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Synthesis of MgO Nanoparticles Containing Different Impurities and Evaluating Its Dosimeter Properties

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ABSTRACT
Today Ionizing Radiation has Widespread Applications In Different Scientific And Practical Areas Such As In Medical And Nuclear Centers As Well As Research Laboratories. Thermoluminescence dosimetry Is A Well-Known Method For Precise Determining The Absorbed Dose. Dosimetry and Dating Are Among The Most Important Applications Of Thermoluminescent Materials. The Aim Of This Research Is To Synthesize Mgo Nanoparticles Containing Different Impurities As Well As Evaluating Its Dosimeter Properties. In This Research, Nanoparticles Of Magnesium Oxide Containing Lithium And Lithium-Aluminum Impurities Were Synthesized. This Technique Is A New Method For Optimizing The Thermoluminescent Properties Of Materials And Expanding Their Dosimetric Applications. Using X-Ray Diffraction As Well As Williamson-Hall Plot, The Formed Phases And The Size Of Synthesized Nanoparticles Were Calculated. In Continue, Thermoluminescent Properties Of The Synthesized Nanoparticles And The Effect Of Impurities On Sensitivity of Thermoluminescence Nanoparticles Were Evaluated. The Results Showed That Adding Aluminium Can Significantly Increase The Intensity Of The Thermoluminescence Of Magnesium Oxide Containing Lithium Impurity. Thus Magnesium Oxide With A Little Amount Of Aluminium And Lithium Is Appropriate For Personal Dosimetric Goals As It Has High Sensitivity To Gamma Ray.
Key Words: Thermoluminescence, Dosimetry, Magnesium Oxide, Lithium, Lithium-Aluminum

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I. INTRODUCTION

Today Ionizing Radiations Are Vastly Used In Different Scientific And Practical Fields In Areas Such As Medical And Nuclear Centers As Well As Research Laboratories. The True Estimation Of The Radiation- Absorbed Dose Is One Of The Main Concerns Of Using Ionizing Radiations. Thermoluminescence dosimetry is A Well-Known Method Of Precise Determining The Amount Of Absorbed Dose. Dosimetry And Dating Are Among The Most Important Areas In Which There Are Applications For Thermoluminescent Materials. Using This Phenomenon (Thermoluminescent Materials) In Dosimetry has Been Such Expanded That Various Commercial Thermoluminescent Materials Such As P, Cu, Lif: Mg, Ti, $Caso_4$ And Al_2O_3:C Have Been Synthesized To Be Used In These Applications And A Lot Of Studies Were Conducted On Them (Noh Et Al., 2001). In Recent Years In Different Scientific And Industrial Areas, Using Nano-Materials Have Been Increased. Reducing The Size Of Particles, The Surface Area To Volume Ration Of Nano-Particles Will Be Increased. This Makes Differences In Their Various Properties Such As Optical Properties Of Nano-Materials In Comparison With The Optical Properties Of Its Bulk Material. The Studies Conducted On The Samples Of Thermoluminescent nanomaterials shows That Dosimetric Properties And Synthetic Parameters Of Nanomaterials Have Significant Differences With The Same Properties In Their Bulk Material (Salah, 2011).

The Luminescence Of Minerals Originates From Their Crystal Properties And Depends On The Concentration Of The Impurities Existed In The Minerals. When Crystal Minerals Are Exposed To Ionizing Radiation, They Save Some Portion Of Absorbed Energy In Their Crystal Network. If These Materials Are Frequently Heated, Release Some Portion Of The Saved Energy As Light Photons. In This Way, Thermoluminescence Phenomenon Will Take Place (Bull, 1986).

In The Past Two Decades, The Quantum Size Of Semi-Conductive Structures Has Been Studied Due To Its New Properties. At Present, In Comparison With Common Materials, Nanostructures Of Semiconductors Can Be Used In More Different Industrial Applications Due To Their Limited Quantum Effects, Surface Effect And The New Optical, Magnetic, Chemical And Structural Properties That They Show. Magnesium Oxide Is A Semiconductor With 7.8 Electron Volt Band Gap And Its Crystal Structure Is Similar To Sodium Chloride. Magnesium Oxide Is Widely Used In Catalysers, Electrochemistry, Fiber Optics, Recycling Toxic Wastes, Antibacterial Materials, Non-Flammable Materials, Superconductors And

Sensors Due To Their Unique Optic, Electric, Magnetic, Heat, Mechanical And Chemical Properties And Are Ideal Alternatives In Active Optic Equipment And Active Optic Compounds (Materials Which Have Luminescence Properties) (Jalili,2008). Alkali Metals Easily Combines with magnesium Oxide And Improve Its Optic Properties. In Recent Years, Magnesium Oxide Containing Different Impurities Has Been Widely Studied (Orante-Barron Et Al., 2005).

Thermoluminescence Is A Method For Studying Electrons And Hole Traps In The Solid Phase. It Also Is Used In Studying Synthetic Processes Of Trapping And Recombination. Evaluating And Comparing Thermoluminescence Data In Different Articles Indicate The Changes Of Thermoluminescence Results With Changes Of Synthesis Parameters (Method Of Synthesis, Synthesis Conditions, Type Of Impurity And Its Concentration) (Kadari, 2010). Most Of Thethermoluminescent Picks Were Observed Below100°C. These Picks Are Unstable At Room Temperature So Are Not Appropriate For Dosimetric Applications. Furthermore, It Was Reported That Some Thermoluminescence Picks Were Synthesized Above 100°C Through Different Methods. Yukihara Et Al. Have Studied The Thermoluminescent Properties And Optical Luminescence Of Mgo, Li, Gd Synthesized Through The Method Of Combustion Synthesis. In Another Word, The New Results Of Studying Mgo, Li, Gd, Support The Application Of These Materials As Athermoluminescent detector And Optical Luminescence. Optical Luminescent Properties Of Mgo, Li, Gd Is Comparable With Commercial Al_2O_3:C And Emission Spectrum In 315 Nm Is Related To Gd^{3+}. Double Impurity Of Lithium-Gadolinium Intensifies The Optical Luminescence Signals. Hence Eliminating Shallow Centers And Trapping Electrons Are Necessary For Decreasing The Fading Of Optical Luminescence Signals (Oliveira Et Al., 2013).

This Article Studies The easibility Of Synthesizing Mgo, Mgo:Li And Mgo:Al,Li Dosimeters Through Controlling Thermoluminescent Properties Using Solution Combustion Synthesis. Samples Of Magnesium Oxide Which Contain Impurity Or Are Without Impurity Were Synthesized Using Solution Combustion Synthesis And Their Properties Were Evaluated Using Thermoluminescence.

II. METHODOLOGY

Samples Of Magnesium Containing An Impurity And Without Impurity Were Synthesized Through Solution Combustion Synthesis As Below:

Samples Without Impurity Were Prepared Through Solving 5.1 Gr Urea And 13.08 Gr Magnesium Nitrate 6-Water In 50 Milliliters Of Distilled Water (Yukihara Et Al., 2013). The Beaker Containing The Solution Was Put On The Magnetic Mixer Under 60°C And Mixing Was Continued For 45 Minutes With The Speed Of 350Rpm And Under Ventilator. Then Mixing Was Stopped And The Above- Mentioned Solution Was Put In The Oven And The Temperature Was Increased To 200°C And Fixed For 2 Hours to Dry The Solution. Then Immediately The Temperature Was Increased To 500°C And Fixed For 8 Minutes In Order To The Combustion Reaction Be Completed. The Combustion Reaction Eliminated All Additives. Reaction Stoichiometry Was Calculated Based On Reduction And Oxidation Reactions Between The Oxidizing And The Fuel (Prashantha Et Al., 2011).

Equation (1):

$$2\,Mg\,(NO_3) + 5(NH)_2\,CO = 2mgo + 5H_2O + 5CO_2 + 7N_2$$

To Do Annealing Process, First, The Powders Were Fully Crashed And Then Were Poured Into An Alumina Crucible. Annealing Operation Was Done In An Insulating Furnace, Under Atmospheric Pressure While They Were Heated To 900°C For 2 Hours With A Heating Rate Of 5°C/Min. Then The Crucible Containing Powders Was Allowed To Remain In The Furnace To Be Cooled And Its Temperature Reaches Room Temperature. To Prepare Doped Samples Of Magnesium Oxide, The Experiment Was Repeated Through The Mentioned Process.

III. CHARACTERIZATION

The Structure Of The Sample And The Size Of Particles Were Evaluated Through The Use Of An X-Ray Diffraction (XRD) Spectrometer. Beams Were Produced Through A60co Light Source. To Read The Radiated Samples, TLD Reader 7100 Was Used. From 50°C To 300°C, The Samples Were Read With Temperature-Scanning Rate Of10°C/Min. The Samples Were Heated Using A Programmed Furnace With ±1 Degree Centigrade Accuracy And Immediately The Samples Were Cooled To Room Temperature. Using A Digital Scale With 0.00001 Precision, The Mass Of Samples Were Measured.

IV. RESULTS AND DISCUSSION

XRD Model Of solution Combustion Synthesized Mgo: $Li_{3\%}$-$Al_{1\%}$Nano-Particles Is Indicated In Figure (1). The Spectrum Is Related To Mgo Nanoparticles. Evaluating The Achieved XRD Model Shows 3 Main Picks O Mgo. The Extra Picks Are Related To Impurities Which Entered Mgo Network.

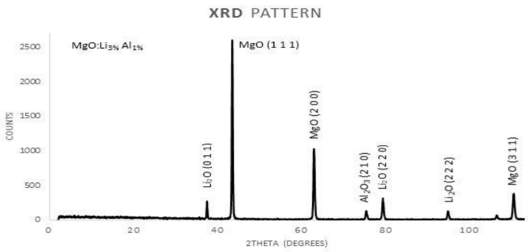

Figure 1 XRD Model Of Solution Combustion Synthesized Mgo: $Li_{3\%}$-$Al_{1\%}$ Nano-Particles

Furthermore, Using Williamson-Hall Plot And XRD Spectrum It Is Possible To Approximately Measure The Size Of Nanocrystals.
Equation (2):

$$\beta cos\theta = \frac{0.9\ \lambda}{D} + 4\varepsilon\theta$$

In This Equation:
K Is Hall Constant
Λ Is X-Ray Wavelength
ε is network Strain

β Is The Width At Half Maximum In Radian Scale. β Was Measured For Magnesium Oxide Containing Aluminum And Lithium Impurity Contamination Whose Particle Diameter Was 42 Nano-Meter.

Each Time Heating Was Conducted Before Radiation At 500°C For 30 Minutes. Using 60CO Light Source, Mgo Nanoparticles, Mgo: $Li_{3\%}$ And Mgo: $Li_{3\%}$ - $Al_{1\%}$ Were Radiated By Gamma Radiation As Much As 500 Mgy. Figure 2 Shows A thermoluminescent Curve For Mgo Nano-Particles Which Were Synthesized Through The Method Of Solution Combustion Synthesis Method. In Completely Pure Mgo, The Release Of Each Electron Is Due To The Heat Transfer Which Is Accompanied By The Formation Of A Hole I.E. The Number Of Electrons And The Holes Which Take Part In Electric Current Is Equal. So There Is No Electron Trap And The Electrons Can Easily Return To Their Lower Energy Levels And Release Their Extra Energy As Photons. As A Result, The Laminating Pure Mgo Nano-Particles Curve Does Not Have Thermoluminescent Picks (Jalili, 2008).

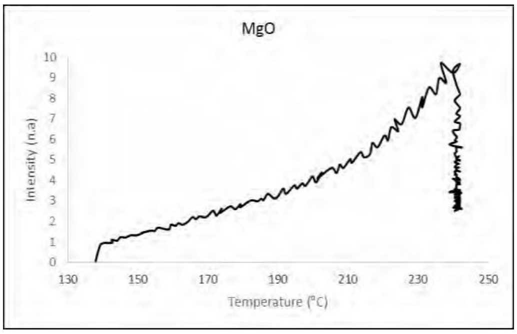

Figure 2 Luminescent Mgo Nanoparticles Curve With 500 Mgy Gamma Radiation

Figure 3 Shows A thermoluminescent Curve For Mgo Nanoparticles With 3% Mole Of Lithium Contamination. According To This Figure, The Curve Of Luminescent Mgo: $Li_{3\%}$ Nanoparticles Contains One Pick Which Was Appeared In 117.16°C And With The Intensity Of 3.52 N.A. The Pick Was Formed At Relatively Low Temperature So It Was Unstable And Is Not Appropriate For Dosimetry Applications.

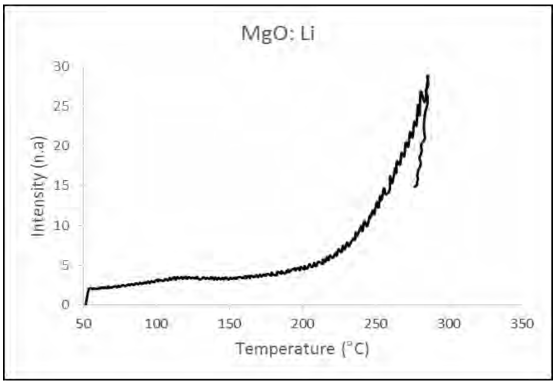

Figure 3 Luminescent Mgo: $Li_{3\%}$ Nanoparticles Curve With 500 Mgy Gamma Radiation

Adding A Little Impurity To Mgo, The Number Of Carriers Of Electric Load Of Mgo Increased While Its Specific Electric Resistance Reduced. So The Thermoluminescent Property Of Mgo Increased. The Process Of Adding An Impurity To Mgo Is Called Contamination (Kadari, 2010). Figure 4 Shows Athermoluminescent Curve For Contaminated Mgo Nanoparticles With 3% Mole Of Lithium And1% Mole Of Aluminum Contamination. According To This Figure, The Curve Of Luminescent Mgo: $Li_{3\%}$-$Al_{1\%}$ Nanoparticles Contains Two Picks Which Were Appeared In 123.78°C And 301.62°C And With Intensity Of 2.78 N.A And 56.67 N.A In Respect. These Picks Were More Stable That The Picks Related To Mgo And Mgo:$Li_{3\%}$ Samples. In General These Nanoparticles Are Appropriate For Dosimetry Applications.

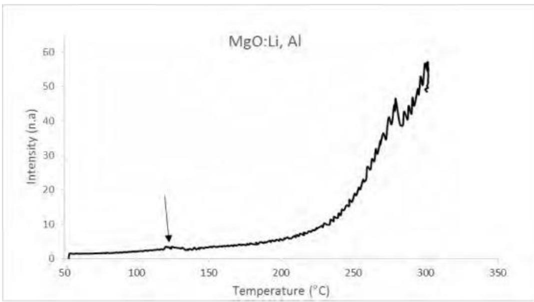

Figure 4 Luminescent Mgo: $Li_{3\%}$-$Al_{1\%\%}$ Nanoparticles Curve With 500 Mgy Gamma Radiation

According To Figure 5, Adding Higher Valence Al^{3+} Contamination To Semi-Conductive Mg^{2+}, The Band Structure Changes As Well And An Energy Level Called Donor Level Will Be Formed Very Close To And Under Conduction Band. Adding Li^{1+} Impurity With Lower Valence To A Semi-Conductive, An Energy Level Called Acceptor Level will Be Formed Above The Valence Band.

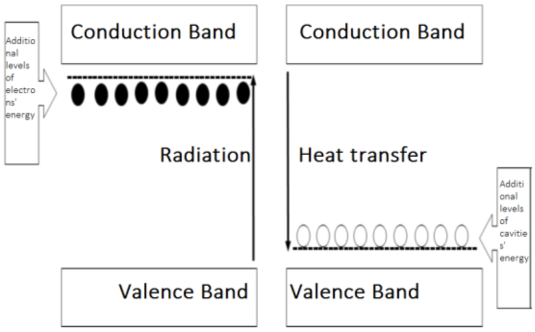

Figure 5 Formation Of Additional Energy Levels Of Electrons And Holes Due To Adding Impurities With Different Valence In Semiconductors

When Both Impurities Were Added Simultaneously, The Places Where Electrons Were Trapped And Intrinsic Defects Increased And Due To The Additional Level Energy Of Electrons, The Intensity Of Thermoluminescent Picks Increased, Too.

V. CONCLUSION

In This Study, Mgo, Mgo:$Li_{3\%}$ And Mgo: $Li_{3\%}$-$Al_{1\%}$Were Synthesized Using Solution Combustion Method. These Synthesized Materials Are Used In Thermoluminescent Dosimetry. The Results Indicated That Solution Combustion Synthesis Is Efficient To Produce Materials With A Thermoluminescent Intensity Which Is Comparable To Commercial Materials. Researches Showed That Samples With Double Impurities Of 1% Mole Of Aluminum And 3% Mole Of Lithium Had The Most Thermoluminescent Response To Gamma Radiation. Lumination Curve Of Synthesized nano-Particles Contained Two Picks At 123.78°C And 301.62°C, With The Intensity Of 3.78 N.A And 56.67 N.A. In General, It Can Be Said That Magnesium Oxide Nano-Particles With Aluminium And Lithium Impurities Are Appropriate For Dosimetry Applications.

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