CHAPTER V
CONCLUSION AND FUTURE RESEARCH

5.1 Conclusions

For basic characterization, BFO thin films on various substrates were analyzed by using XRD, SEM, and EDS. The results demonstrated the effectiveness of the preparation and annealing processes in forming crystalline BFO thin films on NSTO and FTO substrates. XRD confirmed successful crystallization, while SEM provided detailed insights into surface morphology, showing improved crystallinity after annealing. EDS confirmed the elemental composition and successful deposition of the BFO layer.

The ferroelectric property of the BFO/NSTO annealed was confirmed by PFM to test the control of ferroelectricity on an unpatterned BFO/NSTO sample by creating small-sized letters. These results demonstrate that the sample, prepared by a simple method, can effectively show polarization by applying different voltages. The ability to create polarized letters down to 493 nm on the surface highlights the potential for data storage and nano-electronic devices. This study shows that the electric fields can change local polarization states, making it useful for studying small-scale domain changes and developing advanced technologies.

To the ferroelectric properties on different substrates and size effects, focusing on unpatterned samples, samples patterned by FIB, and samples with gold nanohole arrays patterned by EBL. The analysis of ferroelectric properties used topography, PFM amplitude and phase, and hysteresis loops to compare the effects of sample size and patterning. The study shows that the ferroelectric properties of BFO thin films are significantly affected by the size and patterning of the samples. There are two main pieces of evidence that nano-patterning affects ferroelectric properties. First, the domain switching capability varies from clear switching in the unpatterned area, to roughly switching in the nano-grid patterned by FIB, to rarely switching in the nanohole array by EBL.

Second, in terms of hysteresis loops, all three conditions exhibit typical ferroelectric behavior with different ferroelectric coefficients. Although the patterned conditions display smaller overall piezoresponse characteristics, their amplitude responses are more consistent compared to the unpatterned condition. These findings are important for applications in memory devices and sensors, where precise control of polarization is essential. In addition, the one experiment that was most interesting in our thesis was the effect of UV irradiation on ferroelectricity.

The PFM amplitude measurements indicate that UV exposure affects the ferroelectric response of BFO films under both +10V and -10V poling conditions. UV exposure reduces the polarization amplitude, and while partial recovery is observed after UV removal, the ferroelectric properties do not fully return to their initial state. The differences in response between +10V and -10V poling suggest that the direction of the electric field during poling may influence the extent of UV-induced changes. To deepen our understanding reducing of ferroelectric response due to photo-induced charge carriers, the PFM amplitude and phase measurements over time were investigated. The results reveal that UV exposure significantly impacts the ferroelectric properties of BFO films under both +10V and -10V poling conditions. UV exposure accelerates the reduction in amplitude and introduces greater variability in the phase.

The differences in response between +10V and -10V poling suggest that the direction of the electric field during poling influences the extent of UV-induced changes. Understanding these effects is crucial for developing optoelectronic devices that rely on stable ferroelectric properties and controlled by UV exposure. Moreover, the ferroelectric properties of an annealed BFO/NSTO were investigated by using P-E hysteresis loops and voltage response measurements under different UV power conditions. This study shows that UV exposure significantly affects the polarization, piezoresponse, and voltage dynamics of BFO/NSTO samples. The findings highlight the role of electron-hole pairs generated by UV light in screening internal electric fields, leading to decreased polarization and altered voltage behavior. These results are crucial for understanding the behavior of ferroelectric materials under light exposure and have implications for their use in optoelectronic devices.

5.2 Improvement and future research

Perform annealing after patterning to repair damage from the patterning process. This could help recover ferroelectric properties by promoting re-crystallization and reducing defects. BFO films before patterning could apply protective coatings to shield the ferroelectric material from direct exposure to ion or electron beams. This can help keep the ferroelectric domains intact. Investigating the effects of other substrates and deposition methods could further understand the material's behavior and potential applications.

The decrease in polarization after UV exposure shows that photo-induced charge carriers affect ferroelectric properties. We must do more experiments in different samples condition such as unannealed, annealed with different temperature and compare with the STO substrate.