UNIVERSITI PUTRA MALAYSIA

CORRELATION OF SOME DIELECTRIC PROPERTIES WITH PROCESSING AND MICROSTRUCTURE IN Mg-Sn-O SYSTEM

IFTETAN AHMAD TAHA

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By

IFTETAN AHMAD TAHA

Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Science and Environmental Studies, Universiti Putra Malaysia

February, 1999

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To:

My Parents .....

Husband .....

And

Sisters.

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Firstly, I am very grateful to " ALLAH " S.w.t. for giving me the strength, and patient, to complete this research within the specified time.

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LIST OF ABBREVIATIONS

λ	Wave Length
a, b, c	Lattice parameters
d_{hkl}	Reciprocal d vector
hkl	Miller indices
XRD	X-ray diffraction
SEM	Scanning Electron Microscopy
f, ω	Frequency and angular frequency
A	Cross Sectional Area
θ	Bragg angle
$\tan\delta$	Loss tangent
PVA	Polyvinyl alcohol
T	Temperature
TCC	Temperature Coefficient of Capacitance
TCK	Temperature Coefficient of Dielectric
K	Dielectric Constant
Cp	Capacitor
Gp	Conductor
logC	Logarithm of Capacitance
logf	Logarithm of Frequency
C	Capacitance
Tc	Critical Temperature

P	Pressure
t	Time
D	Diffusivity
$\beta_{1/2}$	Full width Half Maximum
I	Current
ε_o	Permittivity of Vacuum
V	Applied Voltage
EDAX	Energy Depressive Analysis by X-ray
Z	Impedance
M	Modulus
Y	Admittance
LP/CPA	Lumped Parameter /Complex Plane Analysis
α	Coefficient of Linear Thermal Expansion
ρ	Density
m	Mass
M_2S	Mg_2SnO_4
MS	$MgSnO_3$
AC	Alternating Current
ppm	Part per million

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science.

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IFTETAN AHMAD TAHA

February 1999

Chairman: **Abdul-Majeed Azad, Ph.D./ Mansor Hashim Ph.D.**

Faculty: **Science and Environmental Studies**

The alkaline-earth stannates having the general chemical formula $MSnO_3$ (M = Ca, Sr and Ba), have been projected as potential electronic ceramics (thermally stable capacitors, humidity sensor, carbon dioxide sensor, etc.). Even though magnesium is a member of the metal group to which Ca, Sr and Ba belong, no reliable technical information on the compounds in the pseudo-binary $MgO\text{-}SnO_2$ system appears to exist in the published literature. In view of the information gaps in the reported research, vigorous and systematic investigation has been carried out on the $MgO\text{-}SnO_2$ system.

The $MgO\text{-}SnO_2$ system has been thoroughly studied with respect to synthesis, processing and characterisation – physical, microstructural and electrical. Two different synthesis routes have been adopted. These routes are solid-state and self-heat-sustained. For each route two mixtures of different molar ratio viz., 2:1 and 1:1 have

been used. In 2:1 molar ratio mixtures Mg_2SnO_4 has been formed as a single phase upon calcination of starting materials at 1200 ^oC/ 24 h in both solid-state and self-heat-sustained techniques with one or two impurity peaks at 1200 ^oC/ 24 h. In 1:1 molar ratio, the reaction product consisted of a two-phase mixture of Mg_2SnO_4 and SnO_2. Evaluation of microstructure that is intimately related to the envisaged properties in the ceramics has been closely and systematically followed as a function of sintering at different temperatures of (1200-1600 ^{o} C) and soak - time (2 - 48 h).

A thorough analysis of the as measured electrical data showed that the material possessed a very weak temperature dependence of capacitance (TCC) and dielectric constant (TCK) in the range 27-300 ^0C over several decades of frequency domain. It was found that TCC value varied between (-200 to +195) ppm / K thus holding the promise to its usage as a thermally stable capacitor component in high-speed electronic devices. The average dielectric constant was found to be in the range 10-18, thus identifying this material as a low dielectric constant system as well.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia bagi memenuhi keperluan ijazah Master Sains.

KORELASI BEBERAPA SIFAT DIELEKTRIK DENGAN PEMPROSESAN DAN MIKROSTRUKTUR DALAM SISTEM Mg-Sn-O

Oleh

IFTETAN AHMAD TAHA

Februari 1999

Pengerusi : Abdul-Majeed Azad, Ph.D./ Mansor Hashim, Ph.D.

Fakulti : Sains dan Pengajian Alam Sekitar

Stanat alkali – bumi yang mempunyai formula kimia am M SnO_3 (M = Ca, Sr dan Ba) telah diutarakan sebagai seramik elektronik yang berpotensi (kapasitor stabil terma, sensor kelembapan, sensor karbon dioksida dan sebagainya). Walaupun magnesium adalah dalam ahli kumpulan logam yang dipunyai oleh Ca, Sr dan Ba, tidak ada maklumat teknikal yang boleh dipercayai terhadap sebatian itu dalam sistem binari-pseudo MgO–SnO_2 yang wujud dalam penulisan yang diterbitkan. Memandangkan terdapatnya jurang maklumat dalam laporan penyelidikan, siasatan secara sistematik dan bersemangat telah dijalankan terhadap sistem MgO – SnO_2.

Sistem MgO–SnO_2 ini telah dikaji secara menyeluruh terhadap sistesis, pemprosesan dan ciri-ciri fizikal, mikrostruktur dan elektrik. Dua laluan sintesis yang berbeza, iaitu teknik keadaan–pepejal dan tahan–haba–sendiri telah gunakan. Untuk kedua-dua laluan ini, dua campuran molar yang berbeza, dengan nisbah 2:1 dan 1:1 telah disediakan. Dalam campuran nisbah molar 2:1, Mg_2 SnO_4 telah terbentuk sebagai fasa tunggal terhadap pemansan bahan awal pada suhu 1200 ^{0}C / 24 jam dalam kedua-

dua teknik iaitu keadaan –pepejal dan tahan – haba – sendiri dengan satu atau dua puncak bendasing.

Dalam nisbah molar 1:1, produk tindakbalas terdiri daripada dua fasa campuran Mg_2 SnO_4 dan SnO_2. Penilaian terhadap mikrostruktur yang berkait rapat dengan sifat-sifat jangkaan dalam seramik telah diikuti rapat dan sistematik sebagai fungsi terhadap pensinteran pada suhu yang berbeza iaitu 1200 – 1600 ^{0}C selama 2 – 48 jam.

Satu analisis yang terperinci terhadap data pengukuran elektrik menunjukkan bahawa bahan ini memiliki persandaran subu yang amat lemah terhadap kapasitan (PSK) dan pemalar dielektrik (PSD) dalam julat 27 – 300 ^{0}C untuk beberapa dekad domain frekuensi. Telah dijumpai juga bahawa nilai KPS berubah antara (-200 kepada +195) ppm / K dan sekaligus memberi jaminan kegunaannya sebagai komponen kapasitor stabil terma dalam peranti elektronik kelajuan – tinggi. Purata pemalar dielektrik yang telah dijumpai adalah dalam julat 10-18, justeru itu juga mengesahkan bahan ini sebagai sistem pemalar dielektrik yang rendah.

CHAPTER I

INTRODUCTION

Relevance / Importance of Electronic Ceramics

Ceramics materials are polycrystalline, inorganic materials which consist of metallic and nonmetallic elements bound together primarily by ionic and / or covalent bonds. The chemical composition of ceramic materials varies considerably, from simple compounds to mixtures of many complex phases bonded together. The earliest use of ceramics was in pottery and bricks (Koller, 1994).

The properties of ceramic materials also vary due to differences in bonding. In general, ceramic materials are typically hard and brittle with low toughness and ductility.

Ceramics are usually good electrical and thermal insulators due to the absence of conduction electrons. They have relatively high melting temperatures and high chemical stability in many hostile environments due to the stability of their strong bonds. In general, ceramics materials used for engineering applications can be divided into two groups: traditional ceramic materials, made