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**13. ABSTRACT** *(Maximum 200 words)*

Major accomplishments of this program are the demonstrations summarized below:

(1) Large grain (0.5 to 0.8µm ),high preferred orientation (100) films of Pt on $SiO_2$/Si substrates by use of high deposition temperatures (600-650$^{o}$C) witha trace of reactive $O_2$ gas in the rf-PM sputtering gas.The Pt film , besides functioning as metallization for bottom electrodes for capacitors, promotes epitaxial like growth within its large grains and high crystal quality of the overlying KTN film.

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(4) High optical transmittivity of KTN films on Sapphire with nearly 99.5% of theoretical transmittivity.

(5) High quadratic EO effect in paraelectric phase of KTN films on GaAs and Sisubstrates. Observed EO response is nearly 70% larger than for substrates.Observed EO effect is nearly 70% larger than for the same effect in PLZT thin films in ferroelectric phase.

# F I N A L   R E P O R T

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6. AUTHORS OF REPORT: Dr.Sanat Sashital

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Manuscript:Title "Synthesis,Characterization and properties of RF-Planar Magnetron Sputtered . $KTa_xNb_{1-x}O_3$ Thin Films".Authors: S.Sashital,S.Krishnakumar and S.Esener.Submitted to Applied Physics Letters.Dec,92.Anticipated publication date: June 7,1993 ..Copies of this Ms have previously been mailed to Drs.R.Guenther and M.Ciftan.

8. SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD: S.Sashital

A Ph.D.(Electrical & Computer-Engineering) was awarded to S.Krishnakumar by UC SanDiego,Ca.(Thesis Advisor:Prof.S.Esener) Dept Of ECE.
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## BRIEF OUTLINE OF RESEARCH FINDINGS

(Final Report)

In adddition to reporting progress during the period Jan 1- May 31,1993 ,this final report also summarizes the major accomplishments of the program .During this reporting period,approximately three phone conversations were had with Dr.M.Ciftan (ARO) in regard to project performance and relevant adminstrative issues.

Optimization of KTN thin film Electrooptic (EO) and Ferroelectric (FE) properties continued during this period.Property Optimization was performed with respect to basic materials characteristics(film structure,composition/stoichiometry etc.) via film synthesis parameters; e.g. substrate temperature,deposition rate,sputtering target composition etc.) As described in earlier progress reports,the epitaxial like film structural quality was excellent and reproducible , as observed from the sharpness and singularity of the x-Ray Bragg reflection peaks i.e. { 100 } and higher orders only.However deficiency of 'K' in the KTN films continued to be a challenge.The deficiency of K originates from the lower sticking coefficient on the substrates ( GaAs,Pt/$SiO_2$ ,Sapphire etc.) at the deposition temperatures used (600-650$^{0}$ C).A higher excess 'K' concentration ( 25-30 atom% ) in the sputtering target with lower substrate temperatures and deposition rates is anticipated to yield stoichioimetric films with good structural quality in future work.The primary effect of 'K' deficiency is thought to lower the peak dielectric constant of the Curie temperature curve (i.e. the dielectric constant versus temperature behavior) of the KTN film than is observed in bulk single crystals.Thus, for KTN films reported here a peak dielectric constant of nearly 2250 is seen for a composition of $K_{.94}Ta_{.62}Nb_{.37}O_3$ as compared to a peak value in excess of 20000 for bulk crystals of the same composition.The superior crystal structural quality of the films is reflected in the single crsytal like sharpness of the Curie temperature plot.

Since a fundamental objective of this program was to demonstrate EO effects in KTN films ( for application to various EO devices/systems of DoD's interest ; e.g. EO light modulators,active and passive waveguides,smart pixels etc.) ,attention was primarily focussed during this reporting period on the measurement of EO and optical properties of films .

Figure 1 shows the measured refractive index 'n' versus wavelength '$\lambda$' of a KTN film (1.8 μm thick ) on a Si substrate.As can be seen ,the variation is qualitatively that of bulk single crystals.However ,the 'n' measured at 6138 A$^{o}$ is lower than that observed in bulk single crystals ( n=2.3). Similar behavior has been reported in other ferroelectric films (e.g. PLZT ) also and is thought to arise from the 'K' or 'A' site cationdeficiency in $ABO_3$ perovskite structure compounds.

EO coefficient measurements were made on KTN films deposited on Si and GaAs substrates.Sputtered Pt film electrodes were applied to yield transverse EO modulators i.e. E fields in film plane and optical field normal to the film.Using standard'Lock-in' techniques,beam splitters,etc. the field induced refractive index change due to applied electric field was studied at room temperature as a measure of the EO effect.For purposes of comparison ,a PLZT(61/29) film on a Pt film substrate(synthesized by Prof.Esener and his group at UCSD) was also similarly studied. Figure 2.clearly shows a substantially higher quadratic EO effect in KTN films (nearly 70% higher for KTN/Si than in PLZT films) . It is noteworthy that the observed quadratic EO effect in the <u>paraelectric phase of KTN at room temperature</u> is higher than the quadratic EO effect in <u>ferroelectric PLZT (Curie Temperature > $50^0$C)</u> .Since the nonlinear EO effect in the FE phase is usually an order of magnitude or higher than in the paraelectric phase,a substantially high value of EO coefficient may be expected for FE KTN films. **This observation of EO effect is the first report of such measurements in KTN films.**The differences in the EO reponse in films on GaAs and Si are thought to arise from the slight differences in crystallinity and composition. Thus,KTN films offer themselves as strong candidates for further studies,EO property maximization via improved materials characteristics and several important devices/systems for military and commercial application.

Major accomplishments of this program are the demonstrations summarized below:

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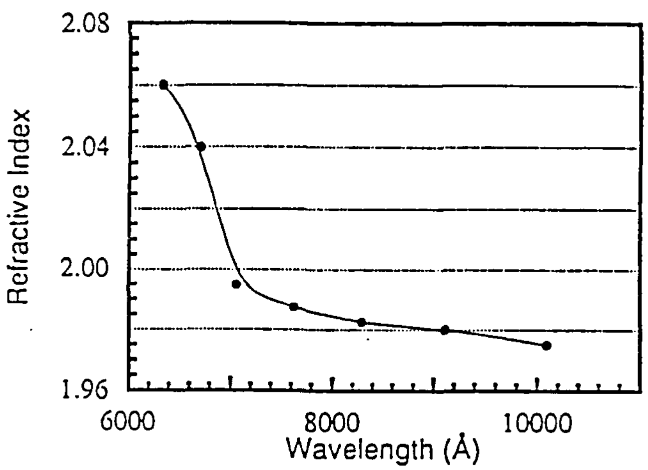


**Figure 1.** Refractive index vs.Wavelength KTN film on Si substrate.

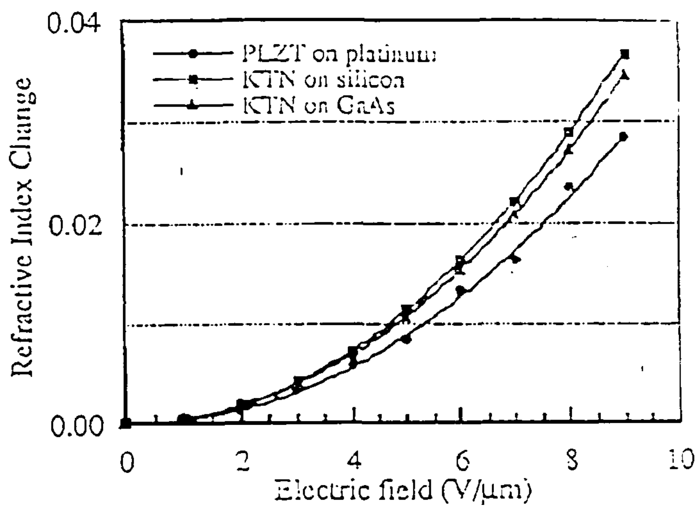


**Figure 2.** EO effect in KTN film on GaAs,Si substrates. PLZT film on Pt/Si substrate shown for comarison


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