Chapter 1

Introductory Chapter: Ferroelectrics Material and Their Applications

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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

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