

**EFFECTS OF METAL OXIDES NANOPARTICLE
FILLERS ON ETHYLENE-PROPYLENE-DIENE
RUBBER (EPDM) PROPERTIES**

**By
Eng. Yasser Mohamed Tufik Ali**

**A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment
of the Requirements for the Degree of
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In
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Under the Supervision of

Prof. Dr. Ehab Fouad Abadir
Faculty of Engineering,
Cairo University

Prof. Dr. Sahar El-Marsafy
Faculty of Engineering,
Cairo University

Prof. Dr. Mohamed Samir
Mobark Academy

Prof. Dr. Ahmed Esmail
National Research Center

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**Approved by the
Examining committee**

Prof. Dr. Ehab Fouad Abadir

Thesis Main Advisor

Prof. Dr. Sahar Mohammed El-Marsafy

Member

Prof. Dr. Shadia Shafik Aggour

Internal Examiner

Prof. Dr. Salwa Hasan El-Sabbagh
National Research Center

External Examiner

**Faculty of Engineering, Cairo University
Giza, Egypt
2017**

Engineer's Name: Yasser Mohammed Tufik Ali
Date of Birth: 12/4/1967
Nationality: Egypt
E-mail: yassxx2176@yahoo.com
Phone: 01064002678
Address: 33 Mahmood Gonium st. Naser City
Registration Date: 16/12/2008
Awarding Date: / /2017
Degree: Doctor of Philosophy
Department: Chemical Engineering

Supervisors: Prof. Dr. Ehab Fouad Abadir
Prof. Dr. Sahar El-Marsafy
Prof. Dr. Ahmed Esmail (National Research Center)
Prof. Dr. Mohmed Samir (Mobark Academy)

Examiners: Prof. Dr. Salwa Hasan El-Sabbagh (National Research Center)
Prof. Dr. Shadia Shafik Aggour
Prof. Dr. Ehab Fouad Abadir (Thesis main advisor)
Prof. Dr. Sahar El-Marsafy (Member)

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PROPYLENE-DIENE RUBBER (EPDM) PROPERTIES

Key Words:

Metal oxides; Nanoparticle; Fillers; EPDM

Summary:

The present work is concerned with improving the mechanical properties and thermal stability of Ethylene propylene diene monomer EPDM by using metal oxide nanofillers. Metal oxide nanoparticles (nMO) such as (nCuO), (nFe₂O₃), (nZnO) and (nNiO) (size 50–100 nm) are synthesized by Sol-Gel technique and characterized. The effect of incorporating nMO, as nanofillers on the curing vulcanization behavior, morphology, mechanical properties, swelling and thermal properties of ethylene-propylene-diene EPDM elastomer compound is studied. The obtained results of the new composite were compared with ethylene-propylene-diene (EPDM) elastomer filled by conventional metal oxide (cMO) such as (cFe₂O₃, cNiO, cZnO, cCuO).

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TABLE OF CONTENTS

	Page
AKNOWLEDGEMENTS.....	
TABLE OF CONTENTS	i
LIST OF TABLES.....	vi
LIST OF FIGURES	vii
NOMENCLATURE.....	ix
ABSTRACT.....	xii
CHAPTER (1) INTRODUCTION	1
CHAPTER (2) HISTORICAL REVIEW.....	3
2.1 Ethylene propylene diene rubbers (EPDM)	3
2.1.1 Vulcanization of EPDM.....	5
2.1.1.1 Sulfur vulcanization	5
2.1.1.2 Peroxide Vulcanization.....	6
2.1.2 Effects of Crosslink Density and Crosslink type	6
2.1.3 Additives to Improve Crosslinking Efficiency	6
2.1.4 Reinforcement of Elastomers	7
2.2 Effect of Activators in Accelerated Sulphur Vulcanisation in Rubbers.....	7
2.2.1 ZnO as Activator for Sulphur Vulcanisation.....	8
2.2.2 Effects of ZnO as Activator of Accelerated Vulcanisation....	9
2.2.3 Effects of Nano ZnO as Activator.....	9
2.2.4 Synergistic Effects of Stearic Acid	9
2.2.5 Zinc Oxide optimisation as Activator for Sulphur vulcanization in EPDM Rubbers	10
2.3 Various Metal effect of Oxide as Activator for Sulphur vulcanization in EPDM Rubbers	11

2.3.1 The Comparison of Metal Oxides In with ZnO.....	12
2.3.2. Metal Oxides as Activator in EPDM Rubber Compounds ...	12
2.4 Nanotechnology in polymeric materials	15
2.5 Types of Nanofillers	15
2.5.1 Spherical Nanoparticles.....	16
2.5.1.1 Metal oxide nanoparticles	16
2.5.1.1.1 preparation of copper oxide (CuO) nanoparticles.....	17
2.5.1.1.2 preparation of iron oxide (Fe ₂ O ₃) nanoparticles...	17
2.5.1.1.3 preparation of ZnO nanoparticle.....	17
2.5.1.1.4 preparation of NiO nanoparticles.....	18
2.5.2 Layered Silicates.....	18
2.5.3 Nanotubes.....	18
2.5.4 Bionanofillers.....	18
2.6 Methods of producing Metal oxide nanoparticles.....	18
2.6.1 Synthesis metal oxide nanoparticle by Sol-gel technique.....	19
2.6.1.1 The complexing sol–gel synthesis.....	20
2.6.1.2 Applications of Sol–Gel in Nanotechnologie.....	23
2.6.1.3 Economic Aspects.....	24
2.6.2 Nanoparticle synthesis in microemulsions.....	24
2.6.3 The co-precipitation Method.....	24
2.6.4 Hydrothermal synthesis Method	24
2.7 Rubber Nanocomposites.....	25
2.7.1 Advantages of Rubber Nanocomposites	25
2.7.2 Challenges of Rubber Nanocomposites	26
2.8 Diffusion and transport of toluene through nano and conventional metal oxide/EPDM,.....	26
2.8.1 Diffusion coefficient (D).....	26
2.8.2 Sorption coefficient (S).....	26

2.8.3 Permeability coefficient (P).....	27
2.8.4 Transport Mechanism.....	27
2.8.5. Activation parameter.....	27
2.9 Thermal Degradation Kinetics.....	28
2.9.1 Kinetic methods used in calculating activation energy	28
CHAPTER (3) STATEMENT OF THE PROBLEM.....	29
 CHAPTER (4) MATERIALS & EXPERIMENTAL TECHNIQUES	 30
4.1 Plan of work.....	30
4.2 Materials and methods.....	30
4.2.1 materials.....	30
4.2.2 Experimental setup.....	33
4.2.2.1 Experimental apparatus	33
4.2.2.2 Drying oven	33
4.2.2.3 Muffle system.....	34
4.2.2.4 Other equipment and auxiliaries.....	34
4.2.3 Methods.....	34
4.2.3.1 Preparation of metal oxide by Sol-Gel process	34
4.2.3.2 Processing EPDM/metal oxide nanocomposites.....	36
4.2.3.2.1 EPDM Rubber Formulations.....	36
4.3 Characterization.....	39
4.3.1 Morphological study of metal oxide nanoparticles XRD, FESEM and TEM.....	39
4.3.1.1 X-ray diffraction analysis.....	39
4.3.1.2. Scanning electron microscopy (SEM)	39
4.3.1.3 Transmission electron microscopy	39
4.3.2 Characterization of metal oxide EPDM/ MO rubber.....	39
4.3.2.1 Scanning electron microscopy (SEM).....	39

4.3.2.2 Cure Characteristics.....	40
4.3.2.3. Mechanical test	40
4.3.2.4 Diffusion and transport of toluene through EPDM/metal oxide.....	41
4.3.2.5 Thermogravimetric analysis (TGA) and (DSC)	42
4.3.2.5.1 Thermal Degradation Kinetics Calculations	42
4.3.2.5.2 Activation Energy	43
4.3.2.5.3 Reaction Order and Frequency Factor	45
CHAPTER (5) RESULTS AND DISCUSSION	46
5.5. Characterization.....	46
5.1.1 Characterization of nano and conventional metal oxide.....	46
5.1.1.1 X- ray diffraction (XRD)	46
5.1.1.2 Transmission electron microscopy (TEM) of nanoparticle...48	
5.1.1.3 SEM of metal oxide nanoparticle nMO.....	51
5.1.2. Characterization of EPDM/MO nanocomposite.....	52
5.1.2.1 SEM of EPDM/MO elastomer.....	52
5.1.2.2 Cure rheological characterization.....	54
5.1.2.3 Mechanical Properties.....	57
5.2 Diffusion and transport of toluene through EPDM/nMO and EPDM/cMO.....	60
5.2.1 Diffusion coefficient (D).....	60
5.2.2 Sorption coefficient (S).....	61
5.2.3 Permeability coefficient (P).....	62
5.2.4 Transport Mechanism.....	62
5.2.5. Activation parameter.....	63
5.3. Thermal Degradation Kinetics of EPDM/nMO and EPDM/cMO.	65
5.3.1. Comparative TG, DTG and DTA studies.....	65

5.3.2. Comparison of degradation activation energies of EPDM/nMO and EPDM/cMO.....	65
CHAPTER (6) SUMMARY AND CONCLUSIONS	68
REFERENCES	70
ANNEXES	80
ARABIC ABSTRACT	

LIST OF TABLES

	page
Table (2.1) Properties of EPDM compounds with different metal oxides	13
Table (4.1) drying oven apparatus with a temperature control unit	34
Table (4.2) EPDM Formulations containing different metal oxide nanoparticle and conventional metal oxide Fillers.	37
Table (4.3) Kinetic methods used in computing activation energy in this thesis	43
Table (5.1) The average grain size in nano and conventional metal oxide	47
Table (5.2) Cured Rheometric Characteristics at 152 °C of EPDM/nMO and EPDM/cMO	56
Table (5.3) Mechanical Properties of EPDM/nMO and EPDM/cMO	57
Table (5.4) Sorption data of EPDM/nMO and EPDM/cMO at different Temp.	62
Table (5.5) Values of equilibrium toluene uptake Q_t (Mol%) and parameters n and k for EPDM/nMO and EPDM/cMO at different Temp.	63
Table (5.6) Values of activation energies of diffusion E_D , permeation E_p and heat of solution ΔH_s for EPDM/nMO and EPDM/cMO.	64
Table (5.7) Data calculated from TG, DTG and DTA thermograms of samples at a heating rate of 20 °C min ⁻¹	65
Table (5.8) Activated Energy determined by Kissinger, Friedman and Ozawa Method.	66
Table (5.9) Frequency Factor determined by Kissinger, Friedman, and Ozawa Method	67
Table(5.10) Reaction order determined by Kissinger, Friedman, and Ozawa Methods.	67

LIST OF FIGURES

	Page
Figure (2.1) General structure of EPDM.....	4
Figure (2.2) EPDM diene monomers.(a) 1, 4-hexadiene, (b) ethylidene norbornene, (c) dicyclopentadiene.....	4
Figure (2.3) EPDM crosslink structures.....	5
Figure (2.4) Cure characteristics with different EPDM/MO	13
Figure (2.5) Swelling and crosslink density of EPDM compounds with different metal oxide as activator	13
Figure (2.6) Cure characteristics of EPDM with different metal oxides.....	14
Figure (2.7) Swelling and crosslink density of EPDM with different metal oxides.....	14
Figure (2.8) Different classes of simplest nanostructures of metal oxides.....	16
Figure (2.9) Methods of producing Metal oxide nanoparticles.....	19
Figure(2.10) Sol-Gel synthesis of inorganic ceramic materials.....	19
Figure(2.11) Sol to Gel transformation.....	20
Figure(2.12) Sol-Gel synthesis of inorganic ceramic materials.....	22
Figure(2.13) Schematical illustration of aging processes in the synthesis of nanoparticles.....	23
Figure(2.14) Diagram of the two sol-gel routes used in inorganic nanoparticle preparation.....	23
Figure (4.1) Experimental setup.....	33
Figure (4.2) Drying oven.....	34
Figure (4.3) Preparation scheme for the metal oxide nano-powder sol-gel method.....	36
Figure (4.4) Shows a two series of EPDM Rubber were prepared...	37
Figure (4.5) The fourth step for EPDM Preparation.....	38
Figure (4.6) The curing characteristics and cure rate of EPDM /MO rubber.....	40
Figure (4.7) ASTM D638 type V dumbbell specimen.....	41
Figure (5.1) XRD patterns of EPDM/nFe ₂ O ₃ and EPDM/cFe ₂ O ₃	47
Figure (5.2) XRD patterns of EPDM/nZnO and EPDM/cZnO.....	47
Figure (5.3) XRD patterns of EPDM/n CuO and EPDM/cCuO	48
Figure (5.4) XRD patterns of EPDM/nNiO and EPDM/cNiO.....	48
Figure (5.5) TEM micrograph of Fe ₂ O ₃ nanoparticle.....	49
Figure (5.6) TEM micrograph of nCuO nanoparticle.....	49

Figure (5.7)	TEM micrograph of nZnO nanoparticle.....	50
Figure (5.8)	TEM micrograph of nNiO nanoparticle.....	50
Figure (5.9)	Schematic illustration of colloid particles conglomeration with EG sol–gel process.....	50
Figure(5.10)	SEM images of (a) nFe ₂ O ₃ (b) nNiO.....	51
Figure(5.11)	a,b SEM images of nZnO.....	51
Figure(5.12)	a,b SEM images of the as-prepared CuO.....	51
Figure(5.13)	SEM images of EPDM/nZnO (A) EPDM/cZnO(B).....	52
Figure(5.14)	SEM images of EPDM/nNiO (A), EPDM/cNiO (B)...	53
Figure(5.15)	SEM images of EPDM/nCuO (A), EPDM/cCuO (B)...	54
Figure(5.16)	SEM images of EPDM/nCuO (A) EPDM/cCuO (B)...	54
Figure(5.18)	The curing characteristics curves of EPDM/nMO (A) and EPDM/cMO (B) at 162°C.....	55
Figure(5.19)	Scorch and cure time of EPDM/nMO and EPDM/cMO.	56
Figure(5.20)	Cure rate index for EPDM/nMO and EPDM/cMO.....	56
Figure(5.21)	M _H : maximum torque with different EPDM/nMO and EPDM/cMO.....	56
Figure(5.22)	M _L : minimum torque with different EPDM/nMO and EPDM/cMO.....	57
Figure(5.23)	Tensile strength (MPa) with different EPDM/nMO and EPDM/cMO.....	58
Figure(5.24)	Elongation at break (%) with different EPDM/nMO and EPDM/cMO.....	59
Figure(5.25)	Tensile Modulus of EPDM/nMO and EPDM/cMO composites at 100% elongation.	59
Figure(5.26)	Tensile Modulus at 300% elongation of different EPDM/nMO and EPDM/cMO composites.....	59
Figure(5.27)	Plot of sorption data Q _t (% mol) of EPDM/nMO (A) and EPDM/cMO (B) at 20°C.....	60
Figure(5.28)	Plot of sorption data Q _t (% mol) of of EPDM/nMO (A) and EPDM/cMO (B) at 40°C.....	61
Figure(5.29)	Plot of sorption data Q _t (% mol) of EPDM/nMO (A) and EPDM/cMO (B) at 60°C.....	61

NOMENCLATURE

A	frequency factor, (min^{-1})
CRI	Cure rate index
CuO	Copper oxide
cMO	Conventional metal oxide
DTG	Differential thermogravimetry
D	Diffusion coefficient
EG	Ethylene glycol
EPDM	Ethylene propylene diene monomer
E	Activation energy [kJ/mol]
E_X	The activation parameters of diffusion or permeation, either E_D or E_p .
E_D	The activation parameters of diffusion
E_p	The activation parameters of permeation
E_a	Apparent activation energy at α [kJ/mol]
Fe_2O_3	Iron Oxide
$f(x)$	The function of the conversion
h	The rubber thickness, m
k	A constant depends on the polymer morphology and the polymer-solvent interaction
k	Rate constant (min)
M	Molecular weight, g/mole
MO	Metal oxide
MEG	Mono-ethylene glycol
M_H	Maximum torque,
M_L	Minimum torque,
M_∞	The mass of toluene sorbed at equilibrium
M_0	The initial mass of EPDM/metal oxide
MWLR	Maximum weight loss rate corresponding to DTG peak maxima, ($\% \text{ min}^{-1}$)
MDR	Monsanto Moving Die Rheometer
NiO	Nikel Oxide
nMO	Metal oxide nanoparticle
n	Reaction order [-]
n	Value determines mode of transport of toluene through the EPDM
Phr:	Part per hundred parts of rubber.
P	Permeability coefficient
PEG	Polyethylene glycol

Q_t	Molar percentage uptake at time t
Q_α	The equilibrium absorption or swelling
R	Gas constant ($8.3134 \text{ J K}^{-1} \text{ mol}^{-1}$) or $82.0567 \text{ cm}^3 \text{ atm/deg.mol}$
R^2	Linear regression
S	The sorption coefficient
t	Time, (min)
t_{90}	Cure time
t_2	Scorch time
$\sqrt{t}$	Square root of time
T	Temperature
T_m	Maximum temperature peak, Temperature at maximum conversion [$^{\circ}\text{C}$]
T_i	Initial degradation temperature, ($^{\circ}\text{C}$)
TGA	Thermogravimetry analysis
w_s	Weight of swollen rubber [g]
w_t	Weight [g]
w_0	Initial Weight [g]
w_f	Final Weight [g]
XRD	X-ray diffraction
x	Amount adsorbed, mole
X	A constant representing either D or P,
X_0	A constant representing either D_0 or P_0 ,
x	Conversion (-)
ZnO	Zinc Oxide
Z	Denotes moles of solvent sorbed at equilibrium swelling

Greek Symbols

ΔH_s	The heat of sorption
θ	The slope of the initial linear portion of the plot of Q_t against $\sqrt{t}$,
β	Heating rate, ($^{\circ}\text{C min}^{-1}$)