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STUDY AND ANALYSIS OF OXIDE MATERIALS USING FUZZY LOGIC TECHNIQUE

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ABSTRACT

In this paper oxides of various conducting materials are studied and this knowledge is used for various electronic applications. The experimental analysis of oxides is done with the help of LCR tanδ digital meter and Q - factor meter. These experimental values are compared with the theoretical values found by using the mass law. Solid state reactions method is applied for the synthesis of oxides materials in which reaction takes place in solid state form. The properties of the product is investigated through various techniques such as X-ray diffraction for phase, evaluation and lattice parameter study. Semiconducting materials are also studied using several parameters and thermal conductivity. The resistivity is calculated by mass law and by pattern recognition method. Fuzzy logic has been used to give better results as it can take large number of factors of failures.

KEY WORDS*:* This paper contains three important terms, they are reliability, permittivity and resistivity.

1. INTRODUCTION

In this paper the experimental and theoretical analysis of various oxides of conducting materials has been conducted. This analysis helps us in better understanding of the properties of these materials. The work has both intrinsic scientific interest and technological utility in dielectrics , semi-conductors and other transducer materials.

This paper deals with the simulation of oxides experimentally using LCR tanδ digital meter and Q - factor meter. The mass law is used to find the measured parameters theoretically. Silver compounds, sodium oxides, iron oxides, mercury oxides etc are put to the study for resistivity. The resistivity is obtained from the Earth materials and probability method

A vector of thermal conductivity is formed then comparison of these results with the well know semi-conductors Ge and Si and their oxides. The resistivity of silicon varies from $640\,\Omega - m$ to $0.3\Omega - m$. SiO_2 has $D = 3.1, \rho = 100\Omega - m$ and dielectric constant $\varepsilon_r = 8.13.$ Parameters of Si and Ge as semi conductors are obtained to compare with the oxides of silicon, SiO_2 and oxide of germanium GeO .

Some available oxides of conductor materials like aluminum, Silver, copper, Iron, mercury nickel, Zinc are studied in this paper. Nitrogen(N), sulphur(S) and oxygen(O_2) can contact them as well and it is noticed, they are dielectric materials. It has very high surface resistivity $\rho_s = 200\Omega$. The resistivity calculations will be made using all these parameters and behavior of Al_2O_3 in mixtures of dielectric materials. The density of Al is 2.71 g/cm^3. While the density of Al_2O_3 is 3.965 g/cm^3. This a peculiar case in the oxides because the density of oxides is always less than the density of element.

Solid state reactions method are applied for the synthesis of oxides materials in which reaction takes place in solid state form. The properties of the products are investigated through various techniques such as X-ray diffraction for phase, Evaluation and lattice parameter study. The microscopic mass law and macroscopic mass law are simple and practical.

The SiO_2 material is used in the making of microprocessor chips and integrated circuits; it is used as dielectric material .The behavior of SiO_2 is very peculiar and out of way of oxide formation law that density of oxides is always less than the base element. Composite materials are formed by layers and laminations. The Fuzzy logic l gives us better results as it can take large number of factors of failures. The neural network reads the Fuzzy membership functions and Fuzzy logic has a Fuzzifiers and defuzzification models. The union and intersection of Al and Al_2O_3 as well as Al oxides are described by Fuzzy cardinality and relative Fuzzy cardinality.

2. ANALYSIS OF PROPERTIES OF OXIDE MATERIALS

Here some available oxides of conductor materials like aluminium, Silver, copper, Iron, mercury nickel, zinc are studied. Nitrogen, sulphur and oxygen can contact them well, and we notice following oxides.

2.1 Al_2O_3

The resistivity of Al_2O_3 is $100\Omega - m$ other parameters can change the resistivity of Al_2O_3

Melting point (MP) = 2290

Boiling point (BP) = 3250 (1)

Density D = 3.965 g/cm^3

n=Refractive Index of light n = 1.768

Permittivity $\varepsilon_r = 12$

Magnetic permeability $\mu_r = 1.00$

Loss tangent $\tan\delta$ = .02

It is dielectric materials. It has very high surface resistivity, $\rho_s = 200\Omega$. The resistivity calculations are made using all these parameters and behavior of Al_2O_3 in mixtures of dielectric materials. The density of Al is 2.71 g/cm^3, while the density of Al_2O_3 is 3.965 g/cm^3. This a peculiar case in the oxides because the density of oxides is always less than the density of element. Silver oxides are not available in the study but utility of $AgNO_3$, $AgBr$ and $AgCL$ as dielectrics and semi conductors can be pointed out. These are comparable to the oxides and these materials are easily available for uses.

2.2 Methodology

Solid state reactions method is applied for the synthesis of oxides materials in which reaction takes place in solid state form. In this method oxygen rich compounds of the constituent materials like oxides, carbonates nitrates or oxalates are used as starting materials. They are mixed in stoichiometric ratio and ground thoroughly in an agate mortor till it become homogeneous. This mix will be heated at temperature around 900° to 1300°c so that further reaction takes place. This heating temperature depends on the type of compound. This heating step is known as calcinations and is carried out in a furnace through resistance heating. The process of grinding and calcinations can be repeated once or twice to complete the reaction, so that the structure becomes perfect.

Further the sample is ground again and compaction is done in the form of pellets by using a die in press by applying pressure of about 10 tonnes. These pellets are sintered at high temperature, which is usually little less than the melting point of the material. The sintering temperature and time is very crucial in deciding the properties of the product. The sintering improves the strength as well as the tensile strength and density.

The most important part of annealing is made. The oxygen balance is activated by the process of annealing [43,44]. In annealing the sample is heated in the presence of oxygen flow. These heating schedules are followed by either rapid cooling or furnace cooling, then the sample is ready for characterization.

The properties of the product is investigated through various techniques such as X-ray diffraction for phase. Evaluation and lattice parameter study. The microscopic mass law and macroscopic mass law which are simple and practical are used. Low temperature resistance measurement by four probe methods. Some other characterization may be done as required the results of these investigations are analyzed to optimize the process parameter for the good samples.

The study proposed work has both intrinsic scientific interest and technological utility as dielectric semi conductors and other transducer materials.

2.3 Silver Compounds

Silver oxides are rarely available we find $AgNO_3$, $AgBr$ and $AgCL$ for our models.

Table 2.1

Materials	MP	BP	D	n	ρ	ε_r	μ_r	$\tan\delta$
$AgNO_3$	485	717	4.352	1.744	60	6	0.99	0.02
AgBr	705	1600	6.473	2.352	100	10	0.99	0.03
AgCl	728	1820	5.56	2.071	100	8	0.99	0.003
$ZnCO_3$	---	---	4.398	1.818	150	6	0.999	0.08
$ZnCl_2$	---	---	2.91	1.687	100	8	0.999	0.09
ZnO	---	---	5.606	2.004	200	4.8	1	0.08

Table 2.2

Materials	MP	BP	D	n	ρ	ε_r	μ_r	$\tan\delta$
CuO	1599	---	6.4	2.1	100	12	0.999	0.06
Cu_2O_3	1508	---	6	2.705	90	14	0.999	0.08
$CuSO_4$	---	---	36.5	1.733	100	16	1	0.02
$CuSO4.5H_2O$	---	---	2.84	1.537	50	60	0.999	0.04

Table 2.3

Materials	MP	BP	D	ρ	ε_r	μ_r	$\tan\delta$
FeS	1470	---	4.74	100	8	1200	0.03
Fe_2O_3	1838	---	5.25	200	7	1400	0.04
Fe_3O_4	1810	---	5.18	300	6	1600	0.06
$HgCL$	670	---	7.15	100	6	0.99	0.08
$HgCl_2$	549	---	5.44	200	8	0.99	0.09
HgO	800	---	11.1	100	10	1	0.06
NiO	2260	---	6.67	90	10	800	0.02
$NiCl_2$	1274	---	3.55	100	12	900	0.04

Sodium oxides

$$NaBr + NaCL + NaF + NaH + NaHCO_3$$

$$NaHSO_4 + NaI + NaOH + Na_2O + Na_2SO_4 \qquad (2)$$

2.4 Iron oxides

Iron is must often used as conductor due to its strength and economy steels can not be made with out iron content less than 90%. The iron is very active in the presence of:

$$SO_2 + SO_3 + S + H_2S$$

The FeS is always mixed with Fe_2O_3 and Fe_3O_4 be can se iron is active in the oxygen content O_2.

A study of a mixture of

$FeS + Fe_2O_3 + Fe_30_4$ is made under the properties: (4)

Molecular weight (M) melting point (MP) Boiling point (BP).

Density (D), refractive index of light Resistivity (ρ), permittivity (ε_r). Magnetic permeability (μ_r) and loss tangent $(\tan\delta)$. The mass law of mixing is used to form a material under solid state characterization. The density of Iron oxide is less than the Iron element, density.

2.5 Mercury oxides

Mercury is used as a conductor in many situations like mercury switch, mercury am per hour meter. The chlorine can react to make such good materials for our uses. A mixture of the components.

$$(HgCL + HgCl_2 + HgO) \quad (5)$$

is formed using mass law of mixing and the above vector of properties is obtained:

$$(M, MP, BP, D, n, \rho, \varepsilon_r, \mu_r, \tan\delta) \quad (6)$$

The resistivity of Fe_2O_3 as semi conductor is .01 to $.1\Omega - m$ an Earth material as $200\Omega - m.$

2.6 Nickel oxides

Nickel conductor are rarely used but nickel is available in large number of alloys and steels in small quantity to increase the strength. Nickel is Magnetostrictive and its compounds like oxides and chlorides should be looked with great alertness. A compound

$$NiCl_2 + NiO$$

is available jointly as mixture and show very interesting properties in table II.3. The resistivity is random and related to the Earth. Earth is the mother to produce these materials. The Earth is a mixture of air, water and the soil. The density of Earth would be

$$D = (5.5 + .001293)/3 = 2.1671 g/cm^3 \quad (7)$$

The dielectric constant of Earth would be:

$$(Earth + Water + Air) \quad (8)$$

$$(15 + 1.0006 + 81)/3 = 32.33 \quad (9)$$

2.7 Zinc oxides

Zinc is used in conductors and fuses. Zinc is affected by CO and CO_2 to form $ZnCO_3$. The chlorine is highly reactivity to Zinc to form $ZnCl_2$. The oxygen also affects the Zinc to form ZnO. A compound with $Zinc$ oxide would be:

$$ZnCO_3 + ZnCl_2 + ZnO \quad (10)$$

The $Zinc\ Zc$ has a density between 7 and 8 and its compounds density is lower than the density of the element Zn. We have respectively.

$$(4.398,\ 2.91,\ 5.606)\, g/cm^3$$

For $ZnCO_3, ZnCl_2$ and ZnO

2.8 Thermal conductivity

Thermal conductivity of elements is greater than the thermal conductivity of oxides and other compounds. A vector of thermal conductivity is formed as follows.

$$(Al, Cu, Ag, Au, Na, Sn, Zn, Pb, Fe) =$$

$$(Tc)^* = (201, 385, 419, 296, 134, 65, 111, 35, 80) \qquad (11)$$

Aluminium, copper, silver, gold, sodium, tin, Zinc, lead and Iron

$$(Al, Cu, Ag, Au, Na, Sn, Zn, Pb, Fe) =$$

$$(Tc)^* = (201, 385, 419, 296, 134, 65, 111, 35, 80) \quad W/mK$$

2.9 Study of semi-conductors

These results are compared with the well known semi-conductors Ge and Si and their oxides. A vector is formed as follows:

Ge: Germanium

1 $D =$ Density = 5.3 g/cm^3

2 $\rho =$ Resistivity = 0.47 Ω-m

3 $\varepsilon_r =$ Dielectric constant = 16.0

4 $\mu_r =$ permeability=0.9999

5 $MP =$ Melting point =936°C

6 $S =$ Specific heat capacity = .08 cal/gc

7 $Tc =$ Thermal conductivity =.55 W/cm ^{0}C

8 $\alpha =$ Thermal coefficient of expansion = 6 x 10^{-6}

9 $Eg =$ Energy gap = 0.67 ev

10 $E_{BP} =$ Barrier potential = 0.30v

A vector of properties is formed for mass law transformation of the doping and impurities as well the reliability off the semi conductors to compare with the oxides

$$\begin{bmatrix} D \\ \rho \\ \varepsilon_r \\ \mu_r \\ MP \\ S \\ Tc^* \\ \alpha \\ E_g \\ E_{BP} \end{bmatrix} = \begin{bmatrix} 5.3\, g / cm^3 \\ 0.47\,\Omega - m \\ 16 \\ .9999 \\ 936 \\ .08\, cal / gc \\ .55\, w / cm\, c^\circ \\ 6\times10^{-6} \\ .67 ev \\ .30 v \end{bmatrix} for\, Ge \tag{13}$$

For Si we have:

$$\begin{bmatrix} D \\ \rho \\ \varepsilon_r \\ \mu_r \\ MP \\ S \\ Tc^* \\ \alpha \\ E_g \\ E_{BP} \end{bmatrix} = \begin{bmatrix} 2.3\, g / cm^3 \\ 0.3\,\Omega - m \\ 12.5 \\ .9999 \\ 1414^{\circ c} \\ 0.17\, cal / gc \\ .8\, w / cm^{\circ c} \\ 4.2\times10^{-6} \\ 1.14 ev \\ 0.70 v \end{bmatrix} \Rightarrow \overset{\lambda i}{\begin{bmatrix} .4343 \\ .123 \\ .08 \\ .123 \\ .336 \\ .132 \\ .336 \\ .421 \\ .512 \\ .712 \end{bmatrix}} \Rightarrow \overset{\text{Ri}}{\begin{bmatrix} .647 \\ .8842 \\ .923 \\ .8842 \\ .714 \\ .896 \\ .7146 \\ .6563 \\ .560 \\ .490 \end{bmatrix}} \tag{14}$$

The resistivity of silicon varies from $640\,\Omega - m$ to $0.3\Omega - m$. The silicon oxide SiO_2 has $D = 3.1, \rho = 100\Omega - m$ and dielectric constant $\varepsilon_r = 8.13.$ The Si is always derived from SiO_2 compound for semi conductors. The Si and Ge as semi conductors is compare with the oxides of silicon SiO_2 and oxide of germanium GeO. We form a mixture to study them as: $SiO_2 + GeO + Si + Ge$

We form a mixture to study. (15)

$$Ge + Si + fe_2O_3 + InSb + Se$$

2.10 Oxides mixing

Following oxides for our study and investigation are prepared.

$$ZnO, Fe_2O_3, Fe_3O_4, HgO, NiO, SiO_2 \text{ and } MgO, Al_2O_3, CuO, Cu_2O_3 \quad (16)$$

Table 2.4

Oxides	D	ρ	ε_r	n	R_i r
ZnO	5.606	200	4.8	2.004	.912
Fe_2O_3	5.25	200	7	---	.876
Fe_3O_4	5.18	300	6	---	.778
HgO	11.1	100	10	---	.668
NiO	6.67	90	10	---	.912
SiO_2	3.1	100	8.13	---	.966
MgO	3.6	90	11	---	.712

Al_2O_3	3.8	200	8	---	.926
CuO	6.4	100	6	2.1	.889
Cu_2O_3	6	90	7	2.705	.896
	5.676	**147**	**7.7193**		

The relative density is given in the tables of chemistry and physical tables of Clarke the resistivity is obtained from the Earth materials and probability method.

The resistivity of Earth, water and air is $100\,\Omega - m$. Thus the resistivity is calculated by mass law and by pattern recognition method. The D, ρ and ε_r accordingly when resistivity of Earth is $100\,\Omega - m$ and permittivity $\varepsilon_r = 15$.

(II).11 Study of SiO2:

We have explained properties of SiO_2 oxide now we will explain reliability of this oxide under the properties as the MTBF and MTTF.

MTBF: Mean time between failures.

MTTF: Mean time to failure

This is an oxide of density $D = 3.1\,g/cm^3$ while its base Si has a density $D = 2.3\,g/cm^3$. The density is increased by:

$$(3.1 - 2.3) = .8 \qquad (18)$$

The dielectric constant $\varepsilon_r = 8.13$ and that of $Si, \varepsilon_r = 12.5$

The dielectric constant is reduced

$$\frac{\varepsilon_{r_1} - \varepsilon_{r_2}}{\varepsilon_{r_1} + \varepsilon_{r_2}} = \frac{12.5 - 8.13}{12.5 + 8.13} = \frac{4.37}{20.53}$$

$\lambda =$ Failure Rate = 0.21285 (19)

Reliability = R=.8082

The specific change in the density would be

$$\lambda = \frac{3.1 - 2.3}{3.1 + 2.3} = \frac{0.8}{5.4} = .148148 \quad (20)$$

R=.8623

The SiO_2 material is used in the making of micro processor chips and integrated circuits. It is used as dielectric material. The behavior of SiO_2 is very peculiar and out of way of oxide formation law that density of oxides is always less than the base element. For dielectric constant of oxides is increased but here it is reduced from 12.5 to 8.13 and density is increased from 2.3 to 3.12 g/cm^3.

2.12 Study of Al_2O_3 in Reliability Space

A space of parameters is formed as follows $(MP, D, BP, \varepsilon_r, \rho, n, \mu_r, \tan\delta)$

$$(2290, 3.965, 3250, 12, 1.768, 1.0, .02)$$

The density of Aluminum is 2.71 and their of Al_2O_3 is 3.965. (21)

$$\lambda_D = \frac{3.965 - 2.71}{3.965 + 2.71} = \frac{1.255}{6.675} = .188$$

$R = .8286 = \text{Re}\,liability.$

The reliability of Al_2O_3 using the eight parameters is

$$R = .766 \tag{23}$$

The security and adequacy. Would be 0.816 and 0.779 respectively

The dielectric constant of Al is $\varepsilon_r = 1$ while that of Al_2O_3 is 12. Thus a change in the dielectric constant would be

$$\lambda_{(\varepsilon_r)} = \frac{12-1}{12+1} = \frac{1}{13} = .846 = R = 0.429 \tag{24}$$

The density failures and dielectric constant failures may go simultaneously

$$\sum \lambda = .188 + .846 = .355 \tag{25}$$

Dielectric constant ε_r is highly delicate than the density. The rate of change of dielectric constant and density are found in practical devices.

2.12.a Reliability of Germanium and Silicon

The property vector of Ge and Si given in equations (13) and (14) can be used and for obtaining the failure rate in the parameters help of fuzzy logic transformation of parameters can be taken to find reliability.

$$Ge \Rightarrow \begin{bmatrix} .828 \\ .776 \\ .939 \\ .812 \\ .526 \\ .778 \\ .821 \\ .786 \\ .889 \\ .798 \end{bmatrix} Si \Rightarrow \begin{bmatrix} .812 \\ .712 \\ .912 \\ .796 \\ .782 \\ .786 \\ .831 \\ .782 \\ .889 \\ .812 \end{bmatrix} = [R]$$

The Fuzzy cardinality of Ge is 7.953 and relative Fuzzy cardinality.

$$R_{(Gc)} = 0.7953$$

The Fuzzy cardinality of silicon is 7.318 and Relative Fuzzy cardinality

$$R_{(Si)} = 0.7318 \tag{27}$$

2.12.b Reliability of all the ten oxides when they are mixed

Table 2.4 Represents ten oxides with their parameters D, ρ and ε_r which are enough to describe the properties of the oxides. The reliability of material is an important problem for engineers as well as for the scientists and technologist.

$D = 5.676\, g/cm^3, \rho = 147\,\Omega - m$ and

$\varepsilon_r = 7.793.$ one can obtain the failure rate of the materials for D, ρ and ε_r as follows:

$$\lambda_D = .1761 \quad R_D = .8384$$

$$\lambda_\rho = .0068 \quad R_e = .993 \tag{28}$$

$$\lambda_{\varepsilon r} = .1283 \quad R_{\varepsilon r} = .879$$

The average reliability would be:

$$R_{av} = 0.903 \tag{29}$$

The mechanical reliability of the solids is more than their oxides. The oxides have lower density and lower tensile strength but their resistivity is in mega ohm-meter or $MM\Omega - m.$ The resistivity of oxides in refined manner for the purpose may very up to 10^{12} to 10^{18} to $10^{28}\,\Omega - m$.

The reliability of oxides always decreases with time and follows mass law of mixing for the mixtures and alloys. Oxides always want to mix with the earth because they have great affinity to the earth.

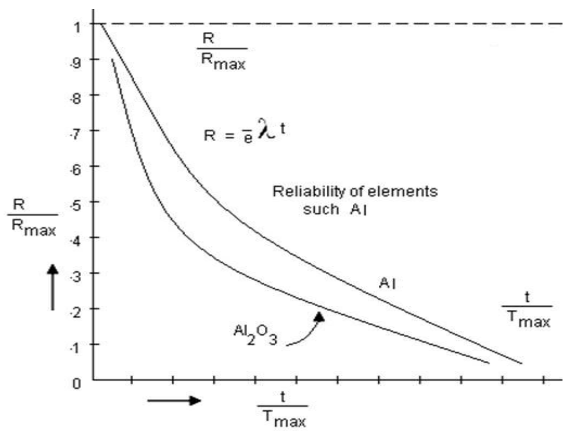

Figure 1 : Reliability of Al and Al_2O_3

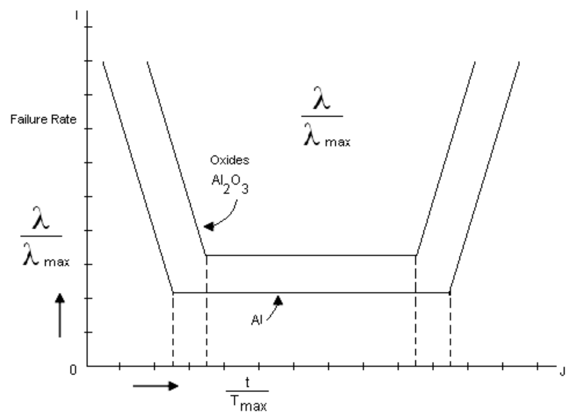

Figure 2 : Failure rate of Al and Al_2O_3

Figure 1 represents the reliability of Aluminium and Aluminium oxide. The oxides have lower reliability due to poor strength, brittleness, Fractured easily, no compatibility. One can form composite materials by layer and laminations.

Figure 2 represents the failure rate of oxides and material aluminium oxides have higher failure rate, Aluminium lower failure rate. The Fuzzy logic will give us better results as it can take large number of factors of failures. The neural network will read the fuzzy member ship functions and fuzzy logic has a fuzzifiers and defuzzification modes. We will discuss this problem in chapter five, where reliability of materials are taken as important problem. We will explain the union and intersection of Al and Al_2O_3 as well as Al oxides will be described by Fuzzy cardinality and relative fuzzy cardinality. In place of mass law we will use the intersection and union of all the properties of alloys oxides and elemental materials.

3. CONCLUSION

The analysis of the properties of the oxide materials of conducting substances helps us create mixtures with properties suitable for electronic applications. The work has both intrinsic scientific interest and technological utility in dielectrics, semi-conductors and other transducer materials. Silicon oxides find use in microprocessor chips and for manufacturing of dielectric substances.

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