FABRICATION AND CHARACTERIZATION OF FLEXIBLE PIEZOELECTRIC GENERATOR COMPOSED OF **POTASSIUM SODIUM NIOBATE (KNN)** BASED CERAMICS DOPED WITH **LITHIUM /PVDF** FOR ENERGY HARVESTING APPLICATIONS.

DISSERTATION THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER'S IN PHYSICS

DELHI TECHNOLOGICAL UNIVERSITY

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DEPARTMENT OF APPLIED PHYSICS

MSPH210 : Dissertation – II

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Under the supervision of

Dr. Richa Sharma

CANDIDATE DECLARATION

We hereby declare that the work which is presented in the Dissertation -II entitled FABRICATION AND CHARACTERIZATION OF FLEXIBLE PIEZOELECTRIC GENERATOR COMPOSED OF **POTASSIUM SODIUM NIOBATE (KNN**) BASED CERAMICS DOPED WITH **LITHIUM /PVDF** FOR ENERGY HARVESTING APPLICATIONS. in the fulfilment of the award of the Degree of Master's in Physics and submitted to the Department of Applied Physics, Delhi Technological University , Delhi is an authentic record of our own carried out during a period from 2021-2023, under the supervision of Dr. Richa Sharma.

The matter presented in this report/thesis has not been submitted by us for the award of any other degree of this or any other Institute/University.The work has been published/accepted/communicated in SCI/SCI expanded/SSCI/ Scopus indexed journal Or peer reviewed Scopus indexed conference with the following details:

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Sources overview

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AYUSH ANAND

TAJINDER SINGH

ABSTRACT

Energy Harvesting has received a lot of attention recently for powering low voltage electrical appliances. We must create and use efficient, clean and renewable energy sources if we are to meet growing global energy users and needs. Researchers are working on replacing batteries in this area and piezoelectricity has been suggested as a promising source. Piezoelectric materials have been widely used to generate electricity. Using piezoelectric materials, this article seeks to create a new form of energy. This essay focuses on piezoelectric devices as a potential energy source, investigates multi-device connections and seeks to generate as much power as possible. Piezoelectric materials can transform mechanical stress into displacement in a dielectric medium and vice versa, making them suitable for use as sensors, actuators and transducers. Due to their high stress response and adaptability, lead-based materials have attracted the most attention; but lead toxicity mandates government regulations restricting their use. Although KNN supported materials appear to be a promising alternative to hazardous Pb based piezoelectric, the distinction between thin films and bulk materials has not been fully evaluated. KNN based materials exhibit qualities that make them ideal for actuator applications, prompting the search for suitable alternative materials. Results will highlight the beneficial practical consequences of the use of piezo systems, providing a clearer picture of the difficulties and benefits of using piezoelectric materials as a support for power generation. We have only stolen so much from natural as people. The fading line of ecological equilibrium needs to be restored, renewed and darkened. Only more recent green energy ventures can make this viable. Studying earlier writings and research on this technology would significantly strengthen the philosophy. The energy generated can be valuable, according to the findings of numerous study studies. The work approaches the above assumptions and looks for maximum power extraction from piezo device.

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List of Symbols And Abbreviations

PVDF	Polyvinylidene fluoride
PEG	Piezoelectric Generator
KNN	Sodium potassium Niobate
XRD	X-Ray Diffraction
FTIR	Fourier Transform Infrared Spectroscopy
KNN-Li	Sodium potassium Niobate doped with lithium
SEM	Scanning Electron Microscopy

CHAPTER 1

AIM & INTRODUCTION

1.1 AIM :- Fabricate PEG composed of KNN doped with Li Ceramics and Polymer PVDF.

1.2 Introduction

The primary goal of our project is to use the stress or force applied to the piezoelectric sensor to generate energy. As a result of energy harvesting, numerous issues relating to the reliance on continually replenishing energy sources could be resolved.

The resultant energy could provide a remedy for

1. growing demand for renewable energy sources.

2. Lessen your reliance on batteries.

3. Energy can be employed in footwear, cars, and other items.

In the modern day, energy harvesting from ambient light, thermal, magnetic, or mechanical energy is a crucial research area. However, replacing the batteries and tiny power supply in sensor systems would be a laborious operation. As a result, it is fairly intriguing to power a limited number of sensor systems with environmental energy.

The lack of available energy sources has also led to a demand for environmental energy to supplement some of the electric energy utilised in daily living. Because of this, capturing mechanical energy from roads or trains to generate electricity is another exciting application. If there are enough moving automobiles or trains, this method might offer a modest to medium quantity of power for operating lighting or even electric motors.

One of the most effective methods for developing power harvesting devices is the use of piezoelectric materials to convert mechanical vibration or strain energy into electric energy based on the piezoelectric effect.. The direct piezoelectric effect has been the subject of a flurry of research during the last ten years in the field of energy harvesting from background vibrations. Piezoelectric materials have excellent electromechanical coupling effects, making them excellent candidates for mechanical energy conversion. Devices for capturing piezoelectric energy are also considerably simpler than electrostatic or electromagnetic ones, for instance.

These factors have made piezoelectric energy harvesting devices very popular.

1.3 PIEZOELECTRIC EFFECT

Some materials, when subjected to mechanical strain, have a propensity to enlarge as a result of the creation of electric potential or voltage. The piezoelectric effect is what it is called.

This discovery was made by Pierre and Jacques Curie in the year 1880.

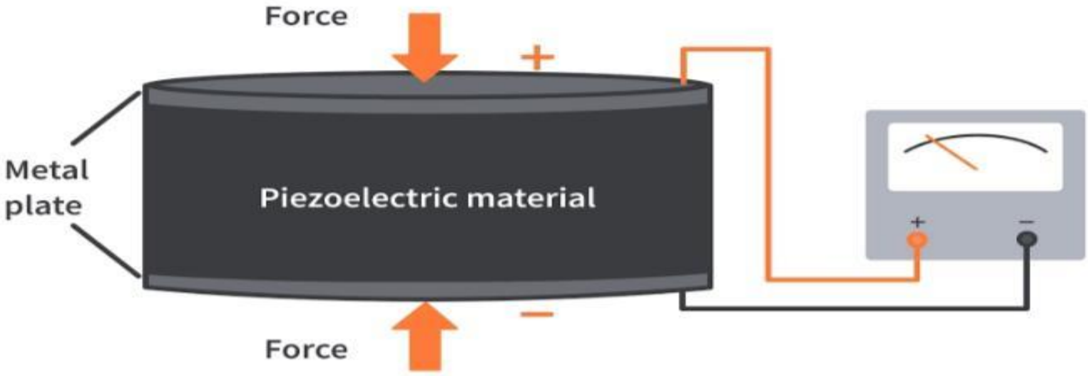

Figure 1 :- Working of Piezoelectric materal

The piezoelectric effect serves as the foundation for the operation of piezoelectric transducers. When forces or stresses from mechanical stress are applied along particular planes, some materials produce an electric voltage. These materials' voltage output is inversely proportional to the force or stress applied because of the piezoelectric effect.

1.4 EMBRACING SUSTAINABLE SOLUTION

- Escalating demand for sustainable energy alternatives
- Presents a range of cost-effective and efficient proposals
- Minimize reliance on conventional battery usage
- Wiring complexity
- Increasing wiring expenses
- Lower embedded intelligence expenses
- The growing acceptance of wireless networks
- Issues with batteries
- Lessen the effect on the environment

1.5 PIEZOELECTRIC MATERIAL (Material with Piezo properties)

1.5.1 Crystals that occur naturally:-

Quartz, Rochelle salt, Topaz .

Minerals also.

1.5.2 Man-made ceramics:-

- $BaTiO_3$, also known as barium titanate.
- KNN, an abbreviation for sodium potassium niobate.
- $PbTiO_3$, referred to as lead titanate.
- PZT, which stands for lead zirconate titanate.
- $KNbO_3$, known as potassium niobate.
- $LiNbO_3$, commonly referred to as lithium niobate.
- $LiTaO_3$, abbreviated for lithium tantalate.

1.5.3 Polymer:-

- Polyvinyledene fluoride (PVDF)

1.6 SURVEY OF LITERATURE

1.6.1 PYROELECTRIC EFFECT

The pyroelectric effect is the phenomenon wherein a change in the material's temperature results in the appearance of an electric potential between the terminals.

1.6.2 PIEZOELECTRIC FILMS

The polarization procedure encompasses subjecting films to a robust electric field to align the molecular dipoles of polar polymers such as PVDF in a unified orientation. Thermodynamic stability is achieved by the polarized electrets until approximately 90 °C. PVDF exhibits exceptional suitability for the creation of polarized films due to its molecular structure as a polar material, high purity facilitating the production of uniform and thin films, and its ability to crystallize in a polarizable form.

1.6.3 PROPERTIES OF PVDF PIEZOELECTRIC FILMS

Exceptional mechanical strength and Consistent dimensional stability sustained high piezoelectric coefficients up to approximately 90°C

PVDF's notable chemical inertness.. Uninterrupted polarization for extended lengths wound onto drums. Thickness ranging from 9 microns to 1 mm.

CHAPTER 2 – WORK EXECUTED

WORK EXECUTED

2.1 Synthesize of KNN by Solid State Reaction Method by Optimizing the Calcination temperature.

CHEMICAL REACTION :-

$K_2CO_3 + Na_2CO_3 + Li_2CO_3 + Nb_2O_5 = 0.15\ LiNbO_3 + 0.942\ [(Na_{0.535}\ K_{0.480})NbO_3] + 4.5\ CO_2$

Stoichiometric amount of K_2CO_3 , Na_2CO_3 , Li_2CO_3 , Nb_2O_5

Mixed all precursor in jar roller mill for 24 hrs in propanol to make it homogeneous.

By using filter paper , remaining the mixed powder from propanol. The powder mixture is dried by putting it in oven at 65°C for 3-4 hrs

Calcined at different temperatures (850°C and 900°C)

2.2 Steps taken to synthesize the KNNLi

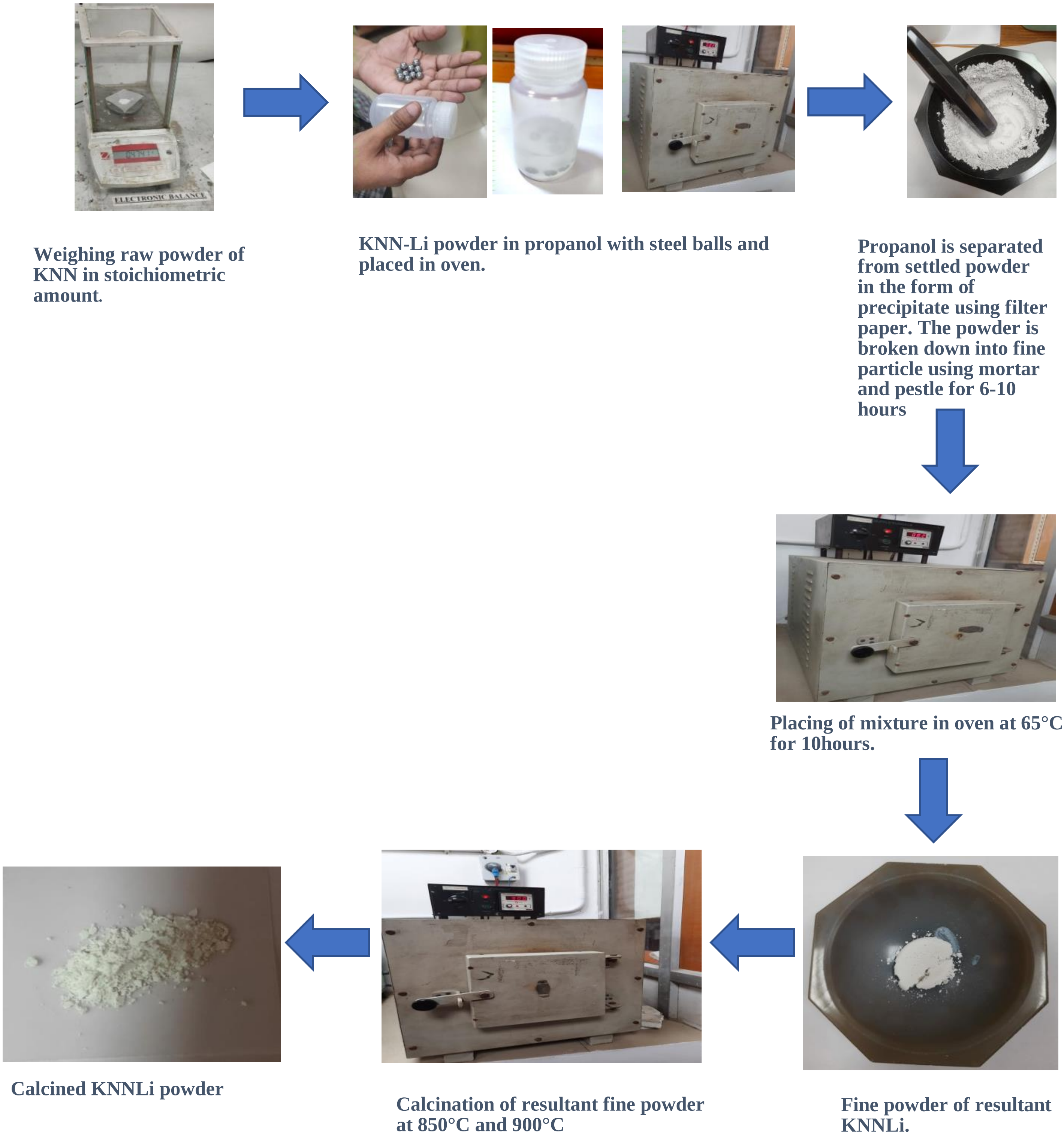

Figure 2:- Schematic presentation of synthesis of KNN-Li/ PVDF Films

2.3 Characterization Of prepared KNN ceramic powder by XRD

Figure 3:- Picture representing XRD diffractometer

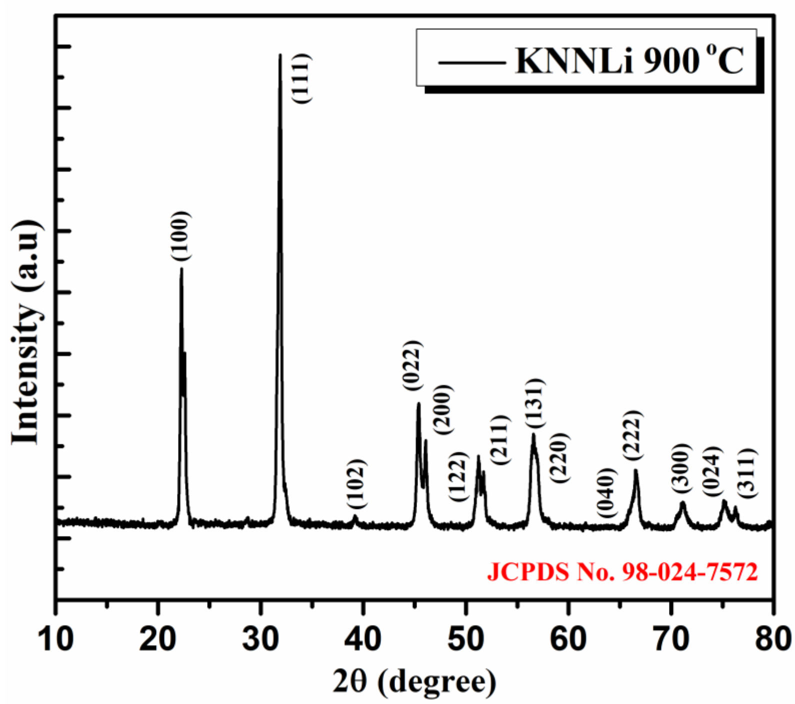

Figure 4:- XRD Pattern

2.4 XRD ANALYSIS

- The XRD Peaks matched with JCPDS card number 98-024-7572
- The X-ray diffraction (XRD) plots clearly reveal the peak splitting, where the intensity of the (022) diffraction peak is higher compared to the (200) diffraction peak. This observation indicates that the calcined ceramics exist in the orthorhombic phase.
- It has orthorhombic geometry and Amm2, the space group.
- No extra peak indicated that the KNNLi ceramics were successfully synthesized by using the solid-state route.

2.5 Reitveld Refinement of KNNLi Table

Phase = Orthorhombic

Space group = Amm2

Number of Space Groups = 38

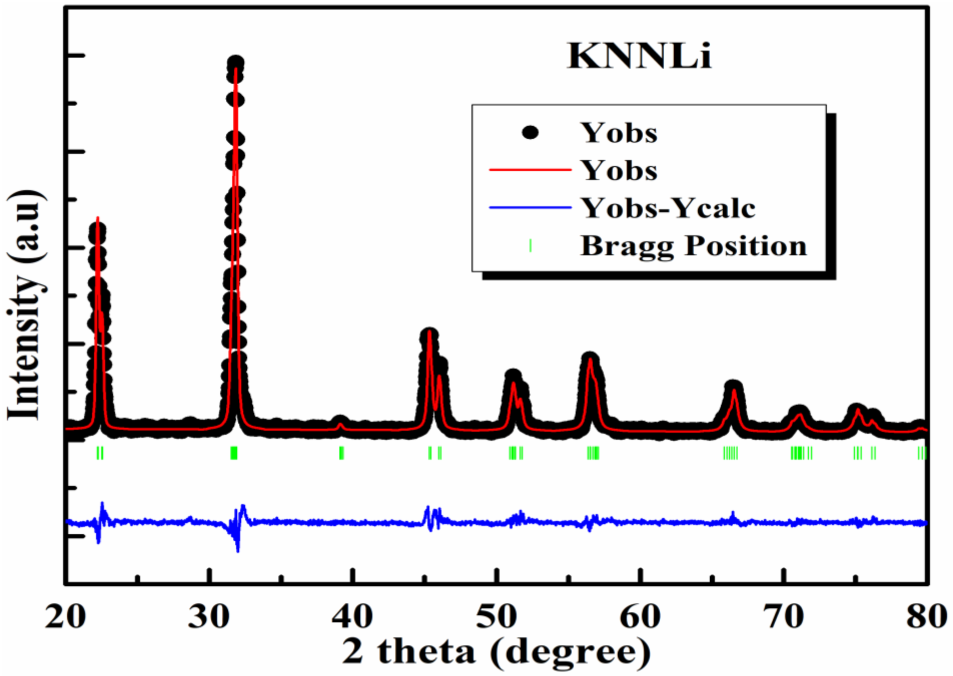

Figure 5 :- Reitveld Refinement of KNNLi

Direct Cell Parameters

a = 3.9450 Å	α = 90
b = 5.6425 Å	β = 90
c = 5.6690 Å	γ = 90

V = 126.1879 Å^3

Table 1 :- Parameter related to Direct Cell

Reciprocal Cell Parameters

a^* = 0.253488 Å	α* = 90
b^* = 0.177226 Å	β* = 90
c^* = 0.176399 Å	γ* = 90

V^* = 0.007924 Å^3

Rp = 19.3 Rwp = 19.8 Re = 8.37 ψ^2 = 5.57

Table 2:- Parameter related to Reciprocal cell

2.6 PREPARATION OF KNN -Li /PVDF Films by DROP CAST METHOD

2.6.1 DROP CAST METHOD

The DROP CAST method is a common technique used for the preparation of thin films in various research fields, including material science and nanotechnology. It involves the deposition of a solution or dispersion onto a substrate, followed by the evaporation of the solvent to form a solid film. This method offers simplicity, cost-effectiveness, and versatility in fabricating films with different properties and compositions.

In the context of KNN-Li/PVDF (Potassium Sodium Niobate-Lithium/ Polyvinylidene Fluoride) films, the DROP CAST method is employed to create composite films with enhanced ferroelectric and piezoelectric properties. KNN-Li is a lead-free piezoelectric material with high dielectric constant and electromechanical coupling coefficient, making it desirable for various applications such as sensors, actuators, and energy harvesting devices. PVDF is a polymer known for its excellent piezoelectric response, flexibility, and durability, making it a suitable matrix material for the KNN-Li composite films.

The DROP CAST method allows for the precise control of the film thickness and composition, enabling researchers to tailor the properties of the resulting films. By varying the concentration of KNN-Li nanoparticles or powders and the PVDF polymer, it is possible to optimize the final film's electrical and mechanical characteristics. The deposition process involves the dispersion of KNN-Li particles within a PVDF solution, followed by the casting of the mixture onto a suitable substrate and subsequent solvent evaporation to form a homogeneous film.

The resulting KNN-Li/PVDF films exhibit synergistic effects, combining the unique properties of KNN-Li and PVDF. The incorporation of KNN-Li nanoparticles into the PVDF matrix enhances the overall piezoelectric performance of the composite film. Moreover, the DROP CAST method allows for easy scalability, making it feasible to produce large-area films for practical applications.

In summary, the DROP CAST method provides a versatile and effective approach for the preparation of KNN-Li/PVDF composite films with enhanced piezoelectric properties. Through careful control of the deposition parameters and film composition, researchers can tailor the films' characteristics to meet specific application requirements.

2.6.2 Preparation of KNN Li /PVDF Films

To prepare KNN-Li/PVDF films using the drop cast method, you will need to follow these steps:

2.6.2.1 Materials and Equipment:

- KNN-Li powder (Potassium Sodium Niobate-Lithium)
- PVDF (Polyvinylidene Fluoride) polymer
- Solvent (e.g., DMF)
- Glass or silicon substrate
- Hotplate or oven
- Petri dish or container
- Spatula
- Ultrasonic bath
- Masking tape (optional)

2.6.2.2 Preparation of KNN-Li Solution:

Weigh the desired amount of KNN-Li powder according to your required composition.

Dissolve the KNN-Li powder in a suitable solvent (DMF) to obtain a homogeneous solution.

Stir the solution for a sufficient amount of time to ensure complete dissolution.

Optionally, you can sonicate the solution in an ultrasonic bath for a few minutes to further enhance homogeneity.

2.6.2.3 Preparation of PVDF Solution:

Weigh the required amount of PVDF polymer.

Dissolve the PVDF polymer in a suitable solvent (DMF) to form a PVDF solution.

Stir the solution until the PVDF is completely dissolved.

2.6.2.4. Film Casting:

Clean the glass or silicon substrate to ensure it is free from dust or contaminants.

Securely fix the substrate onto a flat surface using masking tape if necessary.

Pour the PVDF solution onto the substrate, covering its entire surface. Adjust the solution volume to obtain the desired film thickness.

Gently drop the KNN-Li solution onto the PVDF film surface using a dropper or pipette.

Allow the solution to spread and self-assemble on the substrate surface for a few minutes.

2.6.2.5 Drying and Film Formation:

Place the substrate with the deposited solution on a hotplate or in an oven.

Gradually heat the substrate to a suitable temperature (e.g., 80-100°C) to evaporate the solvent. The specific temperature and time may depend on the solvent used.

Once the solvent is completely evaporated, continue heating the substrate for an additional period to enhance film formation and adhesion.

Allow the substrate to cool down to room temperature before handling the film.

2.6.2.6 Film Characterization:

Carefully remove the film from the substrate if necessary.

Conduct the necessary characterization techniques to assess the properties of the film, including X-ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), and electrical measurements.

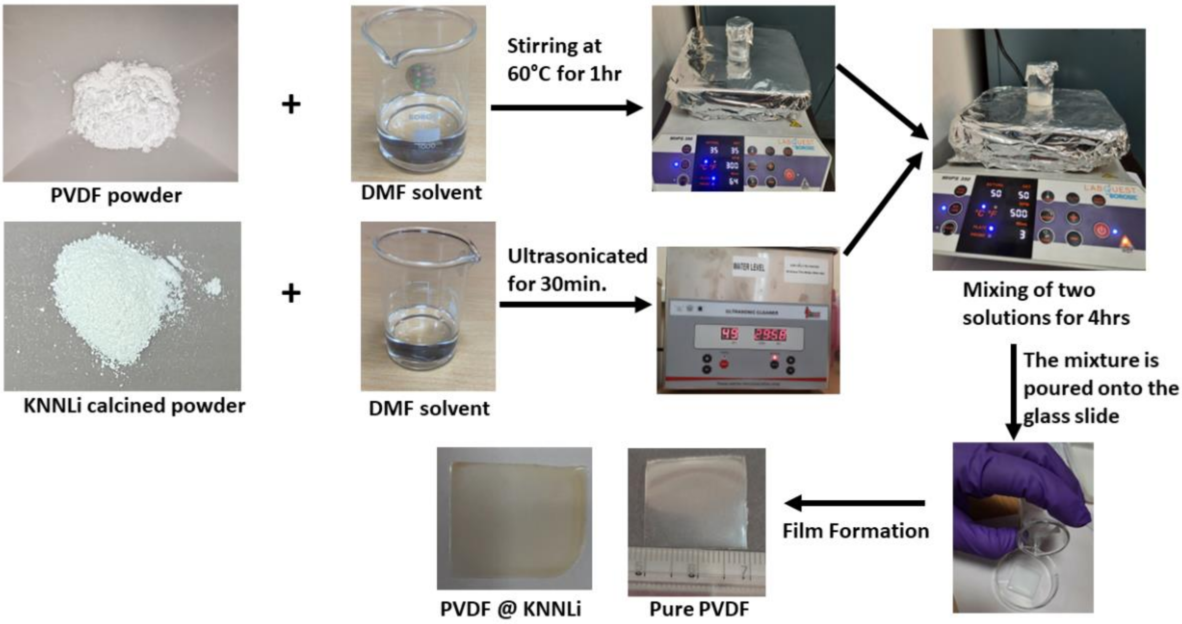

Figure 5 :- Chemical and Materials used for synthesis

2.7 XRD PATTERN Of Synthesized flexible composite films

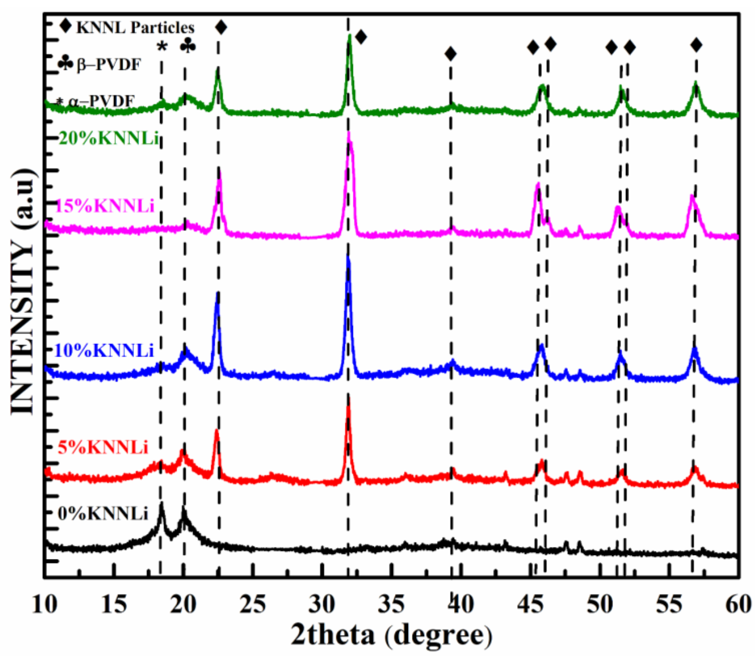

Figure 6:- XRD Pattern of synthesised films.

2.7.1 Interpretation from above structural analysis

▪ The Peaks at correspond to the non –polar of the PVDF respectively.

▪ Further , the peaks marked by * , ♤ , ◇ corresponds to the PVDF and KNN –Li particles respectively.

▪ XRD data confirms the coexistence of the phase

▪ The X-ray diffraction (XRD) plots demonstrate a noticeable increase in the intensity of diffraction peaks associated with KNN-Li particles and a decrease in the intensity of diffraction peaks associated with the PVDF matrix as the concentration of KNN-Li particles in the PVDF matrix increases.

2.8 SEM Analysis of Synthesized flexible composite films

Scanning Electron Microscopy (SEM) analysis was performed to investigate the morphology and surface characteristics of KNN-Li/PVDF composite films. The SEM images provided valuable insights into the microstructure and distribution of the incorporated materials within the composite films.

The KNN-Li/PVDF composite films were prepared by a solution-casting method, where KNN-Li nanoparticles were dispersed within a PVDF matrix. After casting and drying, the films were subjected to SEM analysis to examine their surface morphology.

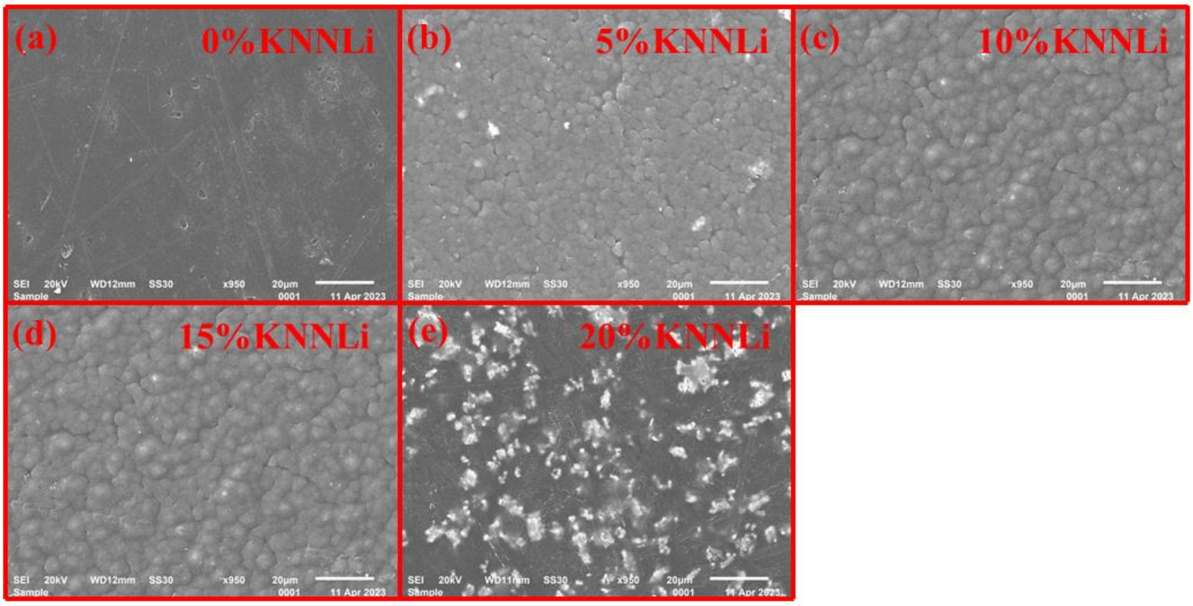

Figure 7:- SEM Analysis of flexible composite films

2.8.1 Interpretation from the above analysis

SEM analysis of the KNN-Li/PVDF composite films revealed that the KNN-Li ceramic particles were uniformly dispersed within the PVDF matrix. This uniform distribution was observed for KNN-Li concentrations up to 15%. However, beyond this concentration, a lack of uniformity was evident as individual particles were observed separately. This suggests that the uniformity of the composite film is influenced by the KNN-Li concentration, with lower concentrations exhibiting better uniformity.

2.9 FTIR Spectra of the flexible composite films

FTIR (Fourier Transform Infrared) spectroscopy of KNN-Li/PVDF composite films can provide valuable information about their chemical composition, molecular interactions, and bonding characteristics.

Here are some key pieces of information that can be interpreted from FTIR spectra analysis:

2.9.1 Polymer Identification: FTIR spectra can help identify the presence of PVDF in the composite film. PVDF exhibits characteristic absorption bands, such as the C-F stretching vibration at around 1200-1300 cm^-1 and the C-H stretching vibration at around 2900-3000 cm^-1.

2.9.2 Chemical Interactions: FTIR spectra can reveal any chemical interactions or bonding between KNN-Li and PVDF. The appearance of new peaks or shifts in the existing peaks can indicate the formation of chemical bonds or interactions between the components. For example, the presence of peak shifts or intensity changes in the C-F stretching region may suggest interactions between KNN-Li and PVDF.

2.9.3 Functional Group Analysis: FTIR spectra provide information about the functional groups present in the composite film. By analysing the characteristic peaks, one can identify the presence of specific functional groups and assess their involvement in chemical interactions or bonding.

2.9.4 Crystalline and Amorphous Phases: FTIR spectra can provide insights into the degree of crystallinity in the composite film. The presence of peaks related to the PVDF crystalline phase, such as the C-H rocking vibration at around 761 cm^-1 and the CH_2 wagging vibration at around 835 cm^-1, can indicate the presence of a crystalline phase. Additionally, the presence of a broad peak in the range of 1100-1000 cm^-1 may suggest the presence of the amorphous phase.

2.9.5 Structural Changes: FTIR spectra can help identify any structural changes in the composite film compared to the individual components. Shifts in peak positions, changes in peak intensities, or the appearance of new peaks may indicate alterations in the molecular structure due to interactions between KNN-Li and PVDF or the formation of new phases.

2.9.6 Film Composition: FTIR spectra can provide qualitative information about the composition of the composite film. By comparing the intensity ratios of specific absorption peaks related to KNN-Li and PVDF, it is possible to estimate the relative proportions of each component in the film.

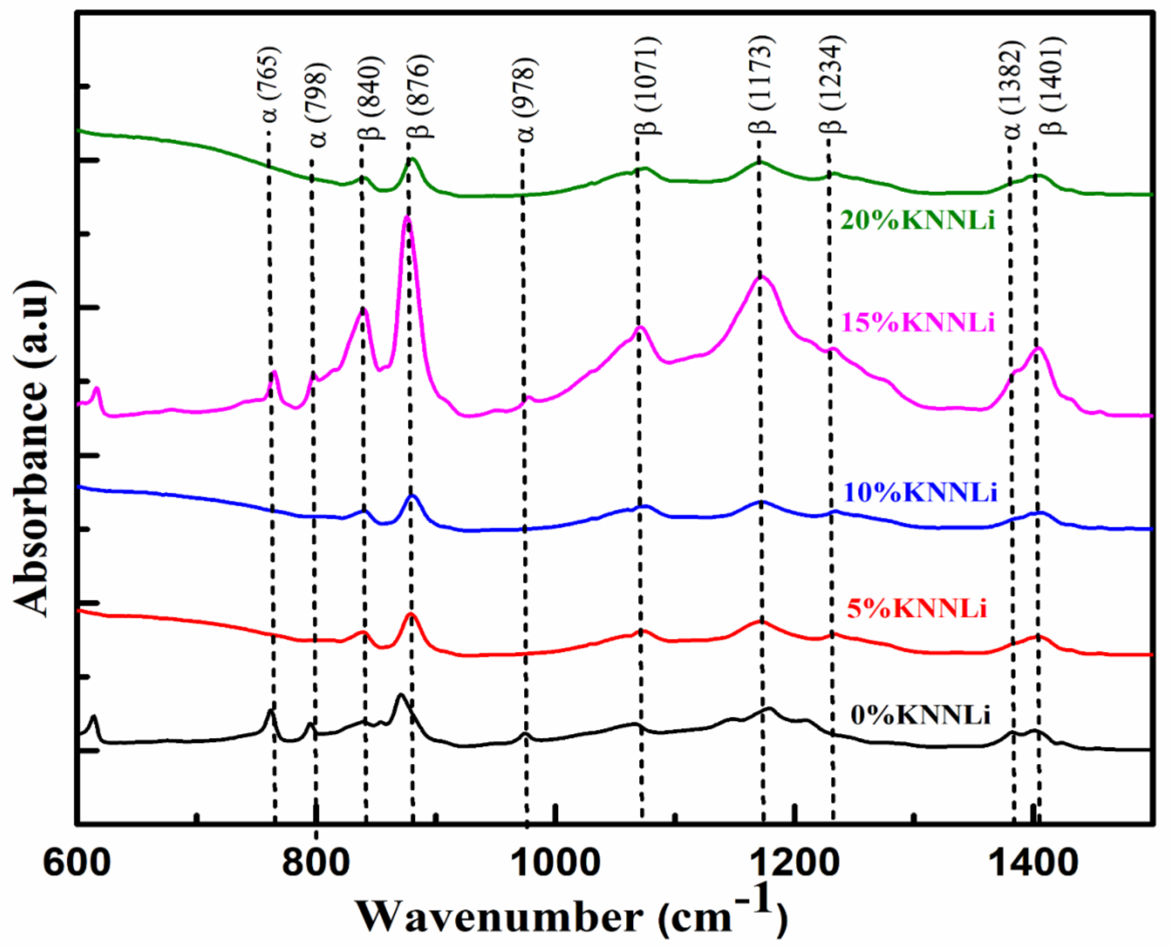

Figure 8 :- Figure showing FTIR Spectra

2.10 Interpretation from the above analysis

▪ The FTIR spectra analysis indicates the presence of both α and β phases in all the fabricated films. The FTIR data obtained correlates with the XRD data, confirming the presence of the β phase of PVDF in both the pure PVDF films and the KNN-Li/PVDF composite films.

▪ The peaks corresponding to 840,876,1071,1173,1234 and 1401 cm^{-1} are related to the polar β-phase of the PVDF.

▪ The peaks corresponding to α –phase are at 765,798,978, and 1382 cm^{-1}.

▪.The intensity of absorption for the peak at 840 cm-1, associated with the β-phase of PVDF, indicates an increase in the content of the β-phase with an elevated concentration of KNN-Li up to 15 weight percent. However, beyond this threshold, the β-phase content decreases.

CHAPTER - 3

3.1 Fabricated Piezoelectric Generator (PEG) and Measurements of Output voltage

The fabricated KNN-Li/PVDF (Potassium Sodium Niobate-Lithium/Polyvinylidene Fluoride) piezoelectric generator is a flexible composite device designed to transform mechanical energy into electrical energy by utilizing the piezoelectric effect. This technology harnesses the unique properties of both KNN-Li and PVDF materials to create a lightweight and flexible generator that can be used in various applications, such as wearable electronics, energy harvesting systems, and sensor technologies.

KNN-Li is a lead-free ceramic material known for its high piezoelectric properties. It exhibits excellent electromechanical coupling coefficient, large piezoelectric coefficients, and high Curie temperature, making it a promising alternative to lead-based piezoelectric materials. PVDF, on the other hand, is a highly polar polymer that possesses inherent piezoelectricity, flexibility, and chemical stability, making it suitable for use in flexible electronics.

The fabrication process of the KNN-Li/PVDF piezoelectric generator typically involves the synthesis of KNN-Li nanoparticles or thin films, followed by the integration of PVDF as a matrix material. Various methods can be employed to prepare the composite, including solution casting, spin coating, or electrospinning, depending on the desired film thickness and properties.

The resulting KNN-Li/PVDF composite film combines the superior piezoelectric properties of KNN-Li with the flexibility and processability of PVDF. When subjected to mechanical stress or vibrations, the composite film deforms and generates electrical charges due to the piezoelectric effect. These generated charges can be harvested and used to power electronic devices or stored in batteries or capacitors for later use.

The flexibility of the KNN-Li/PVDF piezoelectric generator enables its integration into various wearable and conformable devices, allowing for energy harvesting from body movements, ambient vibrations, or other mechanical sources. Additionally, the lead-free nature of KNN-Li makes it environmentally friendly and compliant with emerging regulations regarding hazardous substances.

In conclusion, the fabricated KNN-Li/PVDF piezoelectric generator offers a promising solution for energy harvesting and power generation in flexible and wearable electronics. By combining the unique properties of KNN-Li and PVDF, this composite material provides a lightweight, flexible, and environmentally friendly option for converting mechanical energy into electrical energy. Its versatility opens up possibilities for self-powered wearable devices, wireless sensor networks, and other applications requiring efficient energy conversion.

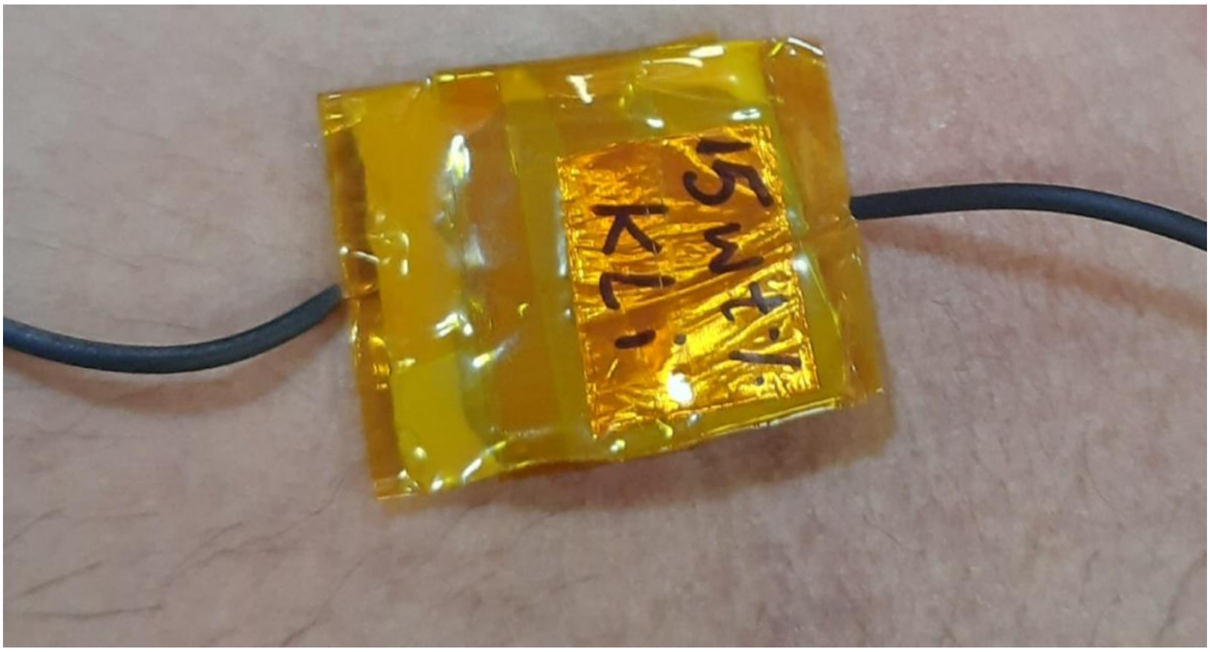

Figure 9 :- Fabricated PEG

3.2 MEASUREMENTS

3.2.1 Piezoelectric Generator Output Voltage

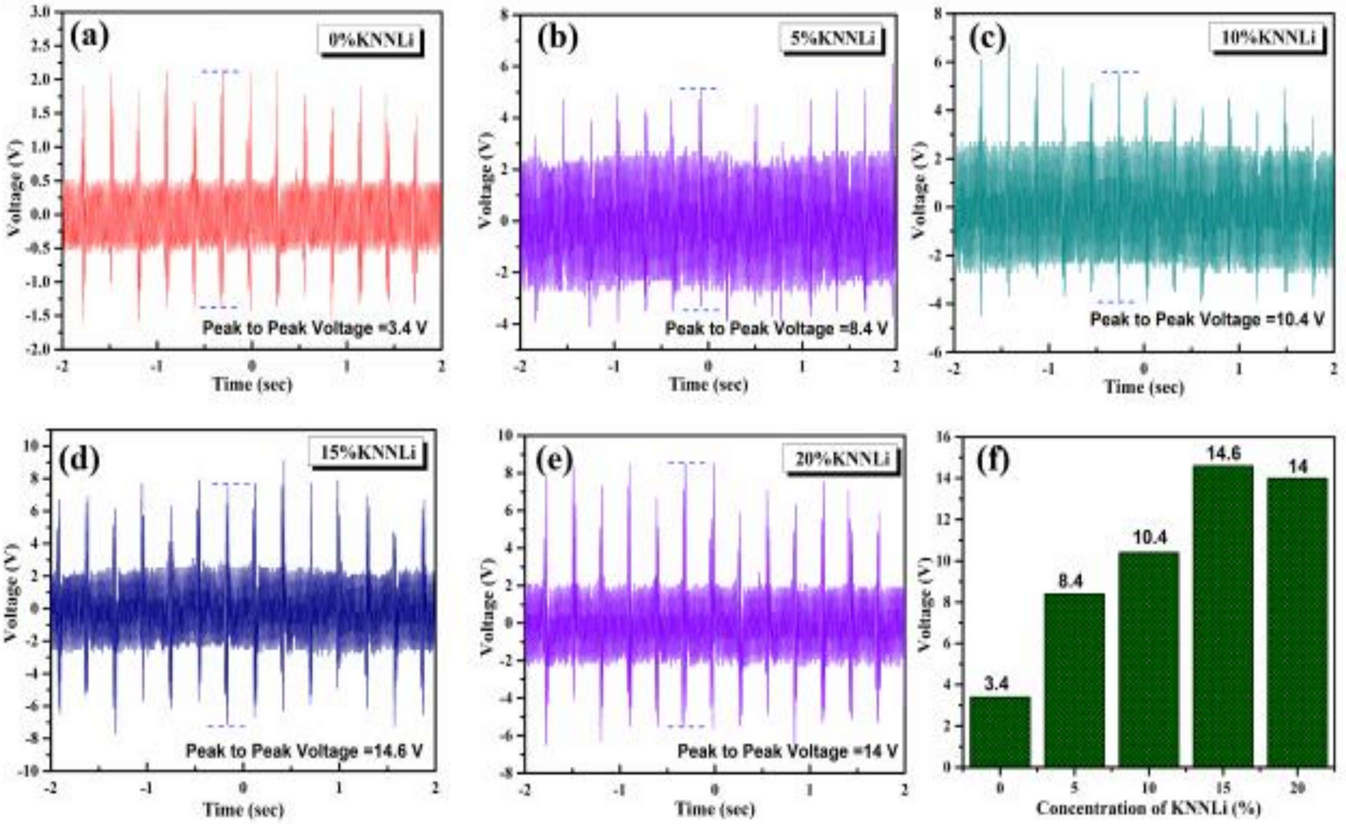

Figure 10:- Statistical Data related to measurements

S.NO	KNN-Li Content (wt.%)	Output Voltage (volt)	Short Circuit Current(μA)
1	0 (Pure PVDF)	3.4	1.07
2	5	8.4	1.15
3	10	10.4	1.28
4	15	14.6	1.30
5	20	14	1.25

Table 3 :- PEG Output voltage

3.3 Result and Conclusion

- A flexible and environmentally friendly Piezoelectric Energy Generator (PEG) was created using a composite film of **KNNLi/PVDF.**

- The incorporation of KNN-Li ceramics as a filler in the PVDF matrix substantially improved the output signals of the PEG device.

- Through testing with an electrodynamics shaker machine, the PEG device achieved a **maximum voltage generation of 14.6 volts.**

- The practical usability of the fabricated PEG device was showcased by successfully harvesting energy from human body motion, including elbow curving and finger bending.

CHAPTER - 4

4.1 ASSESSMENT OF THE ELECTRIC CHARGE OUTPUT FOR PIEZOELECTRIC ENERGY HARVESTING

One method of obtaining power is by using piezoelectric materials, which offer transducers capable of turning mechanical stress or strain into electrical energy. These materials can be used as mechanisms for this purpose because ambient motion (typically vibration) can be transformed into electrical energy that can be stored and used to power other devices.

Portable systems that don't rely on conventional power sources, such the battery, which has a finite working life, can be created by installing power harvesting devices. Power harvesting system development and comprehension have received a lot of research attention.

4.2 ADVANTAGES

High frequency response: They provide a frequency response that is quite high, making it possible to sense quickly changing parameters.

High transient response: Linear output and the ability to detect microsecond events are both provided by piezoelectric transducers.

4.3 LIMITATIONS

The following are a few of the drawbacks of piezoelectric transducers:

Low output: Since the output of the piezoelectric transducers is so low, another electronic circuit must be attached.

High impedance: Due to the piezoelectric crystals' high impedance, they must be connected to the amplifier and the auxiliary circuit, which could result in measurement mistakes. High input impedance amplifiers and long cables should be utilised to reduce these problems.

Forming: It is exceedingly challenging to give the crystals the desired shape with enough strength.

4.4 APPLICATIONS

Cigarette Lighter

An electric current with a high enough voltage is produced when the button is pressed by a spring-loaded hammer striking a piezoelectric crystal, heating and igniting the gas.

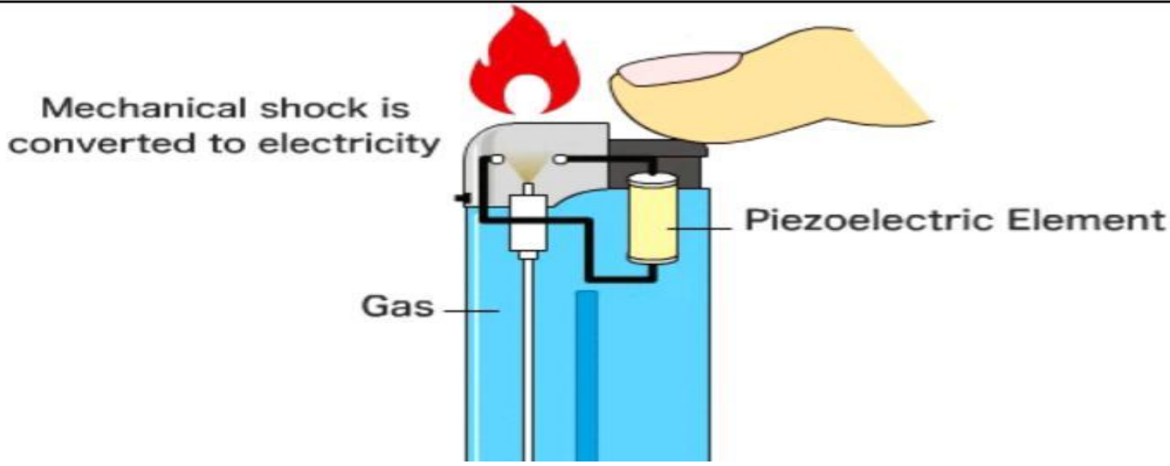

Figure 11:- Cigarette Lighter

Armed Forces

In order to power radios and other portable electronic devices, the military considered incorporating piezoelectric materials inside soldier's boots.

4.5 CONCLUSION

When pressure is applied to the device's face, the charge carriers inside the crystals are deformed, creating an electric field.. In addition, we can use this electric potential to use the device to charge the battery of our mobile or cell phones. various USB devices Astonishingly, piezoelectric technology may transform human motion into electrical power. Energy harvesting is expected to dominate the technical world in the coming ten years.

4.6 SUMMARY

PIEZO - FUTURE SOURCE OF ELECTRICITY

Harvesting renewable energy from the environment around people is gaining more attention as energy use rises as a result of the exponential growth in the number of electronic gadgets. By harnessing such bodily energy to generate electricity, the piezoelectric effect can power more compact devices. More electricity can be produced, and it can be seen as the next promising source of generating power with further development in the field of electronics, better synthesised piezoelectric crystals, and a better selection of installations.

REFERENCES

•K Verma, S Goel, R Sharma, Influence of calcination and sintering temperature on the microstructure, dielectric Ferroelectric and piezoelectric properties of the lead-free KNN ceramics, J Matter Sci. Mater E Electron,2022, https://doi.org/10.1007/s10854-022-09295-2

• K. Verma, R. Sharma, A flexible piezoelectric generator based on KNN/PVDF composite films: Role of KNN concentration on the piezoelectric performance of generator, Chinese Journal of Physics, https://doi.org/10.1016/j.cjph.2022.12.007

• Wang ZL, Song J. Piezoelectric nanogenerators based on zinc oxide nanowire arrays. Science. 2006;312(5771):242-246.

• S. Banerjee, S. Bairagi, S.W. Ali, A critical review on lead-free hybrid materials for next generation piezoelectric energy harvesting and conversion.. https://doi.org/10.1016/j.ceramint.2021.03.054

• S. Mishra, L. Unnikrishnan, S.K. Nayak, S. Mohanty, Advances in piezoelectric polymer composites for energy harvesting applications: a systematic review, Macromol. Mater. Eng. 304 (2019) 1–25, https://doi.org/10.1002/mame.201800463

THANKS