Research Article

Field dependent study on formation of ferroelectric domain in KNbO3 single crystal

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Abstract: The study of ferroelectric domains is essential for understanding the orientation of electric dipoles. This orientation of electric dipole shows the defect and impurities formation in a ferroelectric single crystal. Domain study is important for studying formations of defects and movement of dipoles in Al-doped KNbO3 single crystal. The Al-doped KNbO3 ferroelectric Single-crystal prepared using flux methods; then it chemically etched using methyl alcohol and nitric acid as an etchant. The electric field of 50 V/cm, 60 V/cm, and 70 V/cm was applied to the doped crystal. The variations of domain structure after the applying electric field are observed using the Trinocular microscopy method

Keywords: Domain Impurities: KNbO3: Electric Field

1. Introduction

The ferroelectric material is a crucial part of the perovskite family of the materials [1]. These devices mainly include memory devices, sensors, electro-optics, and LASER. Simultaneously ferroelectric materials are also used in pyroelectric and piezoelectric devices. A lot of modification has been done on ferroelectric materials [2]. Various scientists worldwide and studies have done a broad review about its dielectric properties, hysteresis loop, and mainly domain research. Many ferroelectric materials are currently available for analysis; they mainly include $PbTiO_3$, $BaTiO_3$, and $PbZr/TiO_3$ materials and have undergone many modifications [3]. Among these, on KNbO3 [KN] materials, Korde and Patil et al. has done a lot of work in their lab. The different dopants in KN materials such as aluminum (Al) and ferrous (Fe) are used for doping. This doping combination changes the properties of these crystals [3–5].

KN Materials is a perovskite structure element. KN and $BaTiO_3$ have many similarities; both at room temperature in a single crystal shows orthorhombic phase [6]. As it has different doping adds, its structural properties change. KN single crystal has another important stuff in that it shows phase transition [7]. Phase transitions mean its phase changes at different temperatures, due to which the structure of KN changes, which is very important for practicing dielectric properties and study its hysteresis loop [4]. Formations of hysteresis loop are the main parameter to check the ferroelectric properties of materials. In KN well saturated rectangular hysteresis loop has formed the shape of hysteresis loop were changed by adding different dopant. Also, the parameter value of hysteresis loops such as spontaneous polarization, remnant polarization, and coercive were altered by dopant change [8].

Domain engineering is the main field of science that studies the orientations and formations of ferroelectric domains. The ferroelectric domains are a crucial part of ferroelectric to understand the various structural behavior defects and imperfections produced in the ferroelectric crystals[9]. This article studies the electric field's effects on the ferroelectric domains in various doped KN single crystals.

2. Experimental Studies

2.1. Crystal growth

The KN single crystal has been prepared using the flux method. Al and Fe doping was used while preparing the KN crystal. While preparing, the crystal K_2CO_3 and Nb_2O_5 powder were taken in the ratio of 1.2:1, and it was mixed. Afterward, this mixture was taken in the mortar and crushed for 5 to 6 hours and made into a fine powder. The same finely mixed powder Fe and Al are doped with suitable concentration. In the last, this doped composite powder is placed in a platinum crucible, and this platinum crucible is placed in a programmable furnace. This program runs continuously for eight days and comes with different steps: heating, cooling, soaking and reheating, recooling, and resoaking. In this way, this doped powder is heated up to its highest temperature of 1100°C, and finally, doped KN single crystal was prepared [10].

2.2. Methods of Microscopy

To study the domain properties of crystal; the most important instrument for the observations of domains is microscope. Different microscopes like atomic force microscopy (AFM), Scanning probe electron microscopy are used to practice the domain. Ingle et al. studied the domain in this laboratory using a metallurgy microscope, and he got exciting results of domain structure in pure KN single crystal. Recently, in this laboratory korde et al. used trinocular microscope to modify the domain properties of doped KN single crystal. The specifications of used trinocular microscope are Dewinter trinocular microscope with materials plus software [11].

3. Result and Discussions

The image shown in figure 1 is of the domain formation of an Al-doped KN single crystal. In this photograph, the surface drawn with red color is marked as **X**. In this surface, all the dipoles are moving in one direction by the movements of this dipole formed ferroelectric domains. The width of the created domains is less, and they are making an angle of 60° along the plane, so the domains formed are 60° [12]. The movement of this 60° domain in surface X marks using symbol **AB**. The surface mark as **Y** drawn in blue color in this surface shows that the width of the domains is more in size, the reason behind its larger width that many microdomains formed in the crystal surface is joined together results of this it increases the domain widths[13]. The domain orientations of this large width 60° domain are marked as symbols of **CD**. The schematic representations of formations of 60° domains are shown in figure 2. The surface area mark as P and Q dark spot appears; this dark spot supports appearances of microdomains or called it is impurity dipole[14].

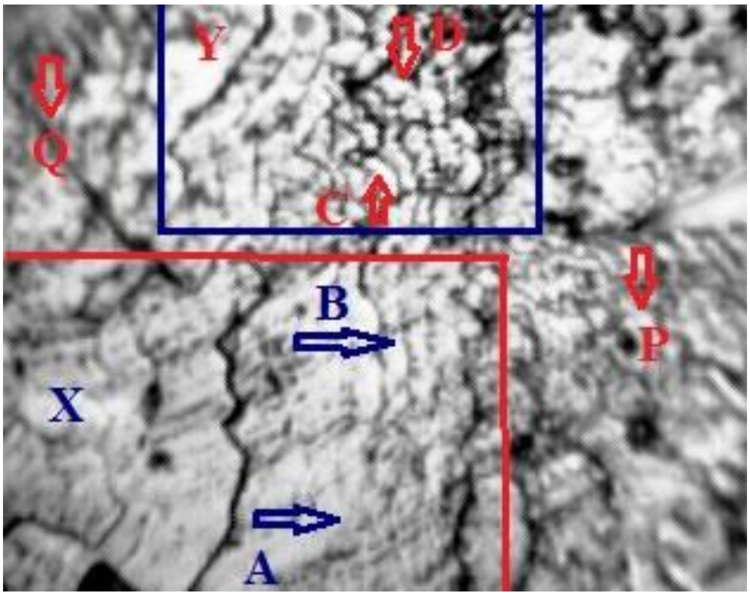


Figure 1. Microphotograph of formations of 60° domains

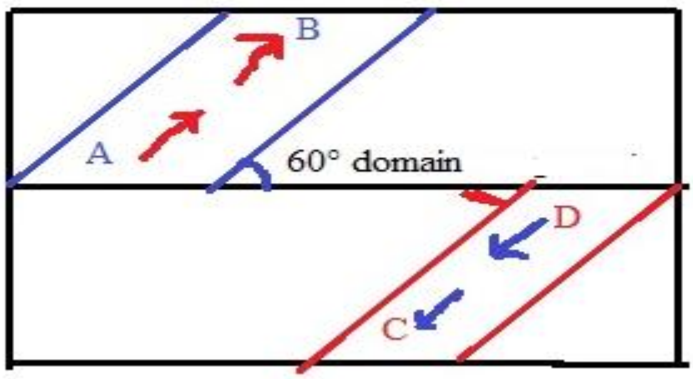
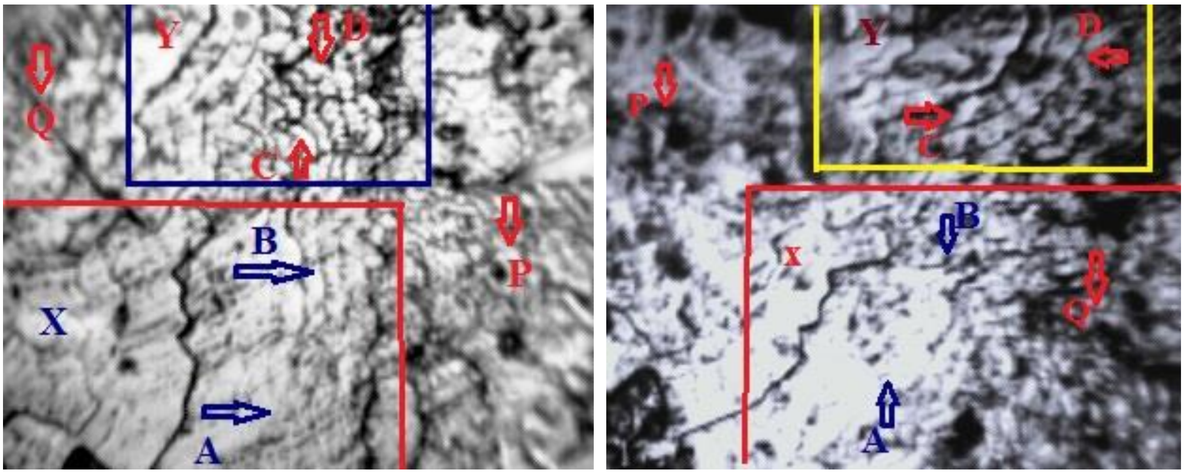


Figure 2. Schematic sketch explain orientations of 60° domain.

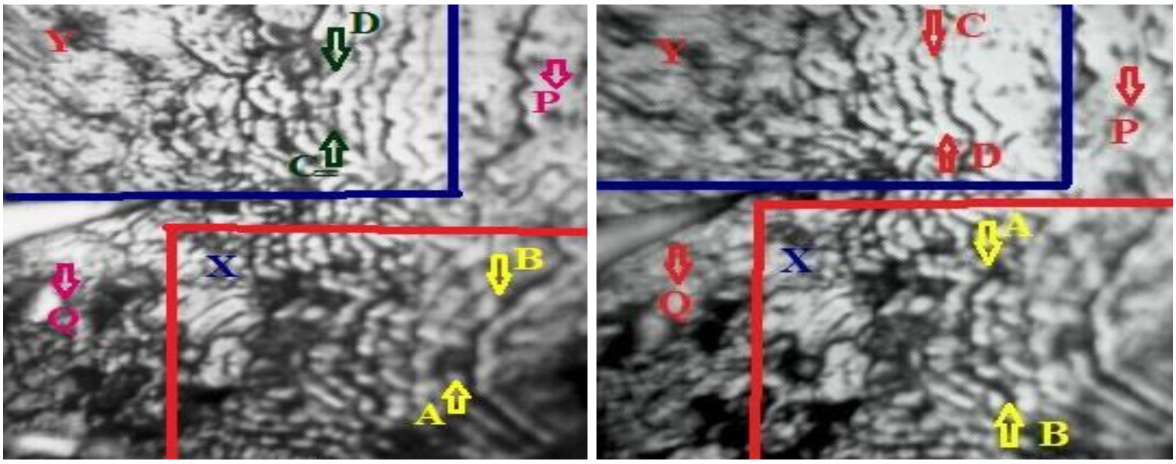
Figure 3 (a) shows the crystal surface without applying field (b) shows the crystal surface after using an electric field of 50 V/cm. After comparing both, it is found that after applying 50 V / cm electric field, some pressure comes on the surface of the crystal, due to which some dipole comes out of the surface and starts moving. Due to this movement, the surface, shown in the microphotograph of **X** and **Y**, the domains in that surface were seen more clearly. Also, the orientations of the domain **AB** and **CD** were changes after the electric field applied[15]. After closely observing this microphotograph, it is seen that using an electric field on the crystal increased the width of the domains. After applying electric fields on surfaces **P** and **Q,** blacker stains are seen, which shows that microdomains are available on the crystal's surface[16].



(a) Without field (b) With field 50 V/cm

Figure 3 :- Microphotograph of 60° domains orientation (a) without field (b) after applying electric field of 50 V/cm.

Figure 4 (a) shows the crystal surface applying field of 60 V/cm (b) shows the crystal surface after applying an electric field of 70 V/cm, after comparing the crystal surface of this microphotograph with the microphotographs of crystal surface without using an electric field and microphotograph of crystal surface using an electric field of 50 V / cm. It shows that applying more electric field brings more stress on the crystal, and due to that, there are deformations in it; due to these deformations, most of the domain wall which is their starts showing up [17]. In the microphotograph of figure 4 (a), the electric field is 60 V/ cm. Here the crystal surface, which is 60 degree domains on the surface of the electric field, is visible; that surface is labeled **X** and **Y[18]**. Together, the domain orientations of **AB** and **CD** also appear to be more explicit and practicable. The same pattern follows even after applying 70 V / cm electric field. Increasing the electric field increases the stress on the surface and increases the domains' width, which is evident in figure 4 (b).



(a) With 60 V/cm electric field (b) with 70 V/cm electric field

Figure 4:- Microphotograph of 60° domains orientations applying electric field of (a) 60 V/cm (b) 70 V/cm.

4. Conclusions

The doped KN single crystal prepared by the flux method, the crystal's ferroelectric property was checked. Because of the suitable ferroelectric property of the crystal, an exciting result in domain property was obtained. The domain study found that 60 degrees of domains are visible before applying an electric field on the crystal surface. The exciting result of this study is that when the crystal is used to electric fields 50 V / cm, 60 V / cm, and 70 V / cm, many microdomains are produced, and as the electric field increases, so does the crystal pay stress. Due to this, it has an impurity dipole form, and due to this, the width of the domain wall is increased. This increase in width is significant to studying nucleation and evaporations of domains in different applying electric fields. Also, this study builds up the foundations to find the critical field of domain nucleation and evaporations.

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