Faculty of Science

Department of physics

The use of Nano technology in photovoltaic development: "Development novel nano- composite materials to improve the efficiency of photovoltaic cells"

Proposal for a research project submitted to

Science and Technology Developmemt Fund (STDF)

Type:

Target project

BY

PROF Dr MABROUK Kamel EL-Mansy

PHYSICS Department , FACULTY OF SCIENCE

Benha UNIVERSITY , P.O. box : 13518

Tel : 0121097778 , Fax :0133222578

Table of contents

1- Abstract

Solar energy is an appealing alternative energy source for the future, with the special advantages of being non-polluting, renewable, widely distributed, and of delivering peak power at the times of peak loads. The total energy reaching the earth is about 3×10^{24} J/year. The cost of converting solar energy to other forms is the principle barrier to its use, especially in photovoltaic devices using the conventional inorganic semiconductor

The need of the electric power in Egypt is still the barrier in new communities development because of the insufficiency of conventional other types of power .Therefore the present project suggests new nano polymer composite to be used in fabricating cheap energy conversion solar cells.

The proposal offers the solution of energy conversion problem based on selecting transparent type of polymer to be used as host matrix for photo sensitive iorganic phase suitable to prepare nano composite for photovoltaic hetero junction .The study will be conducted on such nano composite to improve the device conversion efficiency enhancing the composite conductivity value by reducing the inorganic phase – polymer interface and or increasing the carrier concentration by doping and radiation induce defect states .

The study will be conducted firstly by preparing the polymer nano composites with characteristic energy gap width suitable for preparing hetero junction with the counter electrode. The composite structure will be confirmed using TEM, SEM FT- IR and XRD techniques whereas the energy gap width will be obtained from the UV – visible absorption. Thus the second step the project will concentrate on the improvement of conduction by facilitating carrier transport and or concentration of carrier by irradiation. Thereafter the improved composite will be subjected to hetero junction formation and a trial will be done to improve the junction quality and stability under normal weathering conditions.

The project comprehensive study conclusion based on data obtained for the fabrication of the PV cells and their optimized efficiency. Finally , the project offers the scientific base for producing photovoltaic cell in economical scale for local and international markets and enables scientific publications in peer reviewed journals .

2- Introduction

Identification of the applicant

As an Egyptian academic researcher affiliating to the department of physics, faculty of science, Benha University and working in the field of solid state physics, my interest is being directed towards the electronic properties of polymer composites. I have graduated and finished my M.Sc thesis from Assuit University .I have my Ph.D. degree from Zagazig University "Polymer Composites". Since that time and until now my researches focused on the electronic properties of polymer composites as well as amorphous semiconductors and is extended to energy conversion using the fluorescence dies in polymer. I have several publications more than 40 papers in International journals. In addition the applicant is peer reviewer for local or international journals. The applicant visited some institutes in Europe , Japan and Asia in short durations and had the necessary experience in accomplishing reliable work and publish in international peer –reviewed journals .Travels abroad were also a vital key in building valuable links with people interested in this field.

The reason for the grant request – issue and problem or needs

Recently, there has been growing interest to organic based solar cells to replace the conventional inorganic solar cells due to their low cost , easy processing and shaping. The polymer composites have attracted much attention because of their power conversion efficiency compared to that of conventional inorganic photovoltaic devices of relatively low cost. This type of devices has been regarded as next generation of photovoltaic devices because of their unique characteristics such as transparency. The bulk CuI has semiconductor promising characteristic energy gap about 3eV for thin films and size in nano-meter scale which allows the response to the solar energy excitation in the visible range (400 – 800 nm). In the present study, we aim at improving the solar energy conversion efficiency as a result of reducing the defects at polymer – nano CuI interface. This will be accomplished by introducing a third component and or by enhancing bonding between inorganic nano particles and polymer by ionizing radiation. In addition to the particle segregation, the development of photovoltaic cells of solar energy with more efficient and relatively inexpensive energy is the main goal of the study.

The objectives to be achieved through this funding:

The proposal aimed at conducting a comprehensive study on nano –polymer composite suitable for solar energy conversion in the solar energy visible range. In addition we will try to improve the charge carrier mobility at in the polymer matrix by reducing the inorganic- polymer interface by obtaining bonding chemically or by the ionizing radiation. Little studies have been give using the chemical agent but the last one is a new idea that needs clarification using the facilities of the Egyptian Atomic Energy Authority. The expected outcomes of this project will be manifested by revealing many ambiguities with regard to the nano polymer composites as photosensitive materials which could not be obtained by using the conventional inorganic ones. In addition this study will illustrate the economical method of photovoltaic cells using such nano polymer composite.

The kind of activities to be conducting to accomplish these objectives:

Activities to be conducted in order to accomplish the proposed objectives include: Firstly, literature review in the periodicals to stand on what is available information and data may be obtained by the others of experimental and theoretical studies concerning the project under consideration. Secondly, the nano- composite will be prepared taking into consideration the previous efforts and go through the problem directly to optimize the inorganic –polymer interface using third component and electron or gamma radiation with different doses. The nano-structure improvement can be confirmed by using TEM, SEM and FT-IR methods. The optical energy gap of the composite and the electrical conductivity values can be detected to confirm the improvement of the polymer – nano particles interface. The fabrication of photovoltaic cell will be our target in the third step of study using suitable counter electrode, the junction quality will be characterized and its efficiency for solar energy conversion will be estimated and compared with the data in literature. Finally, the obtained efficient photovoltaic solar cells will be subjected to the normal weathering condition to demonstrate their stability in the normal atmosphere. This type of photovoltaic cells can be fabricated locally by effective technology and low cost.

3-Background

In the recent years there has been a significant interest in renewable energy sources. This has been partially motivated by the increase in oil prices worldwide as a result of geopolitical and economic factors, and the general concern associated with global warming that is exacerbated by the emission of greenhouse gases during the production of primary power by conventional means. While many technologies are being considered to supplement oil as a primary energy source, renewable energy sources are seen as the key to long-term weaning of industrialized economies from strict reliance on oil, coal, and natural gas. These include wind, fuel cells, solar cells, geothermal, biofuels, etc. Solar energy conversion is perhaps the most appealing of all these solutions, since the energy source is readily available.

Development of devices for conversion of solar energy into electricity has attracted a great attention in recent years due to strong interest in renewable energy and the problem of global climate changes. For many decades the solar cell industry has been dominated by inorganic solid-state devices, mainly based on silicon.

Energy conversion efficiency of the best monocrystalline Si photovoltaic (PV) cells is nearly 25% [1, 2], being very close to theoretical limit of 31% for a single junction device [3]. However, manufacturing of Si-based devices is very expensive due to strong requirements to the high purity of the crystalline semiconductor. Therefore, a great effort has been focused for last years on development of low cost solar cells. One alternative is a new generation of photovoltaic beside of cheap fabrication; these devices offer other attractive features, such as flexibility, processability and tunability of the optical band gap. Moreover, a very high optical absorption coefficient of the conducting polymers, in comparison to that of silicon, provides the possibility for preparation of very thin (100–200 nm) solar cells.

Dye-sensitized solar cells (DSSCs) have attracted large attention due to their easy fabrication, low cost and high conversion efficiency. The first report on anew type of dye sensitized solar cell (DSSC) was published by O'Regan and Gra¨tzel [8]. The working principle of these cells is based on electron injection from a photoexcited sensitizer dye into the conduction band of the nano-crystalline TiO2 semiconductor. The original state of the dye is subsequently restored by electron donation from the electrolyte, usually an organic solvent

containing a redox couple, such as I^-/I^{-3}. Regeneration of iodide ions is achieved at the counter-electrode by electrons from the external circuit [7, 8].

Electrolytes play an important role in the photovoltaic performance of the DSSCs and many efforts have been contributed to study different kinds of electrolytes with various characteristics such as liquid electrolytes, polymer electrolytes and so on. The electrolytes used for dye-sensitized solar cells are usually liquids and contain electrolytes, ionic liquid oligomer electrolytes and polymer electrolytes. The best photovoltaic performance was achieved for DSSCs based on liquid electrolytes; however, the leakage and volatilization of the solvent have caused difficulties in fabrication, reduced the long-term stability and limited practical applications. Polymer electrolytes are alternatives to liquid electrolytes in order to improve the stability of electrolytes and thus that of their DSSCs [4].

Recently, some researches have been reported on the high- performance DSSCs employing solid polymer electrolytes. No- gueira et al. [5] prepared polymer electrolytes consisting of poly (epichlorohydrin-co-ethylene oxide) (Epychlomer), NaI and I_2 and applied them to solid-state DSSC. Epychlomer electrolytes showed relatively high ionic conductivity of 1.5×10^{-5} S/cm at 30°C and solar cell efficiency of 2.6% at10mWcm^{-2} due to the reduced crystallinity of polymer chains. Stergiopoulos et al. [6] also reported highly efficient nanocrystallineTiO_2 solar cells employing binary poly (ethylene oxide) (PEO)/titania/LiI/I_2 electrolyte. Their photo electrochemical cells resulted in high overall energy conversion efficiency, i.e., 4.2% at 65.6 mW /cm^2. In this work we aim to develop novel nano -composite polymer electrolyte based on copper iodide and polyvinyl alcohol with efficiency higher than the published data and can be produced economically.

4- Wider Objectives

Population explosion is considered one of the most awful problems that faces our country where over-population in the narrow valley. The solution of this problem requires a creation of new urban communities outside the old valley, but the basic handicap that prevents the overcoming of this problem is the rarity of the necessities of life especially the electrical power

that is used in lighting, water treatment, and providing us with public services such as health, education,….etc

Because of the insufficiency of the sources of conventional power such as petrol, the present project aims at achieving two important things. First, the fabrication of new inexpensive type of photovoltaic cells can be produced locally with simple technology compared to that is available in the local and international markets. Second, the manufacturing of solar cells and other related industries that give youth good opportunities for new jobs and help to develop the new urban communities.

5- Statement of proposed research (SPR)

This study will ***demonstrate*** the preparation of polymer nano composite which will be used for the fabrication of photovoltaic cells. The study will concentrate on the modification of the interface between the inorganic nano particle component and host polymer matrix. The project will focus on solving this problem by creating chemical bonding by adding third component or by subjecting the polymer nano composite to ionizing radiation.

The project will ***test*** the hyposis of the possibility of diminishing the interface barrier which will assist carrier transport through the polymer nano composite (hole mobility). This will give quantitavely the variation of conductivity values of the polymer nano composite and its reflection on the photovoltaic energy conversion efficiency. All these steps are directed towards th*e development* of new generation of polymer nano composites as photovoltaic cells. This type of photovoltaic cells can be produced economically (relative low cost) by simple local technology.

The ***expected results*** can be measured on the basis of accomplishing a complete comprehensive study and to – point conclusions (in report / publications) expressing witnessing a creative work should be seriously taken for application. please see detailed objectives in the next section stated in a systematic way for better presentation.

For the purpose of accomplishing this work, in addition to the applicant, a group of Egyptian and international partners will be invited to participate including a non – Ph.D. holders;

a staff member from the home department; a researcher from the Egyptian Nuclear Energy authority, Cairo, Egypt, Prof. Matsui Osaka prefecture university, Japan, Prof. G.D. Sharma, India; Prof. Magdalena Skompska, Poland; Prof. A El-Ghamdy; King Abdulaziz University KSA and Prof. A . Mansour, Zagazig University. Salaries will only be applicable for the Egyptians whereas money appointed for the international partners will serve as a small share for sample analyses.

This project is expected to come to the overall objective throughout two successive stages. The first stage is a 2 years grant will be a basis for an additional third year as a related grant. The aim of the second stage is to perform hetero junction fabrication (the main target of the project) and its stability in the normal weathering conditions .

6- Technical Methods & Procedure

Methods	objectives
Preparation of polymer nano composite	CuI nano particles are our main target in the present study, since the dimensions enables to control the physical properties such as the optical energy gap width. However we need in this activity to prepare such nano particles by reacting the aqua's solutions of CuCl and NaCl and control the crystal growth rate of the CuI crystals, using caping agent, ambient temperature, the concentration of the reactive components ……etc. This experiment will be done in polymer aqua's solution and the desired nano composite film will be obtained by dipping or by casting.

Microscopy : **1- SEM microscopy** **2- TEM microscopy** **3. FT-IR spectroscopy**	In the present activity , SEM technique is very essential to study the morphology of polymer and nano CuI- polymer composite. Since TEM reveal an information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample (TEM) is a microscopy technique capable of imaging at a significantly higher resolution, owing to the small de Broglie wavelength of electrons., This technique enables us to record and identify both size and dispersion of nano particle besides the polymer composite morphology . In addition The analysis of the micrograph using the image processing can be conducted on the obtained photographs. Since **FT-IR spectroscopy** is an important and popular tool for structural elucidation and compound identification. Therefore, in the present activity FT-IR technique is very essential to study the functional groups in of polymer and nano CuI- polymer composite.
Electrical and photo conduction Techniques	The complex impedance technique which is based on circuit analysis will be benefit in the present study to obtain quantitative analysis on the electrical conductivity and dielectric parameters of polymer and polymer composite. In addition it can be used to obtain information about the hetero junction quality and its suitability for as solar energy conversion. The photoconduction of polymer and polymer composition will be studied using the optical absorption in UV– visible range. This technique will be helpful to obtain the values of the enegy gap width of polymer and polymer composite and to ascertain the suitability of polymer nano composite as photo active material to be used in photovoltaic devices

7- Facilities and equipment

Fortunately, the grant structure allows several short term travels to enable us to use the SEM , TEM , FT-IR and thermal analyzers instruments which are not available in Benha University. As for the present proposal, some of the work will be accomplished in Benha University. Therefore, basics for sample preparation and characterization using dc conductivity setup, complex impedance, optical absorption in UV– visible range are strictly available and accessible in my home institution Benha University.

The material science laboratory at the home institution is also equipped with dc conductivity setup suitable for wide range of measurement down to 10^{-12} mho/cm. In addition there is also RLC bridge up to 5 M Hz that enables us to record the dielectric parameters and to draw the complex impedance diagram

Necessary computers software and modern PC's are available for 3 persons during the project lifetime. These facilities will be improved once the project is accepted and the home university will start to encourage and support the project and the work group.

Cooperating partners from the other institutions and abroad will be responsible for arrangements regarding the availability of the required analytical instruments and will share in the analytical work and data interpretation from the point of being proposed co-author in any of the resulting publications.

The project besides the facilities stated before still needs some equipment such, RLC meter and Glvanostate to accomplish the essential part of junction characterization (250000 LE).

Activity	Time	personal	Place of action	Finance planning
(1) Collecting all literature and previous work related to the project assumptions on photovoltaic energy conversion solar cells. A literature review should help to give a context for the planned research. This can devided into three areas: defining the topic , selecting relevant keywords , and setting limits to research. Read with critical eye , were there any limitations to previous work , or any mistakes ? What did the research conclude? Were there useful recommendations?	4months	The Egyptian group	Egypt	STDF+ Home university
(2) 2.1 - Samples preparation is the essential aim of the project is suitable for photovoltaic cell. Therefore we start with the preparation of pure films of PVA polymer using dipping and or casting technique to ascertain the best method to obtain good quality films using the structure tools confirmations, TEM, SEM and FT-IR and the factors affecting the film homogeneity and stability will be tested.	4 months	The Egyptian group	Egypt	STDF+ Home university
2.2 - The method of PVA film preparation will be considered to reproduce films with the same characteristics. However in this activity, we try to improve the film conductivity to be used as a base for loading with the nano particle of CuI as photo sensitive material. We select a dopant suitable for doping PVA polymer and then it will be subjected to conduction characterization as will as optical absorption techniques to optimize the dopant concentration. A trial will be done to improve the conductivity level by gamma radiation; the dose will also be optimized. The obtained doped or gamma irradiated films will subjected also to structure	4months	The Egyptian group + local participants interested	Egypt	STDF+ Home university

investigation using TEM, SEM, FT-IR and thermal analysis.				
(3) 3-1 In this activity, a trial will be done to prepare nano particles inside the polymer solution by reacting both CuCl and NaI solutions in PVA solution. The particle size of the nano particles of CuI will be controlled by adjusting crystal growth rate. The obtained nano CuI inside PVA solution will be subjected to optical absorption characterization. In addition, solid films will be obtained by casting and or dipping techniques. The XRD and Optical microscope technique will be used to ensure the nano particle size in the desired nano scale. The solid nano composite films will also be characterized by structure investigations and conductivity as well as the optical absorption.	5 months	The Egyptian group and international participants	Egypt+ KSA	STDF
3.2 The structure characterization for nano CuI /PVA composite films will be conducted to obtain more information about the CuI nano particles dispersion and their interface with the host polymer matrix. The techniques of TEM, SEM , FT-IR and DTA are essential for structure characterization and confirmation. The optical absorption and electrical conductivity techniques will also be used to test the suitability of such composite for photovoltaic application.	5 months	The Egyptian group and international participants	Egypt+ Japan	STDF

(4) Reporting and publications Periodical reports will be prepared by all group of the project staff and tasks will be distributed in as much as the PI will supervise the design, structure, reviewing and link to the original proposal. The foreign participating experts will also be asked to improve these reports and proposed manuscripts for international publications. Publication of the data and recommendations will require permissions from the STDF and related ministry, in a way not denying the right of peoples who spend time and effort in this project and will always consider their needs and desires. Findings distribution through oral /poster sessions in international and local conferences in the same field will be done by the whole group including the non- Egyptian partners in a way leading to express their achievements and encourage others for new mutual collaborations.	2 months spreading over the entire period of the project lifetime.	The Egyptian group and international participants	Egypt+ Elsewhere	STDF+ Home university

References:-

1. J. Zhao, A. Wang, P. Altermatt, M.A. Green, Appl. Phys. Lett. 66 (1995) 3636.
2. J. Zhao, A. Wang, M.A. Green, F. Ferrazza, Appl. Phys. Lett. 73 (1998) 1991.
3. W. Shockley, H.Q. Queisser, J. Appl. Phys. 32 (1961) 510.
4. Wang Y.: Recent research progress on polymer electrolytes for dye-sensitized solar cells. Solar Energy Materials &Solar Cells 93(2009)1167–1175.
5. A.F. Nogueira, J.R. Durrant, M.A. De Paoli, Dye-sensitized nanocrystalline solar cells employing a polymer electrolyte, Adv. Mater. 13 (2001) 826–830.
6. T. Stergiopoulos, I.M. Arabatzis,G. Katsaros,P. Falaras, Binary polyethylene oxide/titania solid-state redox electrolyte for highly efficient nanocrystalline TiO2 photoelectrochemical cells,Nano.Lett.2(2002)1259–1261.
7. M.I. Hoffert, Ken Caldeira, A.K. Jain, Erik F. Haites, L.D. Danny arvey, S.D. Potter, M.E. Schlesinger, S.H. Schneider, R.G. Watts, T.M.L. Wigley, D.J. Wuebbles, Nature 395 (1998) 881.
8. B. O'Reagan, M. Gr¨atzel, Nature 353 (1991) 737–740.

Uncited references

9. M. Gr¨atzel, Nature 414 (2001) 338.
10. R.D. McConnell, Renewable Sustainable Energy Rev. 6 (2002) 273.
11. M. Matsumoto, H. Miyazaki, K. Matsuhiro, Y. Kumashiro, Y. Takaoka, Solid State Ionics 89 (1996) 263.
12. M.Y.A. Rahman, M.M. Salleh, I.A. Talib, M. Yahaya, J. Power Sources 133 (2004) 293.
13. P. Wang, S.M. Zakeeruddin, I. Exnar, M. Gr¨atzel, Chem. Commun. (2002) 2972.
14. Y. Saito, T. Kitamura, Y. Wada, S. Yanagida, Synth. Met. 131 (2002) 185.

15. A. Goetzberger, J. Luther, G. Willeke, Solar cells: past, present, future, Sol. Energy Mater. Sol. Cells 74 (2002) 1–11.
16. J. Bandara, H. Weerasinghe, Sol. Energy Mater. Sol. Cells 85 (2005) 385–390.
17. C. Longo, M.-A. De Paoli, J. Braz. Chem. Soc. 14 (2003) 889–901.
18. S, Takabayashim, R, Nakamuraa, Y. A Nakato, J Photochem Photobiol A Chem 2004; 166:107–13.

Curriculum Vitae

Surname	El-Mansy		
Other names	Mabrouk Kamel		
Title	Prof.		
Gender	Male		
Address	Faculty of Science , Benha		
Telephone numbers	+2-013-3225494	Evening	+2-013-3220885
Mobile	+20121097778	Email	elmansymabrouk@yahoo.com
Date of birth	Day Mo Yr 9 2 1950	Place of birth	EL-Menoufia

Education

School/University	Degree obtained	Dates(from - to)
Zagazig University/Benha University	Prof.	1999 - till now
Zagazig University	Assistant Prof.	1990 -1999
Zagazig University	Ph.D	1978 -1981
Assuit University	M.Sc.	1973 -1976
Assuit University	Bachelor Degree in Physics	1968-1972

Employment History

Employmer	Position	Dates(from-to)
Mabrouk Kamel El-Mansy	Demonstrator	1972 - 1976
	Assistant lecturer	1976-1981
	Lecturer	1981-1990
	Assistant Professor	1990-1999
	Professor	1999- till now
	Dean of the faculty of science benha university	2006-till now

Fields of interest

1- Physical properties of polymer composites

2- Material science

List of publications

1. Electrical conduction of GeTeSe chalcogenide glass , Bull. Fac. Science, Assuit Univ. 5 (1976) 175.
2. Structure and electrical properties of GeTeSe films, Bull.Fac.Science , Assuit Univ. 6 (1977)143.
3. Electrical conductivity of heat resistant rubber blends ,Gummi Asbest Kunststoffe 36(1983) 204.
4. Thermal conductivity of carbon black - loaded NR/SBR rubber composites , Gummi Asbest Kunststoffe 37(1984) 448.
5. Gamma irradiation effects on the electrical conductivity behaviour of hexacyano-hexaamine double complexes Rad. phys & chem. 26 (1985) 619.
6. Investigation on electrical conductivity behaviour of carbon black loaded NR/SBR rubber composites , Gummi Fasern Kunststoffe 38 (1985) 597.
7. Crystallization kinetics and structure transformations of GeTeSe chalcogenide glass , Arab J.Physics 6 (1985) 67.
8. Conduction and switching phenomena in GeTeSe chalcogenide glass , Egypt J.Solids 8 (1986)
9. Electrical conductivity of NR/SBR Rubber composites filled with HAF black, Gummi Fasern Kunststoffe 40 (1987) 648.
10. Crystallization kinetics and structure transformation of GeTeSe chalcogenide glass , Arab J. Phys 6 (1985) 67
11. Gamma irradiation effects on the electrical conductivity behaviour of metal chelates of N,N' phenylene Bis Salicylideneimine Arab J.Phys. 8(1987) 67.
12. Investigation on the electrical conduction of GeTeSe chalcogenide glass Arab J. Physics (1987).

13. Gamma irradiation effects on the electrical conductivity behaviour of pure botasium hexacyano-cobalt (II) and its mixed crystals , Acta Ciencia Indica , XXIII , 3 , (1997) 147.

14. Effect of heat treatment and gamma irradiation on the electrical conductivity of Metal Chelate Complexes Ind.J.Pure & Appl. Phys.28 (1990) 410.

15. Pressure sensitive conductive rubber , Appl. Phys. Comm. 9 (1989- 1990) 281.

16. Thermal effects of heat resistant rubber composites II effect of Ba TiO_3 ceramic on thermal effects of carbon black loaded Butyle rubber Applied Physics Comm. 9 (1989) 267

17. Thermal effects of heat resistant rubber blends .I Joule heating effects in carbon black loaded NR/SBR blends , J. Appl.Polym. Sci. 39 (1990) 1903

18. Electrical conductivity behaviour , kinetics and thermodynamic studies on CuO-Fe_2O_3 , Cu_2O-Cr_2O_3 and CuS–Cr_2S_3 systems , Ind. Chem. Soc. 69(1992)727

19. Thermal effects of heat resistant rubber composites II effect of type and concentration of carbon black , Mat. Chem. & physics 36 (1993) 161.

20. Investigation on switching behaviour in GeTeSe chalcogenide glass, Appl. Phys. Comm. 13 (3&4)(1994)187.

21. Influence of γ radiation on electrical and dielectrical properties of $AgPO_3$ glass, Egypt J. Solids 18(1995) 89.

22. Effect of pressure on turnover behaviour in I-V characteristic curves in GeTeSe chalcogenide glass , Il Nuvo Cimento D 17 (1995) 1121.

23. Electrical conduction in gamma irradiated η-alumina Rad. Phys.& Chem. 45 (1995) 151.

24. Effect of composition, thickness and temperature on non-linear I-V curves in vanadium phosphate glasses, Il Nuovo Cimento D, 18 (1996) 963.

25. Effect of growing barrium ferrite phases on the electrical conduction in $Fe_2O_3/BaCO_3$ composites, Mat. Chem.& Phys 52 (1998) 71.

26. Electrical conduction and dielectric relaxation in vanadium phosphate glasses, Mat Chem & Phys. 56 (1998) 236.

27. Effect of Temperature and pressure on non-linear conduction in GeTeSe chalcogenide glass, Il Nuovo Cimento D, 20 (1998) 701 .

28. Effect of vitrification suppression on non-linear conduction in vanadium phosphate glasses, Il Nuovo Cimento, 20 (1998) 1581.

29. Optical Study of Perylene Dye doped poly (methylmethacrylate) as fluorescent solar collector , Polym. Int., 51 (2002) 393.

30. A qualitative study and field performance for a fluorescent solar collector, Polymer Testing, 21 (2002) 277.

31. Electrical conduction and dielectric properties of (PMMA / Perylene) solar concentrators, J. Appl . Polym. Sci , 88 , (2003) 793.

32. The effect of particle size and distribution on the fabrication and magnetic properties of Barium Ferrite powders prepared from co-precipitated precursors, J. Ceram. Soc.(Japan), (2004)200.

33. Magnetic and dynamic mechanical properties of barium ferrite – natural rubber composites, J. Mat. Process. Tech. , 160(2005)229 .

34. Dimers order-disorder transition dependence on the optical absorption parameters of KHCO3 compounds , Surface Rev.& Lett 11(2004) 1-

35. Dielectric Properties and Conductivity of KHCO3, Turk. J Phys, 28 (2004)1.

36. Electrical conduction and dielectric properties of vanadium phosphate glasses doped with lithium , J Phys.Chem.Solids, 63, (2002)1957.

37. Effect of verification suppression on structure morphology , conductivity and dielectric properties of vanadium phosphate glasses , J . Phys. & Chem Solids 65 (2004) 881.

38. Influence of Lithium phosphate concentration and temerature on the electrical conduction of (76V2O5-24P2O5)1-x (LiPO4)x glasses, J . Phys. & Chem Solids 65 (2004) 891.

39. Electrical conductivity and ultrasonic studies in KHCO3 compound,Turk. J Phys.(2008)

40. Bent fluorescent solar concentrators (BFSCs): Spectroscopy, stability and outdoor performance ,Current Applied Physics, 7(2007) 643.

41. Performance Evaluation of Thin-Film Solar Concentrators for Greenhouse Applications, Desalination, 209 (2007) 244

42. An investigation of the electrical conductivity and ultrasonic properties of the KHCO3 compound, 2009. Phys. Scr. 80 035 402

43. A high voltage magnesium battery based on H2SO4 PVA – NaBr polymer electrolyte , J Power Sources 185 (2008) 1509.

44. Characterization and dielectrical study of AgI – Ag2O-P2O5-Fe2O3 glass Mat. Science Research India , .6 (2009) 19

45. Conduction and solid state battery characteristic studies of AgI – Ag2 O-P2O5-Fe2O3 glass , Mat. Science Research India , 6 (2009.) 53.