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# Synthesis and Properties of a Few Selective Microwave Dielectric (Resonator) Ceramics

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Submitted in partial fulfillment of the requirements

of the degree of

Doctor of Philosophy

by


**Sandip Prabhakar Butee**

(Roll No. 02411801)

Supervisors:

Prof. Om Prakash

Prof. A. R. Kulkarni


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Department of Metallurgical Engineering and Materials Science

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY


(Year 2010)

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# Synthesis and Dielectric Studies of Some Layered Cuprate Ceramics

Fourth annual progress seminar report

Submitted in partial fulfillment of the requirements

of the degree of

Doctor of Philosophy

by

**Paresh H. Salame**

(Roll No. 07411006)

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INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

(August 2011)

# Contents

# Abbreviations and Nomenclature

AU- Arbitrary unit

$\overline{d}$ - Average particle size

$E_g$ - Activation energy

EDAX- Energy Dispersive X-ray Analysis

K- Temperature in Kelvin

k- Boltzmann's constant

R.temp- Room temperature

SC- Superconductor

SEM- Scanning electron microscopy

SSR- Solid state reaction

TD- Theoretical density

$T_N$- Antiferromagnetic temperature

XRD- X-ray diffraction

$\rho$- Electrical resistivity

$\sigma$- Electrical conductivity

$\varepsilon_r'$- Real part of dielectric constant

$\varepsilon_r''$- Imaginary part of dielectric constant

tan $\delta$ ($\varepsilon_r'$/ $\varepsilon_r''$) - Dielectric loss or dissipation factor

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# Chapter 4 ( Font size -18/Bold/ Centered )

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# Results and Discussion ( Font size -18/Bold/ Centered )

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The five different T′-type cuprates $Ln_2CuO_4$ (Ln = Pr, Nd, Sm, Eu and Gd) have been prepared (as disks) in ceramic sintered form. The phase purity, microstructure and dielectric properties are evaluated by XRD, SEM-EDS and Impedance Network analyzer respectively. The results are presented and discussed in this chapter.

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## 4.1 X-ray Diffraction Studies of Polycrystalline $Pr_2CuO_4$ ( Font size -16/Bold )

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Figure 4.1 shows the XRD patterns of the nominal $Pr_2CuO_4$ solid state racted at 950 °C for 36 h and of the subsequently sintered pellet (at 1000 °C for 12 h). Both the XRD patterns show clean tetragonal T′-type phase formation. The lattice parameters of $Pr_2CuO_4$ were computed using the Wincell software.

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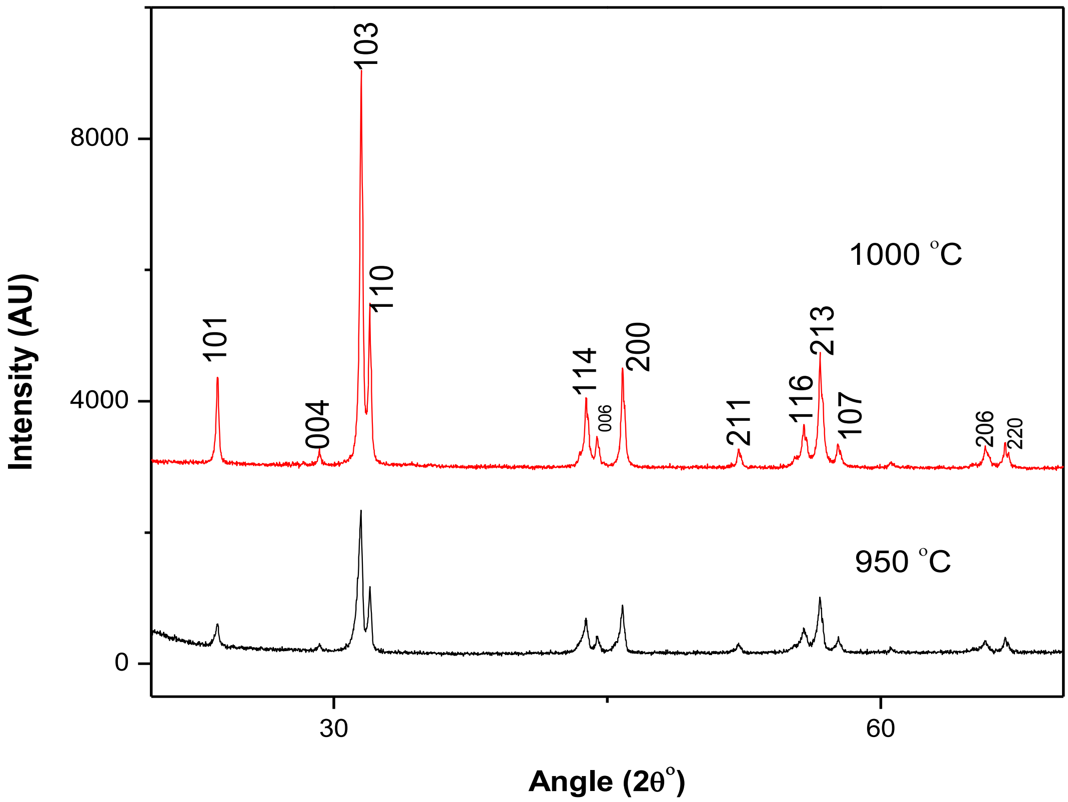
The lattice parameters and unit cell volume are given along with the corresponding JCPDS values in table 4.1. The values in the parentheses represent the uncertainty in the value of last digit of the lattice parameters.




( Font size -11/ Bold ) **Figure 4.1** XRD patterns of the nominal $Pr_2CuO_4$ solid state reacted (950 °C /36 h, air) powder and of the subsequently sintered (1000 °C /12 h) pellet. ( Font size -11 )

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**Table 4.5** Observed and computed (by additive rule of mixture [112]) dielectric properties of $(Ni_{1-x}Zn_x)Nb_2O_6$, $0 \leq x \leq 1.0$, sintered samples. Font size 11, with table and table No. in BOLD

| x | $\overline{D}$ ‡ (µm) | Observed | | | | Applying additive rule between the end members | | |
|---|---|---|---|---|---|---|---|---|
| | | $\varepsilon'_r$ | $Q_u.f$ (GHz) | $\tau_f$ (ppm/$^o$C) | $f$* (GHz) | $\varepsilon'_r$ | $Q_u.f$ (GHz) | $\tau_f$ (ppm/$^o$C) |
| 0.0 | 07.6 | 23.6 | 18900 | -62 | 4.36 | 23.6 | 18900 | -62.0 |
| 0.2 | 12.5 | 24.4 | 24250 | -63 | 4.31 | 24.1 | 35860 | -64.2 |
| 0.4 | 14.0 | 24.9 | 35370 | -66 | 4.27 | 24.6 | 52830 | -66.4 |
| 0.6 | 13.3 | 25.0 | 51330 | -66 | 4.27 | 25.1 | 69800 | -68.6 |
| 0.8 | 17.8 | 25.5 | 90420 | -68 | 4.22 | 25.6 | 86760 | -70.8 |
| 1.0 | 21.2 | 26.1 | 103730 | -73 | 4.18 | 26.1 | 103730 | -73.0 |

‡ Avg. grain size [151], * resonant frequency at which measurements were recorded.

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The adverse effect due to small porosity on the quality factor ($Q_u.f$) could be ignored for the dense (> 97% of the theoretical density) $(Ni_{1-x}Zn_x)Nb_2O_6$, $0 \leq x \leq 1.0$, samples [112]. However, the grain size effect on $Q_u.f$ need not be insignificant. For $NiNb_2O_6$ samples (with narrow size distribution), an average grain size of ~7.6 µm is obtained (see Fig. 4.18 and Table 4.5), which incidentally falls within the same range of grain size ~1-10 µm as reported by Pullar et al. [5] and the $Q_u.f$ =18900 GHz obtained here is also comparable. The $Q_u.f$ reported by Lee et al. [46] for $NiNb_2O_6$ is almost twice the value of what we have obtained; however, the grain size in their samples was not reported.

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References are left justified.

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2. References cited from the internet should be astrix (*) marked and given separately under Bibliography heading with complete details on  a separate page in ascending order.

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