensors with connectivity. The development of the next sensor leads to the sensor connection process to the smartphone or tablet, or connection with the web or cloud storage [40]. So far, we have implemented our ferroelectric technology as automatic switch sensor, infrared sensor, light sensor and temperature sensor, as well as solar or photovoltaic cells, which made for IPB satellite design [5, 7, 11, 18, 19, 27, 32, 36]. There is still a blue ocean of ferroelectric applications yet to be elaborated. It is and hopefully always a bright future.

Acknowledgements

This work is supported by Higher Education Basic Research of Directorate General of Higher Education, Ministry of National Education, The Republic of Indonesia, contract no. 1751/IT3.11/PN/2018 and Postgraduate Research Team of Directorate General of Higher Education, Ministry of National Education, The Republic of Indonesia, contract no. 1548/IT3.11/PN/2018

Author details

Irzaman Husein^{1*} and Renan Prasta Jenie²

*Address all correspondence to: irzaman@apps.ipb.ac.id

1 Department of Physics, Faculty of Mathematics and Science, Bogor Agricultural University, Bogor, Indonesia

2 Department of Community Nutrition and Physics, Faculty of Human Ecology, Mathematics, and Science, Bogor Agricultural University, Bogor, Indonesia

References

- [1] Itskovsky MA. Kinetics of ferroelectric phase transition: Nonlinear pyroelectric effect and ferroelectric solar cell. *Japanese Journal of Applied Physics*. 1999;**38**(8):4812-4817
- [2] Irzaman, Fuad A, Barmawi M. Spectral response of Al/Si photodiodes for IR sensor. In: *Proceeding Instrumentation, Measurement, and Communications for the Future*, Bandung, Indonesia: Indonesian German Conference (IGC); 2001. pp. 340-342
- [3] Irzaman, Sudiana Y, Hikam M, Loeksmanto W, Barmawi M. Analisis struktur kristal dan full width half maximum (Fwhm) dengan metode rietveld (Studi Kasus: Kalsit (CaCO_3)). *Jurnal Kontribusi Fisika Indonesia*. Indonesia: ITB Bandung. 2000;**11**(2):41-48

- [4] Mulyadi, Rika W, Sulidah, Irzaman, Hardhienata H. Barium strontium titanate thin film growth with rotational speed variation as a satellite temperature sensor prototype. IOP Conference Series: Earth and Environmental Science. 2017;**54**:012094
- [5] Dahrul M, Alatas H, Irzaman. Preparation and optical properties study of CuO thin film as applied solar cell on LAPAN-IPB satellite. Procedia Environmental Sciences. 2016;**33**:661-667
- [6] Darmasetiawan H, Irzaman, Nur Indro M, Sukaryo S, Hikam M, Peng Bo N. Optical properties of crystalline Ta₂O₅ thin films. Physica Status Solidi A: Applications and Materials Science. 2002;**193**(1):53-60
- [7] Hikam M, Irzaman, Darmasetiawan H, Arifin P, Budiman M, Barmawi M. Pyroelectric properties of lead zirconium titanate (PbZr_{0.525}Ti_{0.475}O₃) metal ferroelectric-metal capacitor and its application for IR sensor. Indonesian Journal of Materials Science. 2005;**6**(3):6
- [8] Indro MN, Irzaman, Sastri B, Nady L, Syafutra H, Siswadi. Electric and pyroelectric properties of LiTaO₃ and LiFe₂TaO₃ films. Materials Science and Technology. 2010;**6**:19-22
- [9] Irzaman, Darvina Y, Fuad A, Arifin P, Budiman M, Barmawi M. Physical and pyroelectric properties of tantalum-oxide-doped lead zirconium titanate [Pb_{0.9950}(Zr_{0.525}Ti_{0.465}Ta_{0.010})O₃] thin films and their application for IR sensors. Physica Status Solidi A: Applications and Materials Science. 2003;**199**(3):416-424
- [10] Irzaman, Hardhienata H, Maddu A, Aminullah, Alatas H. The Effects of Lanthanum Dopant on the Structural and Optical Properties of Ferroelectric Thin Films. In: Orjuela JEA, editor. Rare Earth Element [Internet]. InTech; 2017 [cited 2018 Jul 4]. Available from: <http://www.intechopen.com/books/rare-earth-element/the-effects-of-lanthanum-dopant-on-the-structural-and-optical-properties-of-ferroelectric-thin-films>
- [11] Irzaman, Siskandar R, Nabilah N, Aminullah, Yuliarto B, Hamam KA, Husin A. Application of lithium tantalate (LiTaO₃) films as light sensor to monitor the light status in the Arduino Uno based energy-saving automatic light prototype and passive infrared sensor. Ferroelectrics. 2018;**524**(1):44-55
- [12] Irzaman, Erviansyah R, Syafutra H, Maddu A, dan Siswadi. Studi konduktivitas listrik film tipis Ba_{0.25}Sr_{0.75}TiO₃ yang dididat ferium oksida (BFST) menggunakan metode chemical solution deposition. Berkala Fisika. Indonesia: Universitas Diponegoro. 2010;**13**(1):33-38
- [13] Irzaman, Sitompul H, Masitoh, Misbakhushshudur M, Mursyidah. Optical and structural properties of lanthanum doped lithium niobate thin films. Ferroelectrics. 2016;**502**(1):9-18
- [14] Mulyanti B, Subagio A, Arsyad FS, Arifin P, Barmawi M, Irzaman, Jusoh SN, Taking S, Jamal Z, Idris MA. Effect of growth temperature and Mn incorporation on GaN: Mn thin films grown by plasma-assisted MOCVD. ITB Journal of Science. 2008;**40**(2):97-108
- [15] Aidi MN, Irzaman H. Classification Detection of FTIR and XRD Spectrum on Thin Film of Lithium Tantalate with ARIMA Model on High Level Accuracy [Internet]. Unpublished; 2018 [cited 2018 Jul 4]. Available from: <http://rgdoi.net/10.13140/RG.2.2.24872.06403>

- [16] Aidi MN, Irzaman H. Arima analysis for detecting FTIR and XRD spectral pattern on barium strontium titanate (BST) thin film [Internet]. Unpublished; 2018 [cited 2018 Jul 4]. Available from: <http://rgdoi.net/10.13140/RG.2.2.18161.17768>
- [17] Irzaman, Pebriyanto Y, Apipah ER, Noor I, Alkadri A. Characterization of optical and structural of lanthanum doped LiTaO_3 thin films. *Integrated Ferroelectrics*. 2015;**167**(1):137-145
- [18] Mulyadi, Wahyuni R, Hardhienata H, Irzaman. Barium strontium titanate thin film growth with variation of lanthanum dopant compatibility as sensor prototype in the satellite technology. *IOP Conference Series: Earth and Environmental Science*. 2018;**149**:012069
- [19] Dahrul M, Syafutra H, Arif A, Irzaman, Indro MN, Siswadi. Manufactures and characterizations of photodiode thin film barium strontium titanate (BST) doped by niobium and iron as light sensor. In: *The 4th Asian Physics Symposium—An International Symposium*. AIP Publishing; 2010. pp. 43-46
- [20] Irzaman, Heriyanto S, Darmasetiawan H, Hardhienata H, Erviansyah R, Huriawati F, Akhiruddin MH, Arifin P. Electrical properties of photodiode BST thin film doped with ferrum oxide using chemical deposition solution method. *Atom Indonesia*. 2011;**37**(3):133-138
- [21] Novianty I, Yani S, Chahyani R, Athiyah Z, Casnan, Fendi, Serah S, Hartono J, Rofiah N, Syahfutra H, Akhiruddin, Irzaman. Electrical properties Fe_2O_3 doped based $\text{Ba}_{0.5}\text{Sr}_{0.5}\text{TiO}_3$ thin film as light sensor. *Indonesian Journal of Materials Science: Special Edition on Materials for Sensor*. 2011. p. 9-12
- [22] Estrada R, Djohan N, Pasole D, Dahrul M, Kurniawan A, Iskandar J, Hardhienata H, Irzaman. The optical band gap of LiTaO_3 and Nb_2O_5 -doped LiTaO_3 thin films based on Tauc plot method to be applied on satellite. *IOP Conference Series: Earth and Environmental Science*. 2017;**54**:012092
- [23] Irzaman, Darmasetiawan H, Hardhienata H, Hikam M, Arifin P, Jusoh SN, Taking S, Jamal Z, Idris MA. Surface Roughness and Grain Size Characterization of Annealing Temperature Effect For Growth Gallium and Tantalum Doped $\text{Ba}_{0.5}\text{Sr}_{0.5}\text{TiO}_3$ Thin Film. *Atom Indonesia*. 2009;**35**(1):57-67
- [24] Setiawan A, Aminullah, Juansah J, Irzaman. Optical and electrical characterizations of niobium-doped $\text{Ba}_{0.25}\text{Sr}_{0.75}\text{TiO}_3$ (BSNT) on p-type silicon and corning glass substrates and its implementation as photodiode on satellite of LAPAN-IPB. *Procedia Environmental Sciences*. 2016;**33**:620-625
- [25] Nuayi AW, Alatas H, Husein IS, Rahmat M. Enhancement of photon absorption on $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$ thin-film semiconductor using photonic crystal. *International Journal of Optoelectronics*. 2014;**2014**:1-8
- [26] Djohan N, Estrada R, Sari D, Dahrul M, Kurniawan A, Iskandar J, Hardhienata H, Irzaman. The effect of annealing temperature variation on the optical properties test of LiTaO_3 thin films based on Tauc plot method for satellite technology. *IOP Conference Series: Earth and Environmental Science*. 2017;**54**:012093

- [27] Irzaman, Putra IR, Aminullah, Syafutra H, Alatas H. Development of ferroelectric solar cells of barium strontium titanate ($\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$) for substituting conventional battery in LAPAN-IPB satellite (LISAT). *Procedia Environmental Sciences*. 2016;**33**:607-614
- [28] Ismangil A, Irmansyah, Irzaman. The diffusion coefficient of lithium tantalite (LiTaO_3) with temperature variations on LAPAN-IPB satellite infra-red sensor. *Procedia Environmental Sciences*. 2016;**33**:668-673
- [29] Yogaraksa T, Hikam M, Irzaman. Rietveld analysis of ferroelectric $\text{PbZr}_{0.525}\text{Ti}_{0.475}\text{O}_3$ thin films. *Ceramics International*. 2004;**30**(7):1483-1485
- [30] Irzaman, Syafutra H, Arif A, Alatas H, Hilaluddin MN, Kurniawan A, Iskandar J, Dahrul M, Ismangil A, Yosman D, Aminullah LB, Prasetyo LB, Yusuf A, Kadri TM. Formation of solar cells based on $\text{Ba}_{0.5}\text{Sr}_{0.5}\text{TiO}_3$ (BST) Ferroelectric Thick Film; 2014. AIP Conference Proceedings. 2014;**1586**:24-34
- [31] Jamal Z, Idris MS, Irzaman, Barmawi M. Lattice constants analysis of $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$ ceramic for $x = 0.3; 0.5$ and 0.7 by visual basic program. *Journal of Nuclear and Related Technology*. 2007;**4**:7
- [32] Ismangil A, Jenie RP, Irmansyah, Irzaman. Development of lithium tantalate (LiTaO_3) for automatic switch on LAPAN-IPB satellite infra-red sensor. *Procedia Environmental Sciences*. 2015;**24**:329-334
- [33] Misbakhushshudur M, Ismangil A, Aminullah, Irmansyah, Irzaman. Phasor diagrams of thin film of LiTaO_3 as applied infrared sensors on satellite of LAPAN-IPB. *Procedia Environmental Sciences*. 2016;**33**:615-619
- [34] Iskandar J, Syafutra H, Juansah J, Irzaman. Characterizations of electrical and optical properties on ferroelectric photodiode of barium strontium titanate ($\text{Ba}_{0.5}\text{Sr}_{0.5}\text{TiO}_3$) films based on the annealing time differences and its development as light sensor on satellite technology. *Procedia Environmental Sciences*. 2015;**24**:324-328
- [35] Kurniawan A, Yosman D, Arif A, Juansah J, Irzaman. Development and application of $\text{Ba}_{0.5}\text{Sr}_{0.5}\text{TiO}_3$ (BST) thin film as temperature sensor for satellite technology. *Procedia Environmental Sciences*. 2015;**24**:335-339
- [36] Irzaman, Siskandar R, Aminullah, Irmansyah, Alatas H. Characterization of $\text{Ba}_{0.55}\text{Sr}_{0.45}\text{TiO}_3$ films as light and temperature sensors and its implementation on automatic drying system model. *Integrated Ferroelectrics*. 2016;**168**(1):130-150
- [37] Irzaman, Syafutra H, Rancasa E, Nuayi AW, Rahman TGN, Nuzulia NA, Supu I, Sugianto, Tumimomor F, Surianty, Muzikarno O, Masrur. The effect of Ba/Sr ratio on electrical and optical properties of $\text{Ba}_x\text{Sr}_{(1-x)}\text{TiO}_3$ ($x = 0.25; 0.35; 0.45; 0.55$) thin film semiconductor. *Ferroelectrics*. 2013;**445**(1):4-17
- [38] Fraden J. *Handbook of Modern Sensors: Physics, Designs, and Applications*. Singapore: Springer; 2010
- [39] McGrath MJ, Scanail CN. Sensing and sensor fundamentals. In: *Sensor Technologies*. Germany: Springer; 2013. pp. 15-50
- [40] Council NR. *Expanding the Vision of Sensor Materials*. Washington, DC: National Academies Press; 1995