CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

1. ZnO and Cu-doped ZnO (ZnO:Cu) were successfully synthesized using the sol-gel technique. The physical characteristics are summarized as follows:

   a. The incorporation of Cu into ZnO led to the formation of a secondary Cu phase with a composition of 8.2%.
   b. The detection of a Cu—O bond at a wavenumber of 704,18 cm^{-1} in the ZnO:Cu sample confirms the interaction of Cu within the ZnO crystal lattice.
   c. The incorporation of Cu decreased the band gap energy from 3.28 eV for pure ZnO to 2.65 eV in ZnO:Cu.
   d. Cu doping influenced the crystal structure and morphology of ZnO, potentially improving its characteristics as a semiconductor material for TEG applications.

2. The temperature difference between the hot and cold sides (ΔT) significantly affected the voltage generated by the TEG module. A larger ΔT resulted in a higher output voltage. Temperature variations at 40°C, 50°C, and 60°C produced average measured voltages of 0.7 mV, 1.1 mV, and 1.4 mV, respectively, with the highest voltage obtained at 60°C. In addition, the most optimal *Seebeck* coefficient value is also found in testing at a temperature of 60°C, with a *Seebeck* coefficient value range of 0.05-0.06 mV/°C. These results align with the *Seebeck* principle, where the mobility of electrons and holes is greatly influenced by the temperature gradient between the hot and cold surfaces, resulting in an increase in generated voltage. The decrease in TEG performance is also influenced by several factors, as shown by the results of XRD, FTIR, UV-Vis, and SEM characterization.

5.2 Recommendations

1. The use of conductive adhesives with strong bonding ability and high electrical conductivity should be improved in the pellet-to-copper foil assembly process to reduce contact resistance and enhance the accuracy of voltage measurements.

2. The process of fabricating the TEG into a flexible TEG (FTEG) requires further investigation, especially regarding assembly methods and mechanical stability, to achieve a more reliable and functional device.

3. Further investigation of the compaction parameters during pellet formation is needed because the density of the material greatly affects charge carrier mobility and transport properties in the semiconductor.

4. The variation of Cu doping concentration should be broadened to find the optimal composition for the best thermoelectric performance.

5. Additional testing with a larger number of samples and wider experimental conditions is recommended to improve the validity and reliability of the data collected.