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## Thermal, mechanical and linear optical studies of pyridine based trimethoxy substituted chromophore for NLO applications

Ganapayya B.<sup>a</sup>, Haleshappa D.<sup>b</sup>, Jayarama A.<sup>c,d</sup>, S.shetty S.<sup>e</sup>, Shashi Kumar K.<sup>d</sup>, Pinto R.<sup>f</sup>  
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### Abstract

A new potentially useful pyridine-based; 1-(pyridin-2-yl)-3-(2, 4, 5-trimethoxyphenyl) prop-2-en-1-one (2PTM) organic crystals were grown at room temperature by means of slow evaporation solution growth method. The grown crystals were characterized for their linear optical studies using UV-visible and photoluminescence spectroscopy. The thermal and mechanical properties are analyzed by vicker's microhardness and the thermogravimetric and differential thermal analysis. Thermal study confirms that the crystal is thermally stable up to 119.2 °C. The studies of photoluminescence reveal that the 2PTM crystal exhibits the characteristics of blue light emissions. The pyridine-based grown novel crystal has an optical band gap of 2.89 eV. Hence 2PTMP crystals can be used for NLO applications. © 2019 Elsevier Ltd.

### Author keywords

Microhardness; NLO; Photoluminescence; Single crystal

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# Structural, linear and nonlinear optical characterization of Ni and Al Co-Doped CdO semiconductor nanostructures for nonlinear optical device applications

Banuprakash M.<sup>a</sup> , Abhishek B.<sup>a</sup>, Acharya H.<sup>a</sup>, Bairy R.<sup>c</sup>, Bhat S.<sup>a</sup>, Vijeth H.<sup>d</sup>, Murari M.S.<sup>e</sup>, Jayarama A.<sup>a, b</sup>, Pinto R.<sup>f</sup>

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## Abstract

The effects of metallic doping (Ni and Al) on thin film CdO nanostructures have been investigated and their morphological, structural, linear and nonlinear optical properties have been studied. Thin films were grown using spray pyrolysis method with a substrate temperature of 300 °C for different Ni and Al doping concentrations (0, 1, 3, 5 and 10 wt%). Studies of films with Powder X-ray diffraction confirm the polycrystalline nature with the cubic crystal structure. The Scherer rule was employed to determine the crystallite size and found to be enhanced. The elemental analysis confirms the incorporation of Ni and Al into the host CdO matrix. The surface morphology was analysed using the Field Emission Scanning Electron Microscope and the grain size was found to be altered by increasing

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Abdolahzadeh Ziabari, A. , Ghodsi, F.E. , Kiriakidis, G.  
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# Crystalline and optical properties of new synthesized chalcone compound (2E)-1-(4'-bromobiphenyl-4-yl)-3-(2,3-dichlorophenyl)prop-2-en-1-one

Vinutha P.R.<sup>a</sup> , Kaliprasad C.S.<sup>b</sup> , Jayarama A.<sup>c</sup>, Narayana Y.<sup>d</sup>

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## Abstract

The chalcone compound (2E)-1-(4'-bromobiphenyl-4-yl)-3-(2,3-dichlorophenyl)prop-2-en-1-one (BDCP) was synthesized using 4'-(4-bromophenyl) acetophenone and 2,3-dichlorophenyl in the ratio 1:2. Powder X-ray diffraction characterization technique was used to study crystallinity and UV-Visible spectroscopy was used to study optical property of the new chalcone compound. UV region shows strong absorption band in the spectrum with a cut-off at 430 nm. In the present study the crystallinity of the chalcone was confirmed using powder XRD method. The BDCP crystal was also studied with Fourier transform infrared spectroscopy and Fourier transform Raman data. XRD data shows many sharp peaks which indicate the crystalline nature of BDCP. The second harmonic generation efficiency was measured using Kurtz and Perry technique and Nd:YAG laser with 1064 nm wavelength. © 2019 Elsevier Ltd.

## Author keywords

Characterization; New chalcone; NLO; SHG; Synthesis; XRD

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# Structure and property relationship of methoxy substituted novel organic crystals for photonic applications

Haleshappa D.<sup>a</sup>, Jayarama A.<sup>b</sup>, Shankaragouda Patil P.<sup>c</sup>

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## Abstract

In the present work, a promising non-centrosymmetric chalcone derivative 3-(2, 4, 6-trimethoxyphenyl)-1-(thiophen-2-yl)-prop-2-en-1-one (2TM) was investigated to define their potential for photonic applications through various characterization techniques. Therefore 2TM has been synthesized and single crystals have been grown using slow evaporation solution growth technique. The UV-Vis-NIR spectrum reveals the transparency of the crystal for the entire visible region. The thermal stability and phase transition of the compound was studied by thermo gravimetric and differential thermal analysis and found to be stable up to 132 °C. For structural conformation, the Fourier transform infrared spectral tests were performed on 2TM. For nonlinear optical studies of the third order, the Z-scan experiment was conducted. The material had reverse saturation absorption and self-defocusing properties and therefore, 2TM showed strong nonlinear absorption coefficients and optical limiting behavior, under continuous wave diode-pumped solid state laser. Second harmonic generation efficiency of 2TM crystal is 1.12 times the urea efficiency. The single crystal x-ray diffraction studies of the crystal showed that the crystal system of 2TM is orthorhombic with space group P n a 21. The structural and property relationship studies are carried out for the methoxy substituted organic

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A novel bromo-substituted thiophene based centrosymmetric crystals: Thermal, mechanical, and third order NLO properties for the optical limiting applications

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# Synthesis, growth and NLO studies of a novel pyridine centered chalcone derivative

Ganapayya B.<sup>a</sup>, Haleshappa D.<sup>b</sup>, Jayarama A.<sup>c,d</sup>, Shetty S.S.<sup>e</sup>, Dharmaprakash S.M.<sup>f</sup>, Pinto R.<sup>g</sup>

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## Abstract

A novel pyridine based derivative 1-(pyridin-2-yl)-3-(2,4,5-trimethoxyphenyl) prop-2-en-1-one (PTMP) was synthesized and single crystals were grown using slow evaporation technique. The functional groups of the synthesized compound PTMP were confirmed using FTIR spectroscopy. Z-Scan technique was used to find the third order nonlinear optical properties of PTMP. Single crystal X-ray diffraction technique was used to investigate the molecular structural properties. X-ray diffraction studies show that the PTMP crystals belong to centrosymmetric space group P 2<sub>1</sub>/c with lattice parameters a = 8.6516(3) (Å), b = 8.7478(3) (Å) and c = 19.5245(7) (Å). Z-scan studies suggest that the compound PTMP is a promising non-linear optical material for NLO applications. © 2019 Elsevier Ltd.

## Author keywords

Chalcone; Laser; Pyridine; Single crystal; Z-scan technique

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## Third order non linear optical properties of novel furan based organic crystal

Satheeshchandra S.<sup>a</sup> , Namratha W.N.<sup>b</sup> , Haleshappa D.<sup>c</sup>, **Jayarama A.<sup>d,\*</sup>**, Shetty N.<sup>a</sup>, Pinto R.<sup>f</sup>  
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### Abstract

A crystal for potential nonlinear optical applications, namely 1-(furan-2-yl)-3-(3, 4, 5-trimethoxyphenyl) prop-2-en-1-one (FT3MP), has been synthesized using slow evaporation technique. The functional groups present in the compound have been studied with Fourier transform infrared spectroscopy. The Z-scan technique with the single beam was used to examine the third-order NLO properties of the crystal. The measured nonlinear optical absorption coefficient ( $\beta$ ), nonlinear refractive index ( $n_2$ ) and the third order nonlinear optical susceptibility ( $\chi^{(3)}$ ) of FT3MP suggest that the crystal is good for possible photonic applications. © 2019 Elsevier Ltd.

### Author keywords

Laser; Susceptibility; Third order non linearity; Z-scan

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# Synthesis, growth and structural characterization of 1-(furan-2-yl)-3-(2,4,6-trimethoxyphenyl) prop-2-en-1-one crystal

Chandra S.<sup>a</sup>, Anusha B.M.<sup>b,c</sup>, Haleshappa D.<sup>d</sup>, Jayarama A.<sup>c,e</sup>, Shetty N.<sup>a</sup>, Pinto R.<sup>e,f</sup>

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## Abstract

The compound 1-(furan-2-yl)-3-(2, 4, 6-trimethoxyphenyl) prop-2-en-1-one (FT2MP) was synthesized using solution growth method and UV-Visible, FT-IR and FT-Raman spectroscopy studies were carried out. In addition, thermal and optical studies have also been carried out. Thermal studies indicate that acetyl furan substituted chalcone crystal FT2MP is thermally stable. It was also observed that chalcone derivatives substituted with multiple methoxy group show better crystallizability. In case of chalcone derivative such as FT2MP, methoxy group linked on benzoyl ring at one end acts as an electron donor and a methyl furan ring at the other end acts as strong electron acceptor thereby enhancing nonlinearity. Third order nonlinear optical studies have been carried out using both open and closed aperture Z-scan experiments. Third order nonlinear optical properties such as absorption coefficient, refractive index, and susceptibilities have been extensively studied and the results show that the high third order optical nonlinearities of the crystal may lead to important applications in optical devices. © 2019 Elsevier Ltd.

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## Development of novel porous membrane for filtration of dump yard ground water contaminants

Deekshitha K.<sup>a</sup>, Rebello N.<sup>b</sup>, Ramaprasad A.T.<sup>c</sup>, Jayarama A.<sup>c,d</sup>, Pinto R.<sup>e</sup>

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### Abstract

Water in urban areas and especially in developing countries is being polluted due to various reasons. Few of the pollution are due to disposal of industrial effluents directly into rivers, improper treatment of waste water and infiltration in waste disposal sites. The primary reason for contamination near dump yards which do not have proper lining material is due to infiltration. This poses a huge threat to the people living near the dump yard sites. In this paper we report a novel membrane developed using PVC and PVA for filtration of water in which PVA partially acts as a sacrificing component in the creation of pores. The porosity of the polymer composite membrane was studied using scanning electron microscope. The contaminations due to Vamanjoor dump yard site located near Mangalore, Karnataka, India are investigated and the various pollutants in the ground water are identified. A composite filter membrane unit is designed and developed which is used as an integral part of the

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# Structural, morphological and optical properties of barium doped bismuth ferrite thin films deposited by spray pyrolysis

Charishma<sup>a</sup>, Veena Devi Shastrimath V.<sup>a</sup>, Baiyy R.<sup>b</sup>, Murari M.S.<sup>c</sup>, Jayarama A.<sup>d</sup>, Pinto R.<sup>e,f</sup>

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## Abstract

In the area of material science and technology, fabrication and characterization of nano-materials play an important role since it leads to the development of devices with interesting performance and potential applications in electronics, magnetics, optics, and photonics. Among the materials perovskite materials are gaining prominence. In this investigation, thin films of bismuth ferrite have been prepared and the impact of co-substitution of barium on their structural, morphological and optical properties have been studied. The spray pyrolysis procedure was used to prepare the thin films of bismuth ferrite with medium thickness by doping barium with concentrations of 1%, 3%, 5% and 10%.

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# Structural, linear and nonlinear optical properties of $\text{Cd}_{1-x}\text{Al}_x\text{S}$ semiconductor nanostructures: Influence of film thickness

Bairy R.<sup>a</sup>, Jayarama A.<sup>b,c</sup>, Murari M.S.<sup>d</sup>

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## Abstract

The work presented here reports the thickness dependent structural, linear and nonlinear optical properties of nanostructured Al-doped CdS thin films. Thin films were prepared with two different thicknesses (0.5  $\mu\text{m}$  and 1  $\mu\text{m}$ ) by employing a spray pyrolysis (SP) technique for different Al-doping levels (0, 1, 3, 5 and 10 wt%). Powder X-ray diffraction studies confirm the polycrystalline crystal structure. The Scherrer rule was used to determine the crystallite size which was found to decrease with increasing doping concentration. Field emission scanning electron microscopy images showed uniform grain size which was found to slightly decrease with an increase in thickness of the films. The optical energy band gap (Eg) of the films was found to decrease with an increase of film thickness. The

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Bairy, R., Jayarama, A., Murari, M.S.  
(2020) *Applied Physics A: Materials Science and Processing*

Effect of Al doping on photoluminescence and laser stimulated nonlinear optical features of CdO nanostructures for optoelectronic device applications

Bairy, R., Kulkarni, S.D., Murari, M.S.  
(2020) *Optics and Laser Technology*

Role of Zn in tuning the band gap, surface morphology, photoluminescence and optical nonlinearities of CdO nanostructures for photonic device applications

Bairy, R., Jayarama, A., Kulkarni, S.D.  
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## Role of Zn in tuning the structural, morphological and optical properties of V<sub>2</sub>O<sub>5</sub> nanostructures deposited by spray pyrolysis

Rai S.K.<sup>a,b</sup>, Rai R.<sup>c</sup>, Bairy R.<sup>d</sup>, Murari M.S.<sup>e</sup>, Jayarama A.<sup>f</sup>, Pinto R.<sup>g</sup>

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### Abstract

Venadium Pentoxide (V<sub>2</sub>O<sub>5</sub>) thin films were deposited by employing a spray pyrolysis technique on glass substrates at 573 K for different Zn-doping levels (0, 1, 3, 5 and 10 wt%) to study the optical, structural and morphological properties of pure and Zn-doped V<sub>2</sub>O<sub>5</sub> thin films. The characterisation study with powder X-ray diffraction confirms the orthorhombic structure and also that the films grow along (2 0 0) direction with increase in the doping concentration. The Scherer rule was employed to determine the crystallite size and found to be enhanced. Field Emission Scanning Electron Microscopy study reveals that the surface morphology modifications increase with Zn-doping. The surface topography of the prepared films was also studied using AFM and found to be enhanced. The optical energy band gap (E<sub>g</sub>) of the prepared films was found to be varying between 3.27 eV and 3.72 eV due to increase in doping concentration. The interesting results of structural and optical parameters with the increase in Zn-doping concentration suggest that these nanostructured films are a promising material for opto-electronic device applications. © 2019 Elsevier Ltd.

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ISSN  
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10.1016/j.matpr.2020.03.062

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# Preparation, characterization and study on the nonlinear optical parameters of novel biphenyl-4-carbohydrazide derivative

Kamath L.<sup>a</sup>, Bairy R.<sup>b</sup>, Jayarama A.<sup>c</sup>, Narayana B.<sup>d</sup>, Gummagol N.B.<sup>e</sup>, Patil P.S.<sup>f</sup>, Samshuddin S.<sup>g</sup>  
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## Abstract

We report here the preparation, characterization and the 3rd order nonlinear optical properties of (N-((E)-(3-Nitrophenyl) methylidene)) biphenyl-4-carbohydrazide, a novel organic NLO material. The characterization of the compound for molecular structural study was carried out by FTIR and X-ray Diffraction. A Photoluminescence and UV-vis spectrum was selected to study the linear optical properties. In dimethyl formamide (DMF) solution, the 3rd order NLO properties have been measured at 532 nm by DPSS continuous wave laser using the Z-scan technique. Open aperture data indicates the presence of two photon absorption (TPA) at 532 nm. The measured experimental values of nonlinear

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Improved nonlinear optical absorption mechanism and susceptibility ( $\chi^{(3)}$ ) of CdS nanostructured thin films: Role of zinc doping

Bairy, R., Jayarama, A., Kulkarni, S.D.  
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Structural, linear and nonlinear optical properties of Cd<sub>1-x</sub>Al<sub>x</sub>S semiconductor nanostructures: Influence of film thickness

Bairy, R., Jayarama, A., Murari, M.S.  
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10.1016/j.matpr.2020.02.698

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## Simulation and analysis of P(VDF-TrFE) cantilever-beams for low frequency applications

Rashmi K.R.<sup>a</sup> , Arjun Sunil Rao<sup>b</sup>, Satyanarayan<sup>c</sup>, Veena Devi Shastrimath V.<sup>d</sup>, Jayarama A.<sup>a</sup>, Pinto R.<sup>b</sup>  
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### Abstract

The work presented here describes a structural design of piezoelectric co-polymer P(VDF-TrFE) cantilever-beams for very low frequency applications; the design is based on silicon bulk-micromachining and micro-electromechanical systems technology. COMSOL simulation software has been used to study the mechanical and electrical behavior of cantilever-beams. The dimensions of the beams designed are: 3mm×0.6mm×5μm, 5mm×1mm×5μm and 10mm×3mm×5μm. The configuration of the cantilever-beam comprises of an active layer of piezoelectric P(VDF-TrFE) with chrome-gold interdigitated electrodes for electrical signal output generated due to vibration of piezoelectric beams. Simulation results show that the cantilever-beam of dimension 10mm×3mm×5μm has a resonant frequency of 42.68 Hz, indicating that P(VDF-TrFE) is a favorable piezoelectric material for low and very low frequency applications. © 2019 Elsevier Ltd.

### Author keywords

COMSOL; MEMS; P(VDF-TrFE); Piezoelectric; Vibration sensors

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Conference Paper	Conference Proceedings	22147853	10.1016/j.matpr.2020.02.961	

# The pivotal role of the pyridine ring in enhancing second order nonlinearity in methoxy substituted chalcones

Menezes A.P.<sup>a</sup>, Jayarama A.<sup>b</sup>, Raghavendra S.<sup>c</sup>

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<sup>a</sup> Department of Physics, Mangalore Institute of Technology and Engineering (MITE), Moodabidri, 574 225, India<sup>b</sup> Department of Physics, Alva's Institute of Engineering and Technology, Shobhavana Campus, Mijar, Moodabidri, 574225, India<sup>c</sup> Department of Physics, Adichunchanagiri Institute of Technology, Chikmagalore, 577102, India

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## Abstract

In the present article, the linear and nonlinear optical properties of an organic chalcone derivative, 3-(3,4-dimethoxyphenyl)-1-(pyridin-2-yl) prop-2-en-1-one (DMPP) are examined and relationship between the crystal structure and the material property has been analyzed and the results are presented. The crystal has the ability to transmit wider range of EM radiation. The optical band gap evaluated by plotting Tauc's graph is 3.08 eV. Third order nonlinear response of the material is studied by the open aperture z scan experiment. The second harmonic generation efficiency obtained by Kurtz experiment is 7.4 times that of urea. The material's NLO response is analyzed with the help of the literature, and it can be concluded that the optimal arrangements of planar molecules in the crystal structure combined by the hydrogen bond interactions result in an increase in SHG efficiency. Further, the role of pyridine ring at the benzoyl arm on the NLO property of methoxy substituted chalcones is also discussed. Due to the wider transparency window and large SH conversion capability, DMPP can be used for various opto electronic applications. © 2019 Elsevier Ltd.

## Author keywords

Chalcone; Nonlinear optics; Second harmonic generation; Z-scan

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Structural, thermal, linear and nonlinear optical studies of an organic optical limiter based on reverse saturable absorption

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## Novel methyl furan based chalcone material for potential nonlinear optical applications

Satheeshchandra S.<sup>a</sup>, Namratha W.N.<sup>b</sup>, Haleshappa D.<sup>c</sup> , Jayarama A.<sup>d,\*</sup>, Shetty N.<sup>a</sup>, Pinto R.<sup>f</sup>

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### Abstract

A mixture of 2-acetyl furan and 3, 4, 5-trimethoxybenzaldehyde was used to synthesize and grow the novel methyl furan-based chalcone derivative 1-(furan-2-yl)-3-(3, 4, 5-trimethoxyphenyl) prop-2-en-1-one (FT3MP) crystal. Thermal stability of the crystal was found to be up to its melting point and the second harmonic generation efficiency was found to be 1.5 times higher than KDP crystal. UV-Vis spectrum showed a cut-off wavelength at 442 nm. The UV-Vis absorption spectral studies showed that the crystal has better transparency in the visible region of electromagnetic spectrum. © 2019 Elsevier Ltd.

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Puranik, H.R., Ravindra, H.J.  
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Synthesis, growth and structural characterization of 1-(furan-2-yl)-3-(2,4,6-trimethoxyphenyl) prop-2-en-1-one crystal

Chandra, S., Anusha, B.M., Haleshappa, D.  
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22147853  
DOI  
10.1016/j.matpr.2020.02.696

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# Synthesis, growth, Hirshfeld surface analysis and crystal structure of a pyridine based chalcone single crystal

Menezes A.P.<sup>a</sup>, Jayarama A.<sup>b</sup>, Ravindra H.J.<sup>c</sup>

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## Abstract

In this article we present the growth and structural details of a pyridine based chalcone single crystal grown using the method, slow evaporation of solvent. The crystal structure was studied by X-ray diffraction method. The solid belongs to orthorhombic crystal system with a non-centrosymmetric space group Pna21. Weak C-H...O intermolecular hydrogen bond interactions stabilize the crystal structure, which is further confirmed by surface analysis by Hirshfeld. As the material crystallizes in enantiomorphic crystal structure, it may be a potential candidate for various photonic applications. © 2019 Elsevier Ltd.

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The significant role of molecular dipole arrangements on the second and third-order nonlinear optical properties of a furan based chalcone

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Menezes, A.P., Jayarama, A., Ng, S.W.

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The significant role of molecular dipole arrangements on the second and third-order nonlinear optical properties of a furan based chalcone

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Conference Proceedings

ISSN  
22147853

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10.1016/j.matpr.2020.02.093

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# Methanol crossover reduction and power enhancement of methanol fuel cells with polyvinyl alcohol coated Nafion membranes

Rao A.S.<sup>a</sup>, Rashmi K.R.<sup>b</sup>, Manjunatha D.V.<sup>a</sup>, Jayarama A.<sup>b</sup>, Veena Devi Shastrimath V.<sup>c</sup>, Pinto R.<sup>a</sup>  
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<sup>b</sup> Department of Physics, Alva's Institute of Engineering and Technology, Moodbidri, Karnataka, India

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## Abstract

This paper presents the effect of polyvinyl alcohol (PVA) coated Nafion membranes on their water uptake, swelling and proton conductivity for various PVA coating thicknesses. These studies show that the optimum coating thickness of PVA on Nafion is 2  $\mu$ m. Methanol permeation studies show that 2  $\mu$ m thick PVA coating forms a barrier for methanol and significantly reduces methanol permeation through the membranes. Further, passive methanol fuel cells are tested with 2  $\mu$ m thick PVA coat on Nafion as proton exchange membranes and their polarization plots show a significant enhancement in power as

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Choudhury, R.R., Gohil, J.M., Dutta, K.  
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Junoh, H., Jaafar, J., M. Nordin, N.A.H.  
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ISSN  
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## Investigation of physical, spectral and thermal properties of a dimethoxy substituted chalcone for opto-electronic device applications

Praveen Menezes A.<sup>a</sup>, Jayarama A.<sup>b</sup>, Ravindra H.J.<sup>c</sup>

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### Abstract

We report herewith the experimental results of various analytical techniques performed on a chalcone material 3-(3,4-dimethoxyphenyl)-1-(pyridin-2-yl) prop-2-en-1-one (DMPP). The Scanning electron microscope images disclosed a layered 2D growth pattern. Existing functional groups were identified using FT-IR and FT-Raman spectra while the hydrogen atoms in the molecule were confirmed by <sup>1</sup>H NMR spectrum. The title crystal is tested for thermal stability. DMPP melts at 118 °C and chemically stable up to 200 °C. This feature makes the material a useful candidate for high temperature optical device applications. © 2019 Elsevier Ltd.

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## Electrical transport properties of polyaniline grafted radiation crosslinked chitosan

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Present work reports about electrical properties of polyaniline (PANI) grafted with electron beam crosslinked chitosan. Measurement of temperature dependent dc & ac conductivity shows a significant improvement in the ac and dc conductivity after doping with 1 M HCl for different time intervals. The dc conductivity results were analyzed using Mott's variable range hopping mechanism. The ac conductivity of grafted polymer obeys power law and behavior of frequency exponent's has been interpreted by the correlated barrier hopping (CBH) model. The variation of dielectric constant with temperature and frequency is consistent with the Debye type dispersion. © 2019 Elsevier Ltd.

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## Optimum hydrogen flowrates and membrane-electrode clamping pressure in hydrogen fuel cells with dual-serpentine flow channels

Castelino P.<sup>a</sup>, Shah A.<sup>b</sup>, Gokhale M.<sup>b</sup>, Jayarama A.<sup>c</sup>, Suresh K.V.<sup>d</sup>, Fernandes P.<sup>d</sup>, Prabhu S.<sup>b</sup>, Duttagupta S.<sup>e</sup>, Pinto R.<sup>f</sup>

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### Abstract

Hydrogen fuel cells have been designed and fabricated with an aim to investigate effect of cell clamping pressure and hydrogen flowrates on the performance of fuel cells. Fuel cells with active area 1.9 cm × 1.6 cm were fabricated with aluminum anode, cathode and other accessories. Membrane Electrode Assembly (MEA) was made up of nafion 212 (50 μm) membrane sandwiched between two gas diffusion electrodes (GDE) on either side of nafion membrane. Anode and cathode GDE had carbon cloth with 0.25 mg/cm<sup>2</sup> and 0.50 mg/cm<sup>2</sup> Pt loading, respectively. Double serpentine flow channels

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