Dr. C. K. MAHADEVAN's STATEMENT OF RESEARCH

I. Philosophy

As per the facilities available, choose the field of research and problem for investigation and contribute to the maximum level possible. Try to improve the quality and quantity of research along with increasing the facilities and improving the research status of the Centre/Institution.

II. Resarch Contributions Already Made

I have about **36 years research experience of which about 32 years at postdoctoral level.** I was doing my research (Ph.D.) guidance at S. T. Hindu College, Nagercoil as a recognized Ph.D. guide of Manonmaniam Sundaranar University, Tirunelveli. Currently, as a Professor of Physics and a recognized M.S. and Ph.D. guide of Anna University, Chennai, I am supporting the research activities in PSN College of Engineering and Technology (Autonomous), Tirunelveli.

(A) During My Stay at I. I. T. Madras

I started my research career as a Ph.D. Scholar in the Physics Department of I. I. T. Madras under the **guidance of Dr. (Mrs.) M. Seshasayee** in the field of **X-ray Crystallography** (Crystal and Molecular Structure Determination). I was there as a **Junior Research Fellow** (October 13, 1980 to October 12, 1982), **Senior Research Fellow** (October 13, 1982 to July 31, 1984) and **CSIR Research Associate (Temporary position offered for 3 years and extendable for 2 more years)** (February 01 to April 08 FN, 1985) for a total period of about 4 years. During this period, I have contributed enormously along with my Ph.D. Guide and other Co-workers. To my credit, I have **published 15 original research papers** (First author in 11 papers and 1 paper single authored) and **1 research review article** (Single authored). Also, I have presented **14 research papers in national conferences.**

We have determined the crystal and molecular structures of 18 compounds and derived several useful results. Disproved the idea that bulky counter ions lead to nonplanar structures. Observed, **for the first time**, mixed stacking and double stacking in some 1, 2-dithiolene complexes. Also, observed possible exchange interaction by means of diadic stacking. An analysis of the significance of the overall charge of $[Ni(mnt)_2]^{n-}$ showed that the ionic effect is prevalent in these systems. Observed that the charge donating efficiency of the phosphorous atoms in the 1,2-diphosphine complexes is less when compared to that of the sulphur atoms in 1,2-dithiolene complexes. Observed, **for the first time**, λλλ ring conformation in some $[M(en)_3]^{2+}$ systems. The published **review article is an informative one** on the structural systematics and physical properties of 1,2-dithiolene complexes of transition metals. My statement appearing in my Review Article is:

Crystal structure determination is as important and necessary in physical, chemical, material and biosciences as soil test in cultivation.

Results published in 7 research papers formed the content of my **Ph.D. Thesis** (guided by Dr. (Mrs.) M. Seshasayee) (Degree awarded in 1984 by the I.I.T. Madras) entitled "Structures of some dithiolene and diphosphine complexes". Later, the published review article along with 7 research papers published formed the content of my self-guided **D.Sc. Thesis** (Degree awarded in 2002 by the Madurai Kamaraj University; the first and only one awardee in Physics, so far of this University) entitled “1,2-Dithiolene complexes of transition metals-Structural systematics and physical properties”.

(B) During My Stay at Other Places Before Joining S. T. Hindu College

I worked as a **Lecturer** (**joined in the permanent vacancy**) for a period of about **4 months** (April 08 AN to August 09, 1985) in the **Department of Nuclear Physics, University of Madras.** There, I started my research work in a new field (Metallic Glasses) but could not contribute to a significant level during that short period.

I worked as a **Postdoctoral Fellow (Temporary position offered initially for 1 year and extendable for several more years)** for a period of about **1 year** (September 01, 1985 to August 31, 1986) in the **Department of Biochemistry, University of California, Riverside**, CA, USA. There I did my research work on Macromolecular Crystallography. A large portion of my responsibilities was devoted to setting up and executing an extensive computer program library for macromolecular crystallographic analysis. My research did not result in a publication for three reasons. First, the transition from small molecule to macromolecular crystallography was a slow and difficult process. Secondly, the publication rate in macromolecular crystallography was below normal as compared to other scientific areas given the difficulty of the research. And finally, my employment there was punctuated by serious health problems which interrupted my work for about 3 months. **I had a major surgery done there that changed my life and made me to return to a place nearer to my native town (Nagercoil, in the southern tip of India). Fortunately, with the Blessings of God, I could recover well and became a hard worker again within a short period.**

So, after a short break, I worked as a **CSIR Scientific Pool Officer (Temporary position offered for 2 years and extendable for 1 more year)** for a period of about 6 months (February 16 to August 22, 1987) in the **School of Physics, Madurai Kamaraj University.** There I started my research work in Crystal Growth and Characterization but could not contribute to a significant level during that short period.

(C) During My Stay at S. T. Hindu College (affiliated to Manonmaniam Sundaranar University) and PSN College of Engineering and Technology (autonomous institution affiliated to Anna University)

What I believe is (One of my thoughts appearing in my book entitled ‘Panchamirdham’):

It is better to have little useful knowledge
Than to have much death-time knowledge

I joined in **S. T. Hindu College,** Nagercoil (My native town) on August 24, 1987 (**in a permanent vacancy**) as an **Assistant Professor** in the **Department of Physics**. At that time, there was no research work carried out in the subject of Physics or Materials Science in any of the Colleges now affiliated to the Manonmaniam Sundaranar University, Tirunelveli. Moreover, research activity is not mandatory as per the UGC norms and Tamilnadu State Government rules. Nevertheless, I started my research work in the field of Crystal Growth and Characterization along with guiding M.Sc. and M.Phil. students (both from Physics and Chemistry disciplines) to complete their thesis work and present/publish research papers in Conferences/Journals. Later, I became a recognized Ph.D. Guide of Manonmaniam Sundaranar University and started guiding Ph.D. Scholars.

The qualitative and quantitative aspects of my research work were considered in a way to develop the Physics Department of S. T. Hindu College to become a Research Center recognized by the Manonmaniam Sundaranar University and to develop a Research Laboratory to meet the basic requirements of Scholars to complete their M.Phil. and Ph.D. Projects. It is a great thing that several researchers (M.Phil. and Ph.D. Scholars and Teachers from Colleges and Universities) from in and around Tamilnadu State have used our Research Laboratory and my expertise. **The major research activity was to develop Manpower to carry out Research Work.**

The **Physics Research Center** (We call it like that), **I have established and developed** with the help of the Management of S. T. Hindu College and funding agencies like UGC, CSIR, TNSCST, DST and DRDO, has **produced more than 110 Ph.D.s (Degree awarded by the Manonmaniam Sundaranar University, Tirunelveli).** In addition, several Scholars have already submitted their Theses for the award of the Ph.D. Degree.

In 2003, I extended my research activity to prepare (by designing a **simple and low-cost solvothermal method using a domestic microwave oven**) and characterize nanostructured materials also. I am happy to mention that this method (Sometimes it is **called as Mahadevan's method) has been used by several Researchers in India (My past Ph.D. Scholars and many others) to prepare colloidal nanoparticles (Nanopowders).**

After retiring from S. T. Hindu College, I joined PSN College of Engineering and Technology, Tirunelveli and have become a recognized M.S. and Ph.D. Guide of the Anna University, Chennai. I continued my research guidance in completing the Ph.D. Thesis work and Paper Publication of some Ph.D. Scholars of Manonmaniam Sundaranar University, Tirunelveli and Anna University, Chennai. To my credit, I have **published** from S. T. Hindu College and PSN College of Engineering and Technology **211 research papers in international journals and 138 research papers in national/international proceedings and other journals.** Also, I have **presented 577 research papers (many of them through my Scholars) and 74 invited/keynote lectures in Conferences**. My major area of research is "**Solid State Materials – Crystalline and Nanostructured Materials" in the sub-subject of 'Solid State Physics – Materials Synthesis and Characterization'.** In addition, I have contributed to some extent in the fields of Alternate Energy Sources, Higher Education and Tamil Literature.

Research work involving the preparation and characterization of new/modified crystalline and nanostructured (solid state) materials in order to explore potential applications is of paramount importance both academically and industrially. This prompted me to involve in such research work.

In the field of **Crystal Growth and Characterization**, along with my M.Sc., M.Phil. and Ph.D. Students, my Research Associates and some Co-workers [From St. Aloysius College (Edathua, Kerala), Christ University (Bengaluru, Karnataka), Annamalai University (Chidambaram, Tamilnadu), SSN College of Engineering (Kalavakkam, Tamilnadu), Anna University (Chennai), BHU (Varanasi, Uthara Pradesh), NPL (CSIR, New Delhi) and Changchun University of Science and Technology (Changchun, China)], have **contributed a lot**.

Proposed a new method (by growing the anthracene single crystals), gel-solution method, to grow organic compound single crystals using silica gel. Succeeded in growing thiourea, CdS, KNO_3, strontium tartrate trihydrate, strontium tartrate tetrahydrate and high quality calcium tartrate tetrahydrate crystals in silica gel media. Grown by the free evaporation (solution) method high quality L-arginine acetate, L-arginine oxalate, K-$PbBr_2$, Na-$PbBr_2$, anhydrous sodium formate, hydrous barium succinate, $(BTCC)_x(BTCI)_{1-x}$, $(LHC)_x(LHB)_{1-x}$, $(ZTS)_x(MTS)_{1-x}$, $CaCd(SCN)_4$, $Zn_xCd_{(2-x)}(SCN)_4$, $ZnHg(SCN)_4$, $CdHg(SCN)_4$, $Mg_xZn_{1-x}SO_4.7H_2O$, $Ni_xZn_{1-x}SO_4.7H_2O$, $Ni_xMg_{1-x}SO_4.7H_2O$ and $Na_xK_{1-x}B_5O_6(OH)_4.2H_2O$ crystals, **for the first time**, and characterized them. **Discovered that proper solid solutions can be prepared directly from the isomorphous precursors taken in suitable proportions even if the end members have lattice mismatching.**

Systematically studied the effect of soluble impurities on **the homogeneous nucleation parameters** of several inorganic and organic crystals **and grouped the results into four rules**. Also, found that cylindrical shape is better to be considered as the shape for the critical nucleus (previously considered as spherical in shape). Studied the effect of several impurities (both organic and inorganic) on the optical, electrical, thermal, etc properties of KDP, ADP, $(ADP)_x(KDP)_{1-x}$, TGS, KB5, NB5, ZTS, BTCC, $MnHg(SCN)_4$, $ZnCd(SCN)_4$, $MgSO_4.7H_2O$, $NiSO_4.7H_2O$, LAA, LAHCl, TGSP, p-MHB, glycine metal (Na/K) sulphates, Na/K acid phthalates, potassium formate, calcium succinate, calcium tartrate tetrahydrate, strontium tartrate trihydrate and strontium tartrate tetrahydrate single crystals and obtained several useful results. **Proposed a new method** (called seeded free evaporation method) to grow large size single crystals of Na_2HPO_4, $(NH_4)_2HPO_4$, ADP, KDP, etc. Several metal (Co, Mn, Ni, Cd, Cu, Sr, etc) malonate single crystals have been grown by the gel methods and characterized. Large size single crystals of GaTe and several organic materials like benzyl, naphthalene, 2-hydroxypyridine, 2-amino-5-chloropyridine, 2-methylamino-5-chlorobenzophenone and 2-hydroxy-4-methoxybenzophenone have been grown by the melt methods and characterized.

In-vitro studies made on **urinary stone crystals** (investigating the effect of drugs and vegetable and fruit juices on the formation of urinary stone crystals) **may probably help** to carry out **further study in the treatment of urinary calculi.**

L-arginine acetate, L-arginine oxalate, manganese malonate, cadmium malonate, nickel malonate, copper malonate, $Ni_{0.5}Zn_{0.5}SO_4.7H_2O$, $MnHg(SCN)_4$, $CaCd(SCN)_4$, 2-amino-5-chloropyridine, KDP (doped with urea and L-arginine) and $MgSO_4.7H_2O$ (doped with urea and glycine) single crystals are **found to be low dielectric constant value dielectric materials**.

Non-stoichiometric single crystals of $K_3BaCl_5.2H_2O$, $K_3CaCl_5.2H_2O$ and $Na_3CaCl_5.2H_2O$ have been grown, **for the first time**, and found that non-stoichiometric $K_3BaCl_5.2H_2O$ is a dielectric material and the other two are **ionic conductors**. It is **understood that a journey from dielectric material to ionic conductor is possible when we are able to prepare highly non-stoichiometric complex crystals by combining an alkali halide and an alkaline earth metal halide.**

The four empirical rules formulated

1) For inorganic materials like KDP and ADP added with impurities having common cation the nucleation parameters increase with impurity concentration for the impurities having higher density and high or equal (molecular) weight cation and decrease with the impurity concentration for the impurities having lower density and low or equal (molecular) weight cation.

2) For inorganic materials like KDP and ADP added with isomorphous impurities the nucleation parameters increase with the impurity concentration for the impurity with larger lattice and decrease with the impurity concentration for the impurity with smaller lattice.

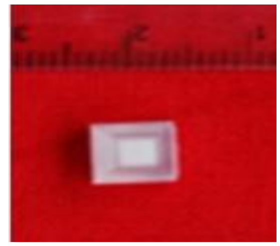
3) For inorganic materials like KDP and ADP added with impurities having no common ion and organic impurities, the nucleation parameters increase with the impurity concentration regardless of density or molecular weight or lattice type of the impurity.

4) For organic materials the nucleation parameters do not vary systematically with impurity concentration.

Some Crystals Grown

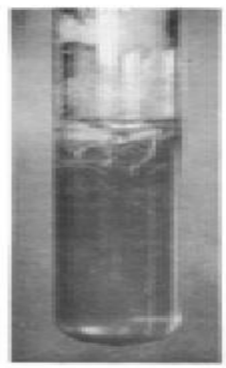
KBC (Dielectric)
[$K_{3.088}Ba_{0.912}Cl_{4.832}.1.369H_2O$]

KCC (Superionic)
[$K_{3.611}Ca_{0.389}Cl_{4.389}.1.177H_2O$]



NCC (Superionic)
[$Na_{3.665}Ca_{0.335}Cl_{4.335}.0.153H_2O$]

Anthracene plate crystal grown above the gel (Gel – solution method)

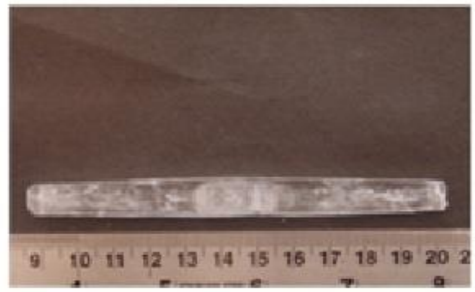


Anthracene whiskers grown within the gel

Calcium tartrate tetrahydrate single crystal grown

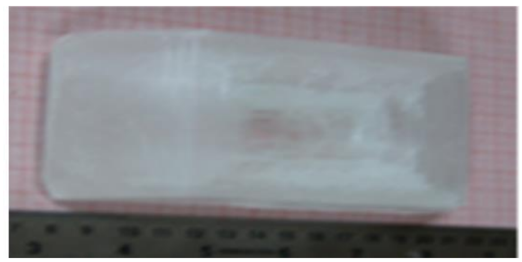
L-arginine oxalate single crystal grown

Photograph showing seed KDP crystal in a trough (Seeded free evaporation method)



Photograph showing the harvested KDP crystal grown in a trough

Largest KDP crystal grown in our Laboratory

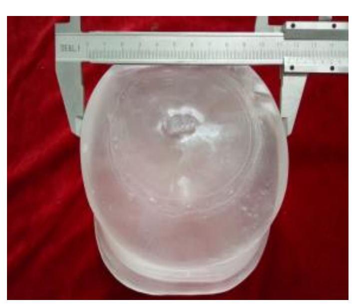


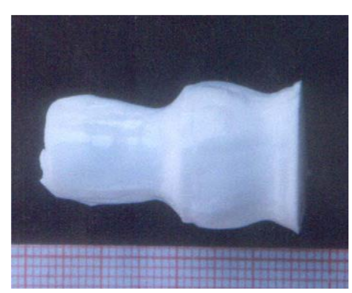
Largest ADP crystal grown in our Laboratory

Grown multiphased ternary mixed crystals of alkali halides, **for the first time**, and found that these crystals have more hardness and more dielectric constant and are more stable than the end member and monophased mixed crystals. Also, **with the collaboration** of research workers from **Changchun University of Science and Technology,** China, **grown** by the Czochrolski method **and characterized large size (weighing about 5 kg) single crystals of $KCl_{1-x}Br_x$.**

The depth profile study made on II-VI compound added alkali halide crystals indicated that the dopant addition creates different layers along the crystal with increase of dopant content from the top to bottom. The crystals cut into thin wafers will be highly useful for devices as each wafer will have different physical properties. Ultimately the **study indicated that a series of materials with different properties can be prepared in a single growth experiment**.

Designed and used a simple and low cost crystal sample holder to carry out the electrical measurements (both AC and DC) by the two-probe (parallel plate capacitor) method. When the area of crystal sample touching the electrode is smaller than the plate area, correction for the air capacitance has to be done. So, **a new formula was derived** by me **to estimate the dielectric constant** which is often called as **Mahadevan's formula/relation**.

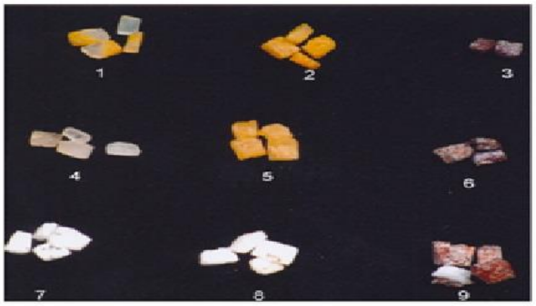




Photograph of $(NaBr)_{0.1}(KCl)_{0.6}(KBr)_{0.3}$ polycrystal (multi-phased) $[(NaCl)_{0.068}(NaBr)_{0.032}(KCl)_{0.570}(KBr)_{0.330}$ in crystal]

Photograph of $KCl_{0.5}Br_{0.5}$ single crystal (large) $[(KCl)_{0.484}(KBr)_{0.516}$ in crystal]

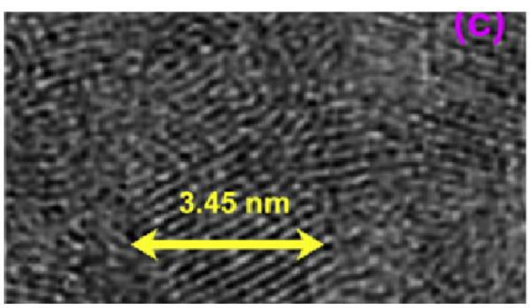
Photograph of $KCl)_{0.1}(KBr)_{0.1}(KI)_{0.8}$ single crystal (multi-phased) $[(KCl)_{0.155}(KBr)_{0.035}(KI)_{0.810}$ in rystal]



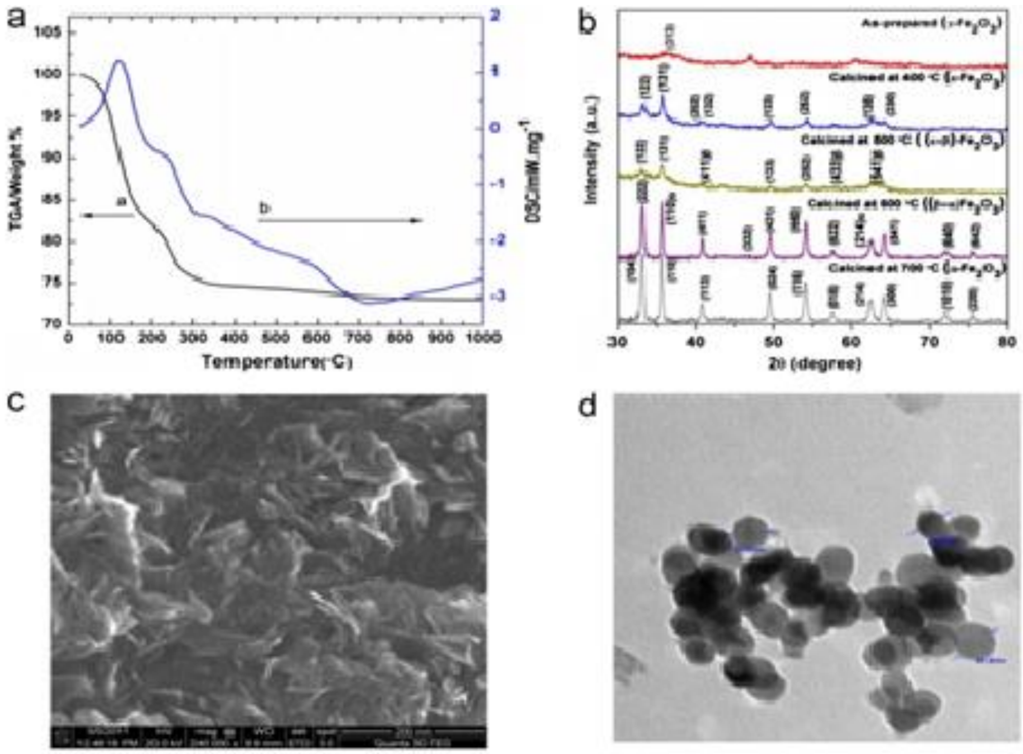
Photograph showing bunches of CdO added cut crystals: 1, 2 and 3-CdO added NaCl: top, middle and bottom, respectively; 4, 5 and 6- CdO added KCl: top, middle and bottom, respectively; 7, 8 and 9-CdO added $(NaCl)_{0.5}(KCl)_{0.5}$ top, middle and bottom, respectively.

Microscopic image of $(NaCl)_{0.5}(KCl)_{0.5}$ crystal surface [M.Priya, C.K.Mahadevan/Physica B 403 (2008) 67-74]

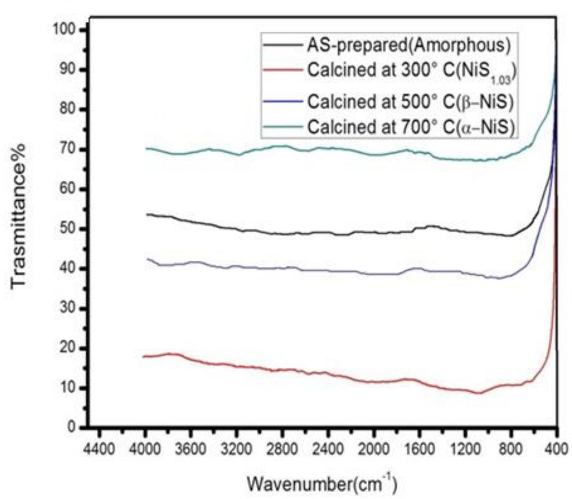
Proposed a new simple solvothermal method using a domestic microwave oven (sometimes called as **Mahadevan's method**) to prepare nanostructured materials. **Succeeded in preparing (with good yield, good quality and useful physical properties) pure and doped nanoparticles** of ZnO, ZnS, CdO, $Cd(OH)_2$, $CdCO_3$, CdS, CdSe, PbS, PbO, NiO, NiS, $NiS_{1.03}$, $Ni(OH)_2$, Mn_3O_4, MnS_2, Co_3O_4, α-Fe_2O_3, Cu_9S_5, CuS, CuO, etc and **nanocomposites** of PbO-PbS, CdS-CdSe, ZnS-CdS, ZnO-CdS, ZnO-ZnS, ZnO-CdO, $CdCO_3$-Mn_3O_4, CdS-MnS_2, $Ni(OH)_2$-Mn_3O_4, Mn_3O_4-MnS_2, etc (all without and with impurity added) by using Mahadevan's method and cheaper chemicals. Nanoparticles of ZnO, ZnS, CdO and CdS could also be **prepared (with good yield, good quality and useful physical properties) at room temperature** by using NaOH as the capping agent.



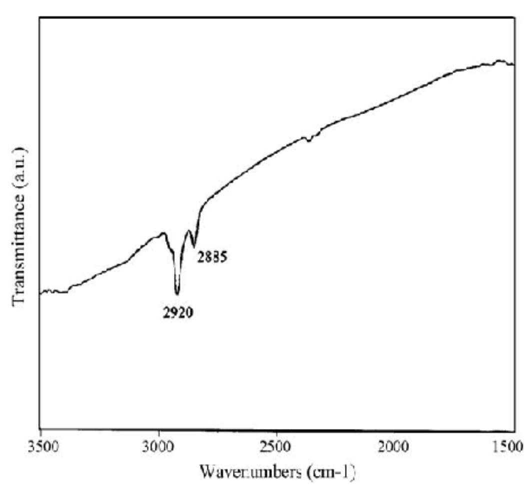
High resolution TEM image of CdS [R.S.S. Saravanan, C.K. Mahadevan / Journal of Alloys and Compounds 541 (2012) 115–124]



(a)TGA and DSC curves for the as prepared Fe_2O_3 samples; (b) PXRD patterns; (c) SEM image of the as prepared sample and; (d) TEM image of the sample calcined at 700°C
[S.I.Srikrishna Ramya and C.K.Mahadevan (2012) Mater.Lett. 89, 111-114]

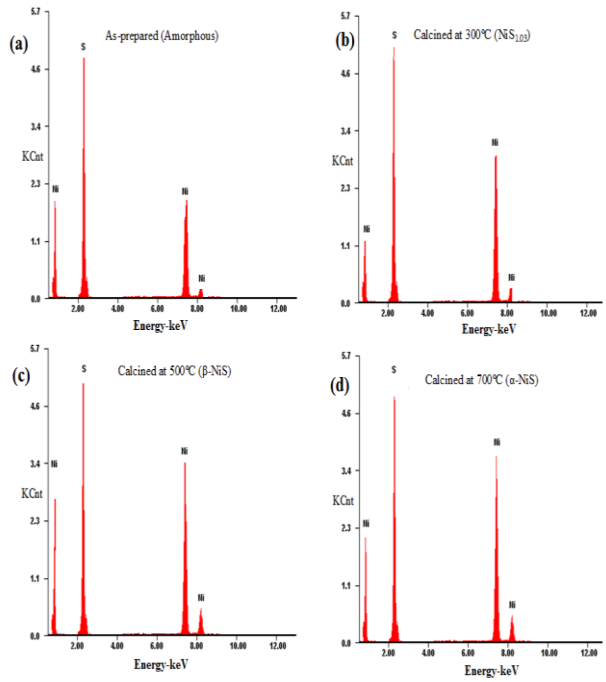


FTIR spectra for NiS nanoparticles prepared by us (Good phase purity obtained)



FTIR spectrum for α-NiS nanocrystals of average size 20 nm reported by Salavati-Niasari et al (2009)
[peaks represent oleylamine carbon chain]

The chemical compositions for amorphous and crystalline NiS nanophases



The EDAX spectra for (a) Amorphous NiS, (b) $NiS_{1.03}$, (c) β-NiS and (d) α-NiS nanoparticles

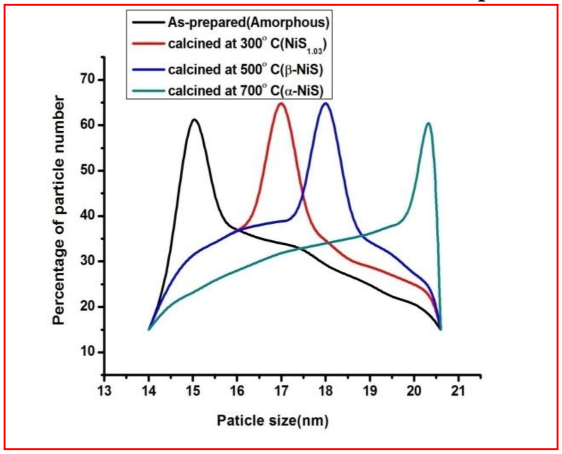
System	Ni	S	Ni:S ratio
Amorphous NiS	49.25	50.75	1:1.030
$NiS_{1.03}$	49.31	50.69	1:1.028
β-NiS	49.85	50.15	1:1.006
α-NiS	49.95	50.05	1:1.002

Presence of Ni and S elements alone (in approximately 1:1 ratio) and no other impurities in the samples prepared. [S.Nagaveena, C.K.Mahadevan/J.Alloys & Compounds 582 (2014) 447-456]

Succeeded in preparing **water soluble (slightly) ZnS and CdS nanoparticles (normally insoluble in water)** by using Mahadevan’s method with ethylene diamine as the capping agent. The **SHG efficiency of ADP and KDP single crystals could be increased significantly** by adding water soluble ZnS and CdS as impurities to them. Succeeded in forming **high quality PVA polymer film sheets** by a simple low-cost solution casting method and found that the use of **different solvents** leads the PVA film to possess **different optical and electrical properties.** Moreover, succeeded in preparing **ZnO/CuO nanoparticles dispersed PVA polymer (nanocomposites) films.**

Found that the $Zn_xCd_{1-x}O$:Mn nanocrystals are dilute magnetic semiconductor (DMS) materials with ferromagnetic order at room temperature. Discovered that forming two – component nanocomposites with ZnO and ZnS and with ZnO and CdS leads to strong enhancement in photoluminescence yield and consequently to new useful materials for photonic applications. Found that amorphous phase of γ-Fe_2O_3 nanoparticles exhibits super paramagnetism. Discovered that doping with Mn enhances the coercivity of α- Fe_2O_3 nanoparticles by more than seven times. Succeeded in preparing all the five phases (amorphous, α-, β-, γ- and ε-) of Fe_2O_3 nanoparticles with high purity by Mahadevan’s method. Also, succeeded in preparing all the four phases (amorphous, α-, β- and $NiS_{1.03}$) of NiS nanoparticles with high purity by Mahadevan’s method. Discovered that anionic doping makes α-NiS nanocrystals a better electrochemical sensing performer.

The particle sizes for all four pure nanophases prepared [S.Nagaveena, C.K.Mahadevan/J.Alloys & Compounds 582 (2014) 447-456]



The size distribution obtained through AFM for Amorphous NiS, $NiS_{1.03}$, β-NiS and α-NiS nanoparticles

System	Particle sizes(nm) from		
	XRD	TEM	AFM
Amorphous NiS	-	15	15
$NiS_{1.03}$	17.8	17	17
β-NiS	18.6	18	18
α-NiS	20.7	20	20.4

III. Citations, Honours and Awards Received

Most of the **research papers** published by me have been well cited (a maximum of more than **121** with an average citation of more than **8**). As per Google Scholar (on November 07, 2018), the **h- and i10 indexes** are respectively **25 and 76**. A group of **Scientists from Greece** have **used** the **experimental data reported by us** in 3 papers (on alkali halide mixed crystals) **for theoretical modeling** (published 5 papers). It should be noted that our publications have been cited in various articles appeared in several international journals, proceedings and books.

I am the **first person** to publish research papers in international journals and produce Ph.D. degrees in Physics / Materials Science / Nanoscience from any College now affiliated to the Manonmaniam Sundaranar University, Tirunelveli. Also, I am the **first person** to be awarded the highest degree (D.Sc. by thesis) in Physics in the Southern Tamil Nadu and first and only Awardee (so far) of the Madurai Kamaraj University. I have been elected as a **Life Member of The National Academy of Sciences, India** and a **Fellow of The Academy of Sciences, Chennai**. Also, I have been selected as one of the Eminent Personalities of India by the International Biographical Research Foundation, India.

I have received the **Prof. P. Ramasamy National Award for Crystal Growth (2006)** from Indian Association for Crystal Growth, **UGC's Research Award** and the **Tamilnadu Scientist Award (2008) (**from **Tamilnadu State Government)** for my scientific research contributions. In addition, **through my Ph.D. Scholars**, received **20 Best Paper/ Best Poster Presentation awards in national/international conferences.**

IV. Future Interest

Interested in developing: (1) New low-cost and non-toxic **pure & hybrid ferrite-polymer nanocomposites** for highly efficient clean energy storage, photonic and EMI shielding, etc devices; (2) Pure and hybrid **alkali halide nanocrystals;** (3) All solid state **Li-ion hybrid supercapacitors**.

PROPOSAL-I

Title:

Development of new low-cost and clean ferrite-polymer nanocomposites for EMI shielding, energy storage and photonic applications

Outline of the Project:

Research work involving the preparation and characterization of new/modified solid state (particularly nanostructured) materials in order to explore potential applications is of paramount importance both academically and industrially.

It is known that Mn_3O_4, Co_3O_4, Fe_3S_4 and $MnFe_2O_4$ exhibit good magnetic, optical and supercapacitor properties and PMMA, PVA and PVP are low-cost and easily processible dielectric polymers. Moreover, $CoFe_2O_4$ is an important and interesting material.

It will be interesting if we can develop simple low cost techniques to prepare new nanostructured mixed spinel ferrites and these ferrite dispersed PMMA/PVA/PVP polymer nanocomposites in film form.

So, it is proposed in this project to develop simple techniques to prepare $Mn_3O_xS_{4-x}$, $Co_3O_xS_{4-x}$ and $Mn_yCo_{1-y}Fe_2O_xS_{4-x}$ (with x = 4, 3, 2, 1 and 0; y = 1.0, 0.75, 0.50, 0.25 and 0.0) nanoparticles (nanopowders) and these ferrite dispersed PMMA/PVA/PVP nanocomposites in film form.

Also, the proposed new nanostructured materials will be prepared, characterized (chemically, structurally, optically, electrically and magnetically) and used in possible EMI shielding, energy storage and photonic devices.

Objectives:

(1) To prepare, by low-cost methods, pure poly(methyl methacrylate) (PMMA), poly(vinyl alcohol) (PVA) and poly(vinyl pyrrolidone) (PVP) films with uniform thickness and new nanostructured materials (nanopowders), viz. $Mn_3O_xS_{4-x}$, $Co_3O_xS_{4-x}$ and $Mn_yCo_{1-y}Fe_2O_xS_{4-x}$ (with x = 4, 3, 2, 1 and 0; y = 1.0, 0.75, 0.50, 0.25 and 0.0) with reduced size, homogeneous morphology, narrow size distribution and chemical phase purity;

(2) To prepare, by a low-cost method, $Mn_3O_xS_{4-x}$ / $Co_3O_xS_{4-x}$ / $Mn_yCo_{1-y}Fe_2O_xS_{4-x}$ dispersed PMMA / PVA / PVP (polymer nanocomposites) films with homogeneous dispersion and uniform thickness for application in EMI shielding, energy storage and photonic devices;

(3) To characterize the prepared nanostructured materials and films chemically, structurally, optically, electrically and magnetically by the available standard methods;

(4) To understand the functional mechanism of the new materials developed;

(5) To fabricate possible EMI shielding, energy storage and photonic devices and assess their performance; etc.

PROPOSAL-II

Title:

Development of pure and hybrid alkali halide nanocrystals

Significance:

Alkali halide crystals have proved useful in several applications which range from X-ray monochromators to tunable lasers. The development of lasers revived the interest in alkali halides as materials for optical components which led to the development of alkali halide polycrystalline materials for use as optical windows.

A preliminary study made by us on alkali halide poly-crystals indicate the possibility of getting nanoparticle aggregation. So, a systematic detailed investigation on the melting and cooling process of pure and hybrid alkali halides is expected to bring fruitful results.

Proposal:

It is proposed to prepare pure and hybrid alkali halide nanocrystals (agglomerated poly-crystals) using the melting and cooling process with high purity, reduced size, narrow size distribution and homogeneous shape.

The prepared nanostructured materials will be characterized chemically, structurally, optically and electrically. Then, possible applications in optical, optoelectronic and electrical devices will be explored.

PROPOSAL-III

Title:

Development of all solid state Li-ion hybrid supercapacitors

Objectives:

(1) To prepare by solution casting method pure PVA polymer films with uniform thickness.

(2) To prepare by solvothermal method new nanostructured Li-based mixed spinel ferrites, viz. $LiMn_yCo_{4-y}Fe_xO_8$ (x varies from 1 to 5 & y varies from 4 to 0 in step of 1; a total of 15 unique combinations) with reduced size, homogeneous morphology, narrow size distribution and chemical phase purity.

(3) To prepare nanostructured $LiMn_yCo_{4-y}Fe_xO_8$ dispersed PVA polymer nanocomposite films and NaOH/KOH dispersed PVA polymer composite films (with 4 different filler loads, viz. 2.5, 5.0, 7.5 & 10.0 wt.%; a total of 68 films) by the optimized solution casting method (a low-cost method) with homogeneous dispersion and uniform thickness for application as cathode and electrolyte materials respectively in Li-ion hybrid supercapacitors.

(4) To characterize the prepared nanostructured materials (Li-based mixed spinel ferrites) and films (pure PVA and polymer composites) chemically, structurally, optically and eletrically by carrying out XRD, FTIR, EDX, XPS, SEM, TEM, UV-Vis-NIR, eletrochemical, etc. measurements

(5) To fabricate all solid state Li-ion hybrid supercapacitors with the newly developed polymer composite films (as cathode and electrolyte materials), activated carbon (as anode material) and Al (as current collector) and assess their performance by cyclic voltammetry (CV) and charging-discharging measurements.

(6) To understand the functional mechanism of the new materials developed.

Interesting and innovative aspects:

(a) Development of a new simple low-cost technique to prepare the new nanostructured spinel ferrites ($LiMn_yCo_{4-y}Fe_xO_8$) with reduced size, homogeneous morphology, narrow size distribution and chemical purity;

(b) Development of a simple low-cost technique to prepare the new polymer composite films ($LiMn_yCo_{4-y}Fe_xO_8$ dispersed PVA polymer nanocomposite film cathodes and NaOH/KOH dispersed PVA composite film electrolytes) with homogeneous dispersion and uniform thickness;

(c) Development of new low-cost but efficient Li-ion hybrid supercapacitors; etc.