The 2018 Interdisciplinary Materials and Materials Physics

Research Experience for Undergraduates

Comparison of Deposition Methods for Lead-Free Piezoelectric KNN Films

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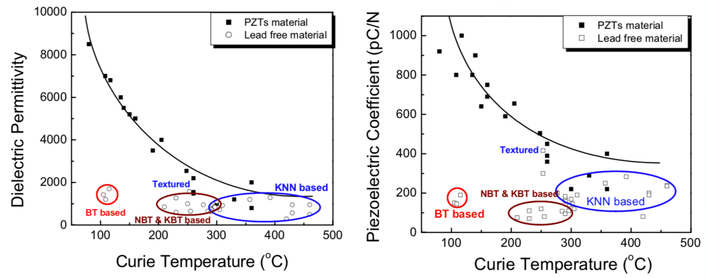
Lead-Free KNN Thin Films

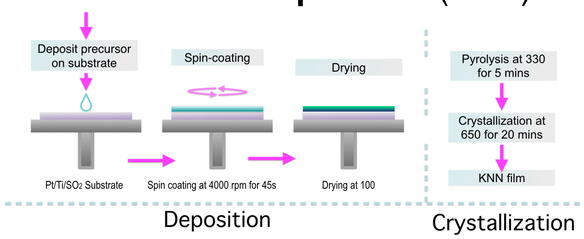
Potassium Sodium Niobate $K_{0.50}Na_{0.50}NbO_3$ (KNN) films are studied for their competitive piezoelectric properties to potentially replace lead-based piezoelectric material used in devices. Chemical Solution Deposition (CSD) and RF Sputtering are two methods used in developing KKN films.



KNN has a high Curie temperature and a low dielectric permittivity making its properties more temperature-stable.

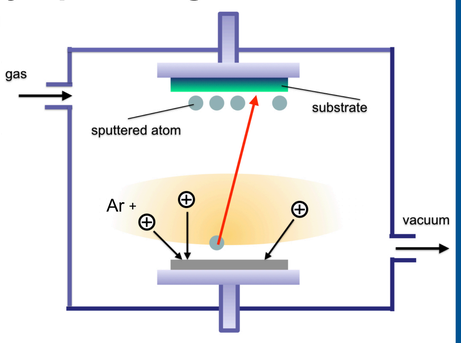
Experimental Procedures

Chemical Solution Deposition (CSD):



Radio Frequency Sputtering:

High energy Argon gas ions strike a target ejecting particles onto a substrate film.



KNN Film Sample Characteristics

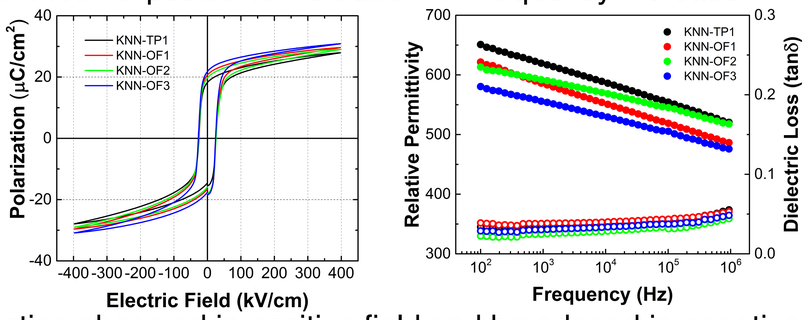
	CSD	RF-Sputtering
KNN Film Thickness	1.44µm	2µm
Substrate	Pt/Ti/SiO₂/Si	Pt/Ti/SiO₂/Si
Area Top Electrode	0.2 mm	0.2827 mm

KNN Film Piezoelectric Properties

Dielectric, ferroelectric, and piezoelectric properties collected:

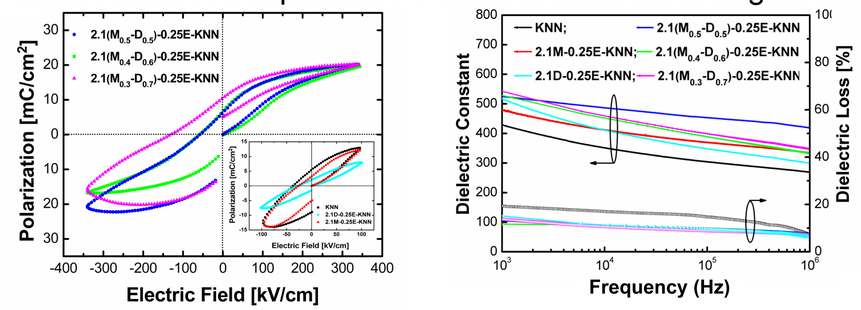
- Dielectric loss expected to increase with frequency increase.

RF-Sputtering



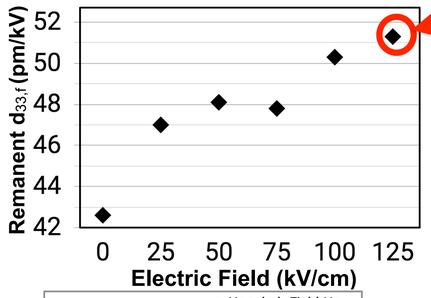
- Polarization observed in positive field and broadened in negative field.

Chemical Solution Deposition

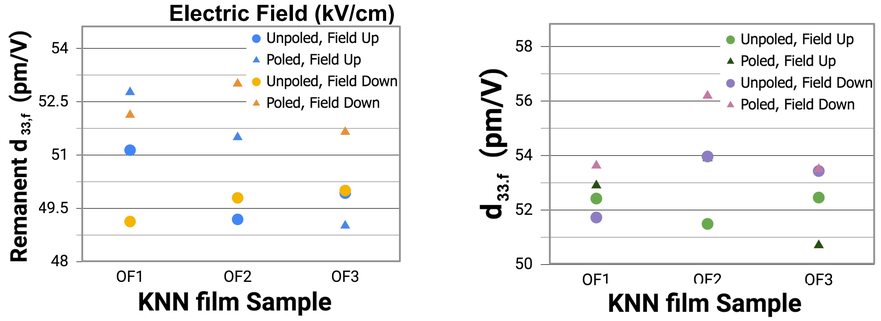


RF-Sputtering

	SMALL Signal, d_{33} [pm/V]				Large Signal, d_{33} [pm/V]			
KNN Thin Film Sample	Unpoled Field Up	Poled Field Up	Unpoled Field Down	Poled Field Down	Unpoled Field Up	Poled Field Up	Unpoled Field Down	Poled Field Down
OF1-KNN	51.14 ±1	52.77±1	49.72±2	52.13	52.42±1	52.9±1	51.72±2	53.63±1
OF2-KNN	49.19±4	51.5±3	49.79±2	53.01±3	51.49±3	53.9±2	53.97±2	56.2±1
OF3-KNN	49.93±1	49.01±2	50	51.65±2	52.46±1	50.7±1	53.43±1	53.5±1
TP1-KNN	46.49±5	51.13±1	48.3±1	52.21	48.75±2	51.45±2	52.88±2	52.71



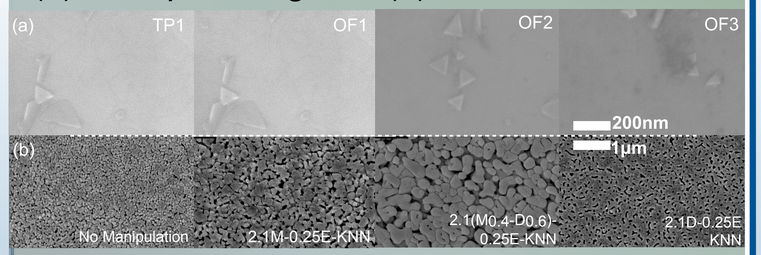
The highest poling condition observed under 125kV/cm at 155°C for RF-sputtered KNN films. A slight increase in both remanent $d_{33,f}$ and large signal $d_{33,f}$ are seen after poling.



Chemical Solution Deposition

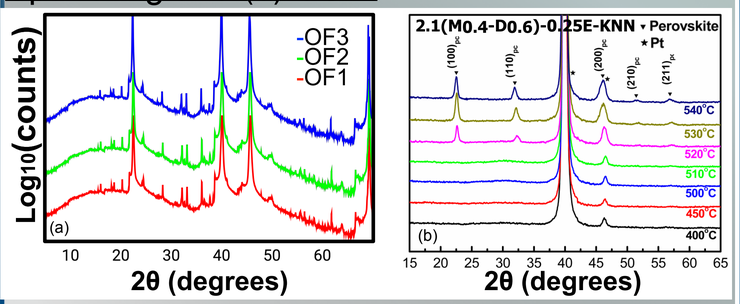
KNN Thin Film Sample	ε_r, at 1 kHz	D [%], at 1 kHz	Large Signal, d_{33} [pm/V]
KNN Control	429	19.2	30.6
2.1M-0.25E-KNN	479	14.1	67.1
2.1(M0.5-D0.5)-0.25E-KNN	525	13.1	73.5
2.1(M0.4-D0.6)-0.25E-KNN	529	11.7	78.3
2.1(M0.3-D0.7)-0.25E-KNN	543	13.8	74.3
2.1D-0.25E-KNN	518	15.2	71.4

Scanning Electron Microscope (SEM) for (a) RF Sputtering and (b) CSD:



- SEM images show KNN film samples' surfaces with potentially enhanced electrical responses.

X-Ray Diffraction (XRD) patterns of (a) RF-Sputtering and (b) CSD:



- XRD patterns show expected (100) KNN perovskite phase formation.

Discussion

Both CSD and RF-Sputtering methods used for making KNN thin films produced favorable dielectric properties. Disadvantages of CSD may come from chemical binding agents added to precursor solution, pinning from spin coat layering, or ion loss due to heating—in both methods. RF-Sputtering advantageously demonstrates strong crystal orientation.

Conclusion

Further study of lead-free KNN film deposition methods makes able improvement and optimization of piezoelectric properties.

References

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