

# Research Promotion Council



## MES PONNANI COLLEGE

Govt. Aided Institution | Affiliated to the University of Calicut | Esttd: 1968

Recognized under UGC 2(f) & 12(B) | NAAC Re-accredited (II Cycle) with A grade(2012)

## *Vision*

**RPC is established to improve the quality of research and establish a good climate for the research for both students and faculties in the college. The research in various fields of science and humanities subjects has to be improved to create highly academic achievements by partnering with research communities around the globe and to produce novel and groundbreaking outputs in concerned areas of research by sharing responsibility as a group of researchers**

## *Mission*

- **Engender the faculty's abilities to obtain and manage research grants from various government bodies**
- **Broadening of research into interdisciplinary areas.**
- **To drive all the departments to conduct scientific and technical activities in the college like seminars, conferences, workshops, and symposiums.**
- **Promotes the number and quality of research publications in peer-reviewed high-quality journals.**

# Research Promotion council

## In-Charges



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## Major Projects (2015-2021)

Principal Investigator	Title of Project	Funding Agency	Amount Sanctioned	Current Status
Dr. S. Suresh kumar Dept. of Aquaculture and Fishery Microbiology	Development of Completely Closed Green Recirculating Aquaculture System (CGRAS) for indoor Ornamental/ Larval fish production	UGC	10.86 Lakhs	Completed
Dr. K.S. Arun Kumar Dept. of Applied Geology	Integrated Geoenvironmental Assessment of Biyyam Kayal in the Coastal Tract of Malappuram District	Department of Environment & Climate Change	10.53 lakhs.	Completed

# DST – FIST Funding

The college got sanction for an amount of 70 lakhs. The allocation of the fund is as follows.

Equipment- Rs. 32 lakhs For teaching facilities and research facilities –Rs. 20 lakhs

For setting up computer labs- Rs. 7lakhs

Renovation of the lab – Rs. 5 lakhs

Maintenance Rs.3 lakhs

# DST – FIST Funding

Equipment	Category	Approximate Price in lakhs
High Resolution UV/VIS Spectrophotometer	Teaching	6.00
Atomic Absorption Spectroscopy(AAS)	Research	20.0
Petrological Microscope	Research	15.00
High Temperature PID controlled Furnace	Research	4.0
Hydrothermal oven with synthesis accessories	Research	5.0
Flame photometer	Research	1.0
Geomatics	Research	7.00

# Research in Aquaculture and Fisheries Microbiology

## Research Guides



Dr. Ranjeet K



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# Research in Aquaculture and Fisheries Microbiology



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# Research in Aquaculture and Fisheries Microbiology

## Prominent Publications

BRAZILIAN JOURNAL OF MICROBIOLOGY 48 (2017)51-61



BRAZILIAN JOURNAL OF MICROBIOLOGY

<http://www.bjmicrobiol.com.br/>



### Environmental Microbiology

## Diversity of retrievable heterotrophic bacteria in Kongsfjorden, an Arctic fjord



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### ABSTRACT

The diversity and abundance of retrievable pelagic heterotrophic bacteria in Kongsfjorden, an Arctic fjord, was studied during the summer of 2011 (June, August, and September). Retrievable bacterial load ranged from  $10^3$  to  $10^7$  CFU L<sup>-1</sup> in June, while it was  $10^4$ – $10^6$  CFU L<sup>-1</sup> in August and September. Based on 16S rRNA gene sequence similarities, a higher number of phylotypes was observed during August (22 phylotypes) compared to that during June (6 phylotypes) and September (12 phylotypes). The groups were classified into four phyla: Firmicutes, Actinobacteria, Proteobacteria, and Bacteroidetes. Bacteroidetes was represented only by a single member *Leuconothlokiella aequorea* during the three months and was dominant (40%) in June. However, this dominance changed in August to a well-known phytoplanktonic species *Rhodococcus fascians* (32%), which could be a result of decrease in the phytoplankton biomass following the secondary bloom. It is the first report of *Halomonas titanicae* isolation from the Arctic waters. It showed an increase in its abundance with the intrusion of Atlantic water into Kongsfjorden. Increased abundance of *Psychrobacter* species in the late summer months coincided with the presence of cooler waters. Thus, the composition and function of heterotrophic bacterial community was fundamentally different in different months. This could be linked to the changes in the water masses and/or phytoplankton bloom dynamics occurring in Arctic summer.

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### Introduction

Arctic marine ecosystems have recently received increased attention, as they are considered to be sensitive to the climate change.<sup>1</sup> Kongsfjorden, a glacial fjord in the Svalbard

archipelago, Spitsbergen 79° N–12° E, is a key site for the monitoring of Arctic biodiversity and also considered for modeling in climate change studies.<sup>1</sup> The marine ecosystem of Kongsfjorden is well explored with regards to hydrography, mesozooplankton, and higher trophic levels, while the knowledge on its bacterial diversity still remains insufficient.<sup>2</sup>

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## Author's personal copy

Thalassas: An International Journal of Marine Sciences  
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## Re-Description of *Sillago malabarica*, Silver Whiting from Southern Indian Waters

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### Abstract

*Sillaginids* possess similar taxonomic characters, which make the specific identification difficult, and many true species may be hidden in the synonymy of wide-ranging species. There are currently 36 valid species of sand whittings in the family Sillaginidae. Thirteen valid species are reported from Indian waters and six species are reported from the Arabian Sea. Investigations into the sillaginid diversity off the west coast of India revealed the presence of a species from the Arabian seawhich, on examination, proved to be very similar to the types of *Sillago malabarica*. Based on conventional taxonomic analysis and DNA barcoding, we therefore raise *Sillago malabarica* (new combination) from the synonymy of *S. shama* and re-describe it here. Distinctive characteristics of the species include XI–XII spines in the first dorsal fin; 1, 21–24 rays in the 2nd dorsal fin; 3–4/7–8 gill rakers on 1st gill arch; Head length 25.2–30.4; Snout length 39.4%–46.8% HL; post-orbital length 34%–37.5% HL; 34 total vertebrae (abdominal: 13, haemal: 4 and caudal: 17); single sharp spine on the opercular edge; swim-bladder with eight or nine lateral processes extending from entire lateral surface of swim bladder; golden silvery body, dorsal and anal fins hyaline, with yellow tips and the absence of a mid-lateral streak or dark bands. Apart from re described species *S. malabarica*, original *S. shama* is also recorded from Indian waters, in our studies.

**Keywords** *Sillago shama* · *S. malabarica* · Taxonomy · Arabian Sea · India

### Introduction

Members of the family Sillaginidae are easily identified due to their great similarity in morphology and general uniformity in color. They have an elongate body, a conical snout, long based dorsal and anal fins, and a horizontal lower portion of the opercle. The body is covered with small or moderate sized ctenoid scales, and the cheek scales are cycloid or ctenoid. There are 2 dorsal fins, the 1<sup>st</sup> with X–XIII slender spines, the 2nd with 1 slender leading spine and 16–27 soft rays. These similar morphological characters, however, have led to much confusion in their specific identification, and many true species may be concealed in the synonymy of wide-ranging species (Shao and Chang 1978; Shao et al. 1986; McKay 1992; Kaga 2013; Kaga and Heemstra 2013). The family is widespread throughout the Indian Ocean and the western Pacific Ocean, spreading from the west coast of Africa, east to Japan and south to Australia. All species are inshore, bottom-dwelling, schooling fishes with a few species found in deeper water to about 180 m (McKay 1992).

The sillaginids, commonly known as sand whittings, were revised by McKay et al. (1985), who recognised 31 valid species in 3 genera *Sillago*, *Sillaginopsis* and *Sillaginodes*, with

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## Mitochondrial DNA Part A

DNA Mapping, Sequencing, and Analysis

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## Molecular identification and phylogenetic assessment of species under genus *Parapenaeopsis* Alcock, 1901, from Indian waters

L. Mog Chowdhury, Kathirvelpandian A, Divya PR, Basheer VS, Rajool Shanis, Mohitha Chelath, A. Pavan-Kumar & Gopal Krishna

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# Research in Aquaculture and Fisheries Microbiology

## Prominent Publications

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Contents lists available at ScienceDirect

### Molecular Phylogenetics and Evolution

journal homepage: [www.elsevier.com/locate/ympev](http://www.elsevier.com/locate/ympev)



#### Short Communication

### Molecular based phylogenetic species recognition in the genus *Pampus* (Perciformes: Stromateidae) reveals hidden diversity in the Indian Ocean

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#### ABSTRACT

Pomfrets (Genus *Pampus*) are commercially important fishes in the Indo Pacific region. The systematics of this genus is complicated due to morphological similarities between species. The silver pomfret from Indian waters has long been considered to be *Pampus argenteus*. The objective of the study was to utilize the mitochondrial COI gene to establish the molecular identity of the silver pomfret distributed in Indian waters and to resolve the phylogenetic relationships among *Pampus* species in the world based on sequence data in the NCBI database. Seven valid *Pampus* species are identified in this study. The mean genetic divergence value calculated between clades representing these species was 7.9%. The mean genetic distance between the so-called *Pampus argenteus* from Indian waters and sequences attributed to *P. argenteus* from the South China Sea, where the neotype of this species was collected, was found to be larger than 12%, strongly supporting the likelihood of the Indian species being distinct. The Indian *Pampus* species show very close affinity to *P. cinereus*, with inter species differences less than 2%. The taxonomic identity of the silver pomfret in India is also discussed here, in light of molecular and morphological evidence.

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#### 1. Introduction

The silver pomfret, *Pampus argenteus* (Euphrasen, 1788), is one of the most widely distributed and economically important fish species, playing a significant role in the commercial fisheries of Kuwait, Iran, China, India, Korea, Malaysia, Thailand and Japan (Parin and Piotrovsky, 2004; AlMomin et al., 2015). *Pampus argenteus* belongs to the suborder Stromateoidei (Nelson, 2006) that is mostly marine, pelagic and occur worldwide in tropical to temperate regions (Haedrich, 1967). The Stromateoidei are classified into six families: Centrolophidae, Amarsipidae, Tetragnonidae, Nomeidae, Ariommatidae, and Stromateidae. Eschmeyer and Fricke (2016) lists 18 nominal species under the genus *Pampus* of the family Stromateidae, of which eight are currently considered valid.

The systematics of fishes in the genus *Pampus* is complicated due to morphological similarities between species (Cheng, 1962; Haedrich, 1967; Liu et al., 2013a, 2013b; Liu and Li, 1998a, 1998b, 2013). *Pampus argenteus* (Euphrasen, 1788) was described on the basis of specimens from “Castellum Chinese Bocca Tigris, Humen, Zhujiang kou” in modern day Guangdong Province, China. Haedrich (1967) placed *Stromateus cinereus* Bloch, 1795; *Stroma-*

*teus candidus* Cuvier and Valenciennes, 1833; *Stromateus securifer* Cuvier and Valenciennes, 1833; *Stromateus griseus* Cuvier and Valenciennes, 1833; *Stromateus punctatissimus* Temminck and Schlegel, 1845; and *Pampus sinoprospus* Fowler, 1934, in the probable synonymy of *P. argenteus*, while acknowledging future studies might show them to be distinct species. Liu and Li (1998a) revived *P. punctatissimus*, originally described from Nagasaki, Japan, from the synonymy of *P. argenteus* on the basis of specimens from Chinese coastal waters. Liu et al. (2013a) revived *P. cinereus* from synonymy and designated a neotype from Guangdong province, China. The authors also noted that the species they identified as *P. cinereus* had been previously misidentified as *P. nazawa*. Liu and Li (2013) described a new species, *P. liorum*, and noted this species had been previously misidentified as *P. cinereus* and *P. nazawa*. *Pampus argenteus* is also very similar in appearance to *P. echinogaster* (Basilewsky, 1855) and differences between the two species were clarified by Liu et al. (2013b) in their redescription of the former. Liu et al. (2013b) also commented on the similarity of juvenile *P. argenteus* to *P. minor* (Liu and Li, 1998b) which had led to cases of the *P. minor* being mistaken for the former.

Recently, molecular markers have proven to be useful in resolving ambiguous phylogenetic relationships as well as in species and strain identification. Cui et al. (2010) analyzed the phylogenetic

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Journal of Threatened Taxa | [www.threatenedtaxa.org](http://www.threatenedtaxa.org) | 26 December 2018 | 10(15): xxxxxx–xxxxx

### FIRST RECORD OF THE RARE FURRY LOBSTER *PALINURELLUS WIENECKII* (DE MAN, 1881) (DECAPODA: PALINURIDAE) FROM THE ARABIAN SEA

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#### OPEN ACCESS



**Abstract:** Two female specimens of the Furry Lobster *Palinurellus wieneckii* (De Man, 1881) with a total length of 118mm and 114mm, respectively, were obtained from the coral reefs off Kavaratti Island, Laccadive Islands, west of India. Only two species are currently recognized in this genus, which were described from a small number of specimens. As *P. wieneckii* is very rare, the present report from the Lakshadweep Archipelago provides a valuable new distribution point, which is the first record for the Arabian Sea. Illustrations and photographs are provided for this rare lobster.

**Keywords:** Distribution, taxonomy, Indian Ocean, Lakshadweep, Laccadive Islands.

Furry Lobster or Coral Lobster of the genus *Palinurellus* Von Martens, 1878 belonging to the family Palinuridae Latreille, 1802 was recorded from the Indo-West Pacific and the western Atlantic. It is rare throughout its range and descriptions were typically based on only a few specimens. The numerous short setae covering its body give the animal its common name, Furry Lobster. It is comparatively smaller in size than other palinurids and

its systematic placement was uncertain until recently. Due to its peculiar appearance, the genus *Palinurellus* was previously regarded as belonging to a separate family, the Synaxidae Bäte, 1888. Recent phylogenetic analyses using molecular tools, however, showed Synaxidae to be an invalid family and, subsequently, the genus *Palinurellus* was placed in the family Palinuridae (Holthuis 1966; Palero et al. 2009; Tsang et al. 2009; Chan 2010; Chien et al. 2013).

Only two species are currently recognized in the genus *Palinurellus*, *P. gundlachi* (Von Martens, 1878) from the western Atlantic and *P. wieneckii* (De Man, 1881) from the Indo-West Pacific (Chan 2010). The definitions of these two species, however, remain somewhat unclear because of the limited number of specimens available (Holthuis 1966). We report *P. wieneckii* for the first time from the Arabian Sea and the entire Indian coastline, providing an intermediate report of the species in the wider Indo-West Pacific.

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**Competing interests:** The authors declare no competing interests.

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Research Article | **Journal of Aquaculture and Marine Science** | Open Access

### Bacterial Diversity of Giant Freshwater Prawn, *Macrobrachium rosenbergii* and Screening for Probiotic Potential Bacteria

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#### Abstract

In an attempt to explore the probiotic potential of bacteria found in the endemic habitat of *Macrobrachium rosenbergii*, bacteriology of the samples associated with the natural environment of *M. rosenbergii* has been studied. A total of 752 isolates were characterized up to genus level. While feed items and the intestine of adult *M. rosenbergii* showed highest total viable count ( $2.20 \times 10^7$  to  $7.20 \times 10^8$  cfu g<sup>-1</sup> and  $2.95 \times 10^7$  to  $1.37 \times 10^8$  cfu g<sup>-1</sup> respectively), it was relatively low in the water ( $6.00 \times 10^6$  to  $1.46 \times 10^8$  cfu ml<sup>-1</sup>) as well as in the larval samples ( $8.40 \times 10^7$  to  $6.40 \times 10^8$  cfu g<sup>-1</sup>). Characterisation of the various genera of heterotrophic bacteria revealed good diversity of both gram negative and gram positive genera. Bacterial genera such as *Acinetobacter*, *Aeromonas*, *Alcaligenes*, *Vibrio*, *Bacillus*, *Streptococcus* and *Enterobacteriaceae* were identified from all the samples. The screening and probiotic potential study found that *Brevibacillus laterosporus* isolated from the larval sample showed antibacterial activity against fish and prawn pathogens. No adverse effect was noticed when the Post Larvae (PL) of *M. rosenbergii* challenged with the selected probiotic strains and showed good hydrolytic enzyme potential.

**Keywords:** Heterotrophic bacteria; Natural environment; *M. rosenbergii*; Antibacterial activity; *Brevibacillus laterosporus*

#### Introduction

Aquaculture is developing very rapidly in recent years and has significant role in the economic development of the nation; also contribute to the world supply of food and food security. Both developed and developing countries practise small scale to large scale aquaculture systems and have important contribution to food supply, income generation and trade. Approximately 90% of global aquaculture production is based in Asia [1,2]. *Macrobrachium rosenbergii*, popularly known as Giant freshwater prawn has great export market worldwide and is an excellent candidate for freshwater aquaculture. Being the largest species, *M. rosenbergii* is commercially exploited from Vembanad Lake, Kerala, India with a peak fishing season during monsoon and post monsoon. The health of aquatic animals has greatly influenced by the environment which they live and their health status is directly influenced by the presence of microorganisms when compared to the health status of terrestrial animals or humans [3].

Disease outbreak is promoted by intensification and represents one of the biggest causes of loss in aquaculture [4–6]. Since conventional disease management strategy, such as treatment with antibiotics is leading to unfavourable consequences like emergence of drug resistant bacteria, researchers are encouraged to find out alternative strategies such as vaccination, use of immunostimulant and probiotics for the health management of aquatic animal is being tried out. The regulation of antibiotics by European Union [7] and the demand of alternative products against antibiotics [5], open the way to use environment friendly products. The World Bank invested

US\$ 275 million during 1996–2010 for disease related research in shrimp aquaculture [8]. Use of probiotics as an alternative source instead of antibiotics is proving to be an environment friendly mode of health management and capable of modulating the immune system [9]. Recently, the study using bioRx technology combined with the addition of probiotics showed the enhancement of disease resistance and nonspecific immune responses in *M. rosenbergii* [10].

The research for beneficial probiotic bacterial cultures are reported in recent years for the culture of commercially important aquaculture organisms [11,12]. The selection and development of probiotics for different cultured species in India assumes greater significance considering the rejection of farm raised shrimp by EU, citing presence of trace levels of antibiotics in the shrimp. *M. rosenbergii* is emerging as a popular species for aquaculture in India owing to many favourable attributes. Cruz et al. [5] strongly suggested the importance of microbial ecology study and the relationship of microbes with the cultured organism and the importance of phylogenetic identification of probiotic microorganisms. Taking this into consideration an attempt has been made to study bacteriology associated with the natural environment of *M. rosenbergii* and evaluate the probiotic potential of these bacterial isolate to use in the hatchery and culture system of *M. rosenbergii*.

#### Materials and Methods

##### Description of the Study Area

The Vembanad estuary is one of the Ramsara site in India and it is one of the largest tropical wetland with mangroves. It is located between 9° 29' and 10° 10' North latitude and 76° 13' and 76° 31' East longitude, extending a stretch of 60 Km from Cochin bar mouth in the north to Aleppey in the south with an estimated area of 21050 ha. Kumarakom region of Vembanad estuary was chosen as the sampling area and this region is a part of Kuttanad known as the home ground of *M. rosenbergii* [13].

##### Collection of Water Samples

Water, sediment and adult *M. rosenbergii* samples were collected from four different stations (Figure 1) and necessary precautions were taken to minimize the contamination of the sample. Water and sediment samples were collected in sterile bottles and sterile jars respectively. The adult *M. rosenbergii* were collected by fisherman in live condition and brought to the laboratory for analysis. The larvae and Post Larvae (PL) were collected by using 500 µm plankton net and the collected larvae were identified into different stages of growth by using the manual for the culture of *M. rosenbergii* [14].

Two samples of larval and PL feed items were collected using a

# Research in Aquaculture and Fisheries Microbiology

## Prominent Publications

*A Statistical Approach to Optimize Cold Active  $\beta$ -Galactosidase Production by an Arctic Sediment Psychrotrophic Bacteria, Enterobacter ludwigii (MCC 3423) in Cheese Whey*

**Anesa P. Alikunju, Susan Joy, Mujeeb Rahiman, Emilda Rosmine, Ally C. Antony, Solly Solomon, K. Manjusha, A. V. Saramma, et al.**

### Catalysis Letters

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Effects of seasonal anoxia on the distribution of phosphorus fractions in the surface sediments of southeastern Arabian Sea shelf

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### ARTICLE INFO

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### ABSTRACT

The seasonal upwelling along the southeastern Arabian Sea (SEAS) brings cold, nutrient-rich low oxygen surface water to the continental shelf. The subsurface oxygen deficiency due to upwelling is severe in some years, the intensity of which could profoundly influence the nutrient cycling along the SEAS. Herein, we studied the effect of seasonal anoxia on fractionation of phosphorus during the peak upwelling period of August 2013. Abundance of five fractions of phosphorus (P), namely exchangeable or loosely sorbed P ( $P_{ex}$ ), iron-bound P ( $P_{Fe}$ ), authigenic P ( $P_{au}$ ), detrital apatite plus other inorganic P ( $P_{ao}$ ) and organic P ( $P_{org}$ ), in surface sediments of SEAS shelf has been studied using a sequential extraction procedure (SEDEX) to examine their distributions and sources. Total P (TP) concentrations ranged from 209 to 1081  $\mu\text{g g}^{-1}$  with an average of 508  $\pm$  256  $\mu\text{g g}^{-1}$ . Among the five P fractions, the authigenic P was the dominant species, representing about 60% of TP. The relative abundance of P fractions was in the order:  $P_{ex} > P_{Fe} > P_{org} > P_{ao} > P_{au}$ . Multivariate analyses revealed that the P fractions were primarily associated with the organic constituents and fine sediments. The hypoxic bottom condition associated with summer monsoon upwelling significantly reduced the concentrations of  $P_{Fe}$ ,  $P_{ao}$ , and  $P_{org}$  in the surface sediments. The enhanced release of organic bound and iron oxides bound P under low oxygen condition was evident from the enhanced C/P and N/P ratios and lower C/N ratio in the sediments. The intense biomeralization of organic matter and reduction of Fe-Mn oxides due to the periodic anoxia resulted in the transformations of their associated P fractions and enhanced accumulation as authigenic calcium phosphate mineral.

### 1. Introduction

Phosphorus (P) is an essential nutrient for all living species and is believed to be the ultimate limiting nutrient for marine primary production on geological time scales (Howarth et al., 1995; Van Cappellen and Ingall, 1996; Tyrrell, 1999; Paytan and McLaughlin, 2007). Continental weathering processes mainly control the natural supply of P into the marine environment (Filippelli, 2002; Paytan and McLaughlin, 2007). Most of the weathered fractions are trapped or buried in the shelf sediments and thereby removed from the P cycle before they reach the open ocean. In addition, due to its high particle reactivity, P is sorbed onto clay minerals, iron oxyhydroxides and carbonates. Furthermore, the formation of authigenic minerals such as apatite take out P from the seawater (Eijsink et al., 2000; Zhang and Huang, 2007,

2011). Variable decomposition rates of organic carbon and P under oxic and anoxic conditions such as highly productive upwelling regions has major implications in P geochemistry due to redox-dependent recycling (Delaney, 1998). The high productivity due to upwelling will promote fish production. Dissolution of fish debris in sediments may also control benthic pore-water phosphate fluxes and burial of biogenic apatite is documented as an important mechanism for reactive P removal in the upwelling regions (Froelich et al., 1988; Schenau et al., 2000; Schenau and De Lange, 2001).

The biogeochemistry of southeastern Arabian Sea (SEAS) is highly dynamic due to seasonal reversal of wind and currents. The upwelling brings cold nutrient rich, low oxygen waters which makes the SEAS one of the most productive regions of the world (Qasim, 1982; Gupta et al., 2016). In addition, the region is influenced by intrusion of the Bay of

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### RESEARCH PAPER

Journal of Basic Microbiology

## Nitrogen fixing potential of various heterotrophic *Bacillus* strains from a tropical estuary and adjacent coastal regions

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In the present study, we report the nitrogen fixing potential of heterotrophic diazotrophs isolated from a tropical estuary and adjacent coastal sea. Results of the study revealed that most of the species that are capable of fixing nitrogen in the study area belongs to the genus *Bacillus*. The isolates from the estuary showed maximum homology with *Bacillus megaterium*, *B. cereus*, *B. safensis*, *B. licheniformis*, *B. aerophilus*, *B. oceanisediminis*, *B. flexus*, *B. aquimaris*, *B. vietnamensis*, and *B. subterraneus*, whereas the diazotrophic isolates from coastal samples were closely related to *B. subtilis*, *B. megaterium*, *B. circulans*, *B. aerophilus*, *B. flexus*, and *B. oceanisediminis*. Experimental studies to determine the nitrogen fixation potential of isolates revealed considerable variation among different strains and the highest nitrogen fixing potential was recorded in *B. megaterium* (210.05  $\pm$  7.0 nmol C<sub>2</sub>H<sub>4</sub>/mg protein/day) followed by *B. flexus* (108.76  $\pm$  3.66 nmol C<sub>2</sub>H<sub>4</sub>/mg protein/day) and *B. circulans* (98.28  $\pm$  4.32 nmol C<sub>2</sub>H<sub>4</sub>/mg protein/day). Molecular basis of nitrogen fixation by these heterotrophic *Bacillus* strains has been explored in terms of the presence of *nifH* gene in them. We observed that heterotrophic *Bacillus* sp. have potential ability to fix nitrogen.

### KEYWORDS

acetylene reduction assay, *Bacillus*, heterotrophic nitrogen fixation, *nifH*

### 1 | INTRODUCTION

Biological nitrogen fixation is considered as one of the most important natural mechanism on earth [1]; and is carried out by diazotrophic bacteria that replenishes fixed amount of nitrogen to the environment [2]. In general, Cyanobacteria are considered as the key contributors to marine nitrogen fixation [3,4], however, it is reported recently that diazotrophs also include a wide array of heterotrophic microorganisms,

who play significant role in the nitrogen cycle of aquatic environments [5]. *nifH* gene has been frequently used to study the presence and diversity of nitrogen fixers [6]. Zehr et al. [7] reported that the *nifH* gene encoding the dinitrogenase reductase are part of the nitrogenase complex, is a universally used marker for studying the diazotrophic group and gene activity in diverse ecosystems. The distribution and diversity of these heterotrophic organisms in natural ecosystems indicate significant ecological role in the aquatic environment.

*Bacillus* is an aerobic, rod shaped, endospore forming bacteria [8], and is a major community of the microbial flora

Yousuf Jesmi and Thajudeen Jabir contributed equally to this work.

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# Research in Aquaculture and Fisheries Microbiology

## Prominent Publications

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### Diversity of sediment bacterial communities in the South Eastern Arabian Sea

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#### ABSTRACT

The bacterial community structure in the surface sediments of the South Eastern Arabian Sea (SEAS) was assessed using high-throughput Illumina based sequencing. An attempt was also made to evaluate the role of environmental variables on the distribution of the bacterial community. A total of 53 phyla, 111 classes, 155 orders, 179 families, and 215 genera were detected in the study area. There was no significant difference in the major bacterial communities between nearshore and offshore stations whereas the relative abundance of the majority of OTUs showed station/depth wise variation. *Proteobacteria* was the dominant phylum observed in all the stations, which ranged from 50.3% to 59.5% of the total sequences retrieved. Other abundant phyla observed were *Chloroflexi* (7.4% of total sequences), *Actinobacteria* (6.4%), *Acidobacteria* (5.5%), *Nitrospirae* (2.7%), *Gemmatimonadetes* (2.4%), *Bacteroidetes* (1.5%), candidate phylum "Latescibacteria" (1.4%), and *Spirochaetes* (1.1%). All the remaining phyla were observed in lower numbers, comprised of <1% of the total sequences. Within the *Proteobacteria* 63.8% of sequences were *Deltaproteobacteria*, 21.8% were *Gammaproteobacteria* and 1.6% were *Alphaproteobacteria*. The dominant genera observed within the phylum *Proteobacteria* were *Photobacterium*, *Desulfococcus*, *Acinetobacter*, *Pseudomonas*, *Marinobacter*, *Nitrospina*, and *Desulfosarcina*. The dominant genera observed under the phylum *Chloroflexi* were *Deltahaloceocoides*, *Anaerolinea*, *Galdinia*, and *Thermogemmatispora*. Among the environmental variables, total nitrogen and total sulphur were showed influence on the OTUs distribution in the study area. The dominant phyla in the SEAS such as *Proteobacteria*, *Chloroflexi* and *Nitrospirae* were also significantly influenced by these environmental variables.

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#### 1. Introduction

The sediments of the marine environment act as the final storage ground for nutrient inputs from water column processes and various anthropogenic sources. This nutrient availability makes sediments a suitable environment for the diverse taxa of microbes (Fierer and Lennon, 2011). Microbial abundance of marine sediments is estimated at about  $35.5 \times 10^9$  cells, comprising 55%–86% of the Earth's prokaryotic biomass and 27%–33% of the living biomass (Whitman et al., 1998). Most of these microorganisms are involved in the functioning of various biogeochemical cycles in the ocean and are responsible for the regeneration of nutrients from sediments to water column (Atlas and Bartha,

1993). The regeneration of nutrients, especially the limiting nutrients, is critical for sustaining the productivity of the upper water column (Brandes and Devol, 1997). The role of microorganisms in ecosystem multifunctionality has been closely related to species diversity of different groups of organisms. The microbial diversity and abundance are known to be strongly driven by the soil's physico-chemical conditions (Fierer and Jackson, 2006; Lauber et al., 2009; Marinari et al., 2012). Since the resident microorganisms are fine tuned to adapt to these environmental conditions, their abundance and community composition are of great importance in understanding the biogeochemical processes in marine sediments. Sediment bacterial diversity has been investigated from different oceans, such as the Pacific (Bienhold et al., 2016; Shulse et al., 2017), Atlantic (Varliero et al., 2019), and Arctic (Dong et al., 2017; Hoffmann et al., 2017). However, the sediment microbiomes of Indian ocean especially the South Eastern Arabian Sea have not yet been well investigated using advanced sequencing technologies.

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### Relative Prevalence of Antibiotic Resistance among Heterotrophic Bacteria from Natural and Culture Environments of Freshwater Prawn, *Macrobrachium rosenbergii*

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#### Abstract

As antibiotic residues and multidrug-resistant (MDR) bacteria are of increasing concern to those involved in the seafood industry, there is an intense international focus to monitor MDR bacteria in seafood. There is also a trend to source seafood from organically raised farms in order to reduce antibiotic usage in culture operations. Hence this study was conducted to compare the antibiotic resistance among bacteria associated with various samples from the natural and culture environment of *Macrobrachium rosenbergii*. Samples from the natural environment included water, sediment, eggs, larvae, postlarvae (PL), feed items, and gut samples of *M. rosenbergii* and those from the culture environment were water, sediment, eggs, feed pellets, and gut samples of *M. rosenbergii*. Bacteria from water samples of natural and culture environments were frequently resistant to ampicillin, erythromycin, and penicillin, while more than 50% of the strains from sediment were resistant to erythromycin, nalidixic acid, and penicillin. Bacterial isolates from commercial feed had a relatively high degree of antibiotic resistance. Interestingly, occurrence of multiple drug resistance was higher among the bacteria associated with the samples from the natural environment of *M. rosenbergii*, pointing to more favorable selection pressure for drug resistant mutants in the natural environment.

The growth of the shrimp and prawn aquaculture industry has increased the need to intensify hatchery and farming practices to maximize profits. Problems of diseases often accompanied this intensification as environmental conditions deteriorated and brought the decline of the industry (Oliveira et al., 2012). Disease outbreaks are being increasingly recognized as significant constraints on aquaculture production and trade, affecting the economic development of the sector in many countries. Bacterial diseases are a major cause of mortality in shrimp larviculture and fish hatcheries (Chrisolite et al., 2008; Sandaa et al., 2008; Kitiyodom et al., 2010). It

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is common practice among hatchery managers to control bacterial infections or even the presence of potentially pathogenic bacteria in the system with the help of therapeutants, especially antibacterials (Lewin 1992; Defoirdt et al., 2011; Rico et al., 2012).

Wide use of antibiotics resulted in a global increase in antibiotic resistance among pathogenic bacteria, a wide range of antibiotics are now being used in the hatcheries and farms of freshwater prawn and marine shrimp in India to control bacterial populations (Sahul Hameed and Balasubramanian 2000; Vivekanandhan et al., 2002; Heuer et al., 2009) and the potential consequences of antibiotic use in the treatments are the development of antibiotic-resistant microorganisms, multiple antibiotic resistance (MAR), resistance transfer to pathogenic bacteria, and reduced efficacy

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doi: 10.1111/jwas.12287

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# Research in Aquaculture and Fisheries Microbiology

## Prominent Publications

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### PREVALENCE OF MULTIPLE ANTIBIOTIC RESISTANT AND EXTENDED SPECTRUM BETA-LACTAMASE (ESBL) PRODUCING *ESCHERICHIA COLI* IN A TRADITIONAL FISHING HARBOUR AND SURROUNDING WATER BODIES IN THE SOUTH-WEST COAST OF INDIA

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**Abstract:** In the present study, a total of 106 isolates of *Escherichia coli* were obtained from 390 samples collected from Ponnani harbour and surrounding water bodies like Ponnani estuary, Puthoponnani backwaters and Canoli canal over a period of two years. Antibiotic sensitivity studies were carried out by employing 12 antibiotics to determine the multiple antibiotic resistance (MAR) and the resistance profile of different isolates. Extended-Spectrum Beta-Lactamase(ESBL) production and virulence characteristics like haemolysis, cell surface hydrophobicity, and serum resistance of the strains were also investigated in the current study. Results revealed that 58.4% of isolates were resistant to ampicillin. Resistance to other antibiotics was comparatively lower (<20%), and all the isolates were sensitive to imipenem. Altogether 16(15%) isolates demonstrated multiple antibiotic resistance in the present investigation. MAR index of *E. coli* isolates from Ponnani harbour, and surrounding water bodies ranged from 0.25 to 0.41. But the MAR index of all the sampling locations were less than 0.25. ESBL production was observed in 6.6% of *E. coli* isolates, and the study also revealed a significant association between multiple antibiotic resistance and ESBL production. Twenty-six (24.5%) isolates were found to be haemolytic twelve (11.3%) were hydrophobic, and twenty (18.8%) isolates exhibited serum resistance.

**Key words:** Antibiotic resistance, ESBL production, MAR index, Serum resistance

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### Phylogenetic Grouping and Virulence Genes Distribution in Uropathogenic *Escherichia coli* Isolated from Environmental Samples in Ponnani, South India

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#### Abstract

Isolation and phylogenetic characterisation of *E. coli* were carried out along with the identification of uropathogenic strains by detection of virulent factors. The samples were collected from Ponnani harbour and the surrounding water bodies. The virulent factor genes were detected with the help of PCR. Isolates were screened for the presence of genes *hly D*, *afa*, *sfa* and *pap* and were considered as Uropathogenic *Escherichia coli* (UPEC) if two or more virulent factor genes were present. Phylogroup assignment was carried out by scoring the presence/absence of the genes in the order *arpA/chuA/yjaA*. Of the 25 chosen isolates for phylogenetic studies, 8 (32%) belonged to group B<sub>2</sub> and 6(24%) belonged to Group A. The group C, D and E were represented by only one isolate, whereas, 2(8%) isolates represented group B<sub>1</sub>. The group F had 4 (16%) isolates. In the current investigation, of the 25 isolates of *E. coli* were selected for the detection of virulence gene by PCR, 17 strains were found to possess one or more virulence factor genes

**Keywords:** Ponnani harbour, Phylogenetic studies, UPEC, Virulent factors

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Special Issue 1 (COVID-19)

### Healthcare management through mitigation of COVID-19 pandemic with leafy vegetables

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#### Abstract

COVID-19 pandemic becomes one of the leading challenges across the world. To fight against the virus, compulsory maintenance of nutritional status is very important. Age, sex, health status, medications and lifestyles are the important factors affecting individuals regarding their nutritional status. Due to the COVID-19 pandemic, the nutritional status of individuals is destabilized. To survive the current situation, a sustainable nutritional dietary should be maintained for strengthening the immune system. One of the most important ways to maintain the immune system is to supplement enough vitamin C. A spectrum of viruses that belongs to the coronavirus in humans usually causes the common cold, which is recently severe acute respiratory syndrome (SARS). SARS considered a major threat to public health, which is an emerging infectious disease. According to WHO, COVID-19 caused by the coronavirus, in which most people probably have low immunity. Eighty-five per cent of the immune system has been made by plant-based food supplements, which increase beneficial intestinal bacteria. Minerals like zinc, magnesium, micronutrients, herbal foods and vitamins C, D and E and plenty of water promote health, which is highly helpful to overcome the infection. Many studies revealed that COVID-19 infection prevented by the powerful antioxidant glutathione and bioflavonoid quercetin; to control COVID-19, plant-based foods playing a very important role to increase the immunity of people. Leafy greens and vegetables play a very important role in food and nutritional safety. Green leafy vegetables are an excellent source of vitamins, phenolic compounds and minerals. Calcium and iron are rich in leafy vegetables than that of staple food grains. Folic acid is also present in leafy vegetables. Different leafy greens, especially *Moringa oleifera* leaves, contain a high amount of folic acid compared to other leafy and non-leafy vegetable plants. This review paper aims to explore the nutritional and antinutritional factors of some important leafy vegetables. The content of nutritional and antinutritional factors varies among the genera and species of most of the edible leafy vegetables. Antinutritional factors are considered the important compound in the plant, in which they determine the absorption capacity of nutrients in human beings. Important dietary factors such as phyates, oxalates, nitrates, glycosides and cyanogenic are fruitful in many health-related problems. This article mainly explores the significance of nutrition and the use of leafy vegetables to boost up the immunity system in human beings and provide reliable dietary strategies about food safety and nutrition to survive COVID-19 pandemic around the world, especially in India.



# Research in Geology



## GIS & REMOTE SENSING LAB



# Research in Geology



## Petrology Lab

The Petrological microscope procured under the DST-FIST scheme is a multi (Penta-) ocular microscope

## PerkinElmer PinAAcle 500 Flame Atomic Absorption Spectrometer (AAS)



# Research in Geology



Dr. V. A. AYISHA  
Associate Professor



Dr. V.K. BRIJESH  
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Dr. C. SREEJITH  
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# Research in Geology: Prominent Publications



Precambrian Research  
Volume 364, 15 September 2021, 106342



## Beach placers of southwestern India: An archive of Precambrian supercontinent growth histories

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<https://doi.org/10.1016/j.precamres.2021.106342>

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### Highlights

- SW coast of India preserve sediments sourced from all Precambrian supercontinents.
- Zircon U–Pb age ranges from Paleoproterozoic to Late Cambrian (~3500–450 Ma).
- Paleoproterozoic to Paleoproterozoic zircon sourced from local and distal

## Article

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## Charnockite: a candidate for 'Global Heritage Stone Resource' designation from India

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# Research in Geology: Prominent Publications

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## Heavy Metal Accumulation in Sediments of a Tropical Estuary: A Case from the Southwest Coast of India

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### Abstract

Levels of heavy metals (Cr, Cu, Pb, Zn, Fe, Mn), organic carbon content and textural characteristics in the surficial sediments of Akkulam-Veli estuary (SW coast of India) are presented. Spatial variations were in accordance with textural characteristics and organic matter content. Anthropogenic inputs (sewage, effluent discharge, municipal solid waste, eutrophication and tourism influx) have given rise to a gradient in concentration of metals in estuarine sediments. Extent of heavy metal accumulation in estuarine sediments has been evaluated using Contamination Factor (CF), Index of Geoaccumulation (Igeo) and Pollution Load Index (PLI). High CF and PLI values in the sediments of estuary can be attributed to high inflow of these metals through anthropogenic inputs and the role played by the finer fraction and TOC in the distribution and retention of trace elements in the sediments. Subsequently the accumulation of metals in this estuarine system is aggravated by weak flushing. However Igeo of Fe, Mn, Cr, Cu, Mn remains zero class probably due to the predominance of lithogenic flux.

**Keywords:** estuary; texture; organic carbon; heavy metals; pollution load index; contamination factor; Index of geoaccumulation; Akkulam-Veli estuary



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## Remote Sensing Applications: Society and Environment

Volume 20, November 2020, 100411



## Landslide susceptibility modelling using integrated evidential belief function based logistic regression method: A study from Southern Western Ghats, India

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Abstract

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# Research in Physics: Facilities



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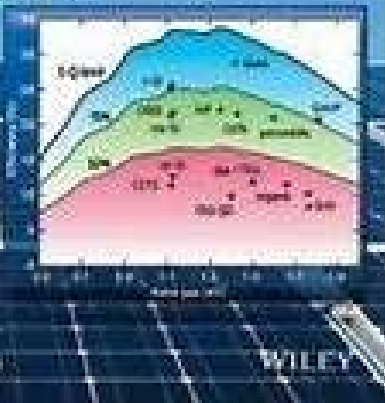




# Research in Physics: Prominent Publications

## EMERGING PHOTOVOLTAIC MATERIALS Silicon & Beyond

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**Pulsed laser deposition and optical band gap engineering in multinary transparent conducting oxide thinfilms**

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**ABSTRACT**

Synthesis of ternary and multinary oxide-based films offers the possibility of tuning electrical and optical properties of the existing materials over wide range. Here we report about synthesis and characterization of  $Zn_{0.9}Sn_{0.1}In_{0.1}Ga_{0.1}O_4$ ,  $Zn_{0.9}Sn_{0.1}In_{0.1}O_4$  and  $Zn_{0.9}Sn_{0.1}Ga_{0.1}O_4$  grown by a pulsed laser deposition method. These compounds have been synthesized on the base of  $Zn_2SnO_4$  by substituting  $Zn^{2+}$  and  $Sn^{4+}$  cations with group-II elements such as  $In^{3+}$  and  $Ga^{3+}$ . The newly synthesized films are shown to possess a very smooth surface with lower RMS components and exhibit dense grown crystallites with homogeneous distribution of small grains. Highly textured growth of inverse cubic spinel structured thinfilms along (111) direction is identified from X-ray diffraction studies. Raman analysis provided supplementary evidences for XRD results. Giant increases of the band gap from 3.60 eV to 3.90 eV have been reported by the development of multinary compounds. The electrical features obtained from Van der Pauw Hall measurements show enhanced charge carrier mobility, resistivity and moderate charge carrier concentrations.

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### 1. Introduction

Transparent and conducting thinfilms are technologically important materials because of its numerous device applications as electrode materials in thinfilm transistors, organic light emitting diodes (OLEDs), LEDs, thin-film photovoltaic, flat-panel displays, polymer-based electronics and architectural windows [1–3]. They require energy efficient transparent conducting contacts for their proper functioning, since, most of these devices utilize the phenomena of light induced electricity or vice versa [3–6].

Materials derived from various metal oxides (TCOs), thin metal films, sulfides, selenides, nitrides, nanocomposites, graphenes and polymers are reviewed as efficient candidates for many practical purposes [2]. However, among these materials, TCOs exhibit more thermal stability, easy to deposit and possibility of synthesizing of new transparent conducting materials (TCM) with controllable properties [2]. Engineering of multicomponent oxides composed of binary and/or ternary compounds might offer possibility of tuning material properties in a suitable desired manner [7–8]. Zinc stannate ( $Zn_2SnO_4$ ), a binary compound with inverse cubic spinel structure is one of the suitable candidates for multication compound engineering since it exhibit very high optical transmittance and n-type electrical conductivity as a result of its intrinsic deviations

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**Micro-strain, dislocation density and surface chemical state analysis of multication thin films**

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**ABSTRACT**

Multication complex metal oxide thin films are rapidly expanding the class of materials with many technologically important applications. Herein this work, the surface of the pulsed laser deposited thin films of  $Zn_2SnO_4$  and multinary compounds obtained by substitution/co-substitution of  $Sn^{4+}$  with  $In^{3+}$  and  $Ga^{3+}$  are studied by X-ray photoelectron emission spectroscopy (X-PES) method. Peaks corresponding to the elements of Zn, Sn, Ga, In and O on the film surface has been identified and contribution of the elements has been studied by the computer aided surface analysis (CASA) software. Binding energies, full-width at half maximum (FWHM), spin-orbit splitting energies, asymmetric peak-shape fitting parameters and quantification of elements in the films are discussed. Studies of structural properties of the films by x-ray diffraction (XRD) technique showed inverse spinel type lattice with preferential orientation. Micro-strain, dislocation density and crystallite sizes in the film surface have been estimated.

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**1. Introduction**

Because of many technologically important properties such as transparency to visible light and good electrical conductivity, transparent conducting materials (TCM) have found diverse optoelectronic device applications [1–4]. Classic TCMs used in the semiconductor industry are based on oxides of elements with five closely grouped  $d^{10}$  cations (Zn, Sn, In, Ga and Cd) [5]. Sn-doped  $In_2O_3$  is most widely used transparent conducting oxide (TCO). Al-doped ZnO and Ga-doped ZnO have also been reviewed many times [5–8]. Search of novel TCOs has led to the development of multication materials, which are based on combinations of divalent 2+ (e.g.,  $Zn^{2+}$  and  $Cd^{2+}$ ), trivalent 3+ (e.g.,  $In^{3+}$  and  $Ga^{3+}$ ) and tetravalent 4+ (e.g.,  $Sn^{4+}$ ) cations [9]. These combinations are known as ternary and multinary TCOs [10]. In this paper, we discuss the structural properties and electronic structure of the thin films of the multication metal oxides. We deposited two compounds in the  $(2+)(4+)(3+)$  cation coordination and one in  $(2+)(4+)(3+)(3+)$  coordination by pulsed laser deposition technique on quartz substrate [11]. Cubic spinel structured  $Zn_2SnO_4$  (ZTO) known also as zinc stannate, is selected as the parent material. The ZTO films possess wide band gap with high optical transmittance to visible light, are chemically stable and exhibit high electrical resistivity, so that they can be used as buffer layer in thin film solar cells [12]. Meanwhile, ZTO exhibit pronounced non-stoichiometry with chemical formula  $Zn_{2-x}Sn_{1+x}O_{4-x}$  and at high temperatures permits aliovalent substitutions and co-substitutions of  $Sn^{4+}$  by  $In^{3+}$ ,  $Ga^{3+}$  through solid state reactions [10]. As reported in our previous article the average optical transmittance of  $Zn_2SnO_4$  films was ~85% with electrical resistivity of ~264  $\Omega \cdot cm$ , that by cation substitution was reduced to ~10<sup>-3</sup>  $\Omega \cdot cm$  [11]. In all cases, regardless of the modest n-type carrier concentrations, the magnitude of the experimentally measured mobility of electrons in cation substituted  $Zn_2SnO_4$  was much higher than in  $Zn_2SnO_4$ . The reported charge carrier mobilities are 20.06  $cm^2 V^{-1} s^{-1}$  for  $Zn_2SnO_4$ , 75.01  $cm^2 V^{-1} s^{-1}$  for  $In^{3+}/Zn_2SnO_4$ , 21.25  $cm^2 V^{-1} s^{-1}$  for  $Ga^{3+}/Zn_2SnO_4$  and 70.02  $cm^2 V^{-1} s^{-1}$  for  $In^{3+}/Ga^{3+}/Zn_2SnO_4$  [11]. In this paper, we report about structural properties, electronic structure of thin films of complex metal oxides synthesized by pulsed laser deposition method.

**2. Experimental procedure**

The thin films of the compounds are grown on quartz substrate by common optimized deposition conditions. Previously we have

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# Research in Physics: Prominent Publications

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ORIGINAL PAPER: CHARACTERIZATION METHODS OF SOL-GEL AND HYBRID MATERIALS

## Core level X-ray photoelectron emission spectra and structure-related multi-excitonic photoluminescence with reduced recombination rate in mesoporous TiO<sub>2</sub>/RuO<sub>2</sub>/CuO nanomaterials

Juliya Acha Parambil<sup>1,2</sup> · V. M. Abdul Mujeeb<sup>2</sup> · K. P. Sreenivasan<sup>1</sup> · P. Jayaram<sup>3</sup>

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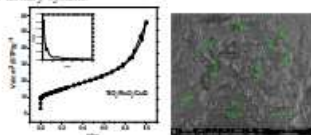
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### Abstract

Highly textured mixed metal oxide nano systems consisting of TiO<sub>2</sub>, RuO<sub>2</sub>, and CuO (TiO<sub>2</sub>/RuO<sub>2</sub>/CuO) were developed through triblock copolymer and Pluronic P123 assisted sol-gel method followed by calcinations at relatively lower temperature from the corresponding inorganic precursors. The powder X-ray diffraction pattern connotes the formation of mixed TiO<sub>2</sub> structure made up of anatase and rutile phases with reduced crystal symmetry when the compounds aggregate from TiO<sub>2</sub>/RuO<sub>2</sub> to TiO<sub>2</sub>/RuO<sub>2</sub>/CuO phase. The X-ray Photoelectron spectra is conspicuously indicated growth of both tertiary and quaternary configuration of elements in the specimens. The Gaussian-Lorentzian Sum peaks obtained in O1s and Ru3d<sub>5/2</sub> elemental scanning were deconvoluted for corresponding individual components raised due to multivalent state or mixed emissions. N<sub>2</sub> sorption studies using BET analysis shows the specific surface area of TiO<sub>2</sub>/RuO<sub>2</sub>/CuO is 53 m<sup>2</sup>/g and the same for TiO<sub>2</sub>/RuO<sub>2</sub> is 40 m<sup>2</sup>/g. The textural property ascertains both compounds exhibit type IV adsorption isotherms with hysteresis loop analogous to the features of mesoporous materials. The surface topography retrieved using scanning electron microscopy (SEM) exhibit the formation of agglomerated nanostructures with average particle size of 21 and 35 nm respectively for mesoporous TiO<sub>2</sub>/RuO<sub>2</sub> and TiO<sub>2</sub>/RuO<sub>2</sub>/CuO. The near band edge emissions are cumulative emissions from excited and de-excitation electron or due to the formulation of electron-hole pairs. These emissions are resolved and reported. Photoluminescence intensity of TiO<sub>2</sub>/RuO<sub>2</sub> is significantly higher than TiO<sub>2</sub>/RuO<sub>2</sub>/CuO, this is mainly attributed to reduced recombination of photo-excited electron-hole pairs in TiO<sub>2</sub>/RuO<sub>2</sub>/CuO.

### Graphical Abstract

Sol-gel synthesized mesoporous TiO<sub>2</sub>/RuO<sub>2</sub>/CuO nanomaterials with specific surface area of 53 m<sup>2</sup>/g and reduced average pore diameter. The surface topography with average particle size 35 nm in mesoporous TiO<sub>2</sub>/RuO<sub>2</sub>/CuO. The particle size increased after the formation of tertiary system.



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## Multiple deep-level defect correlated emissions and phosphorescence in Eu<sup>3+</sup> doped Gd<sub>2</sub>O<sub>3</sub> compound systems

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### ABSTRACT

Various concentrations of Europium doped Gadolinium Oxide powders are synthesized by high temperature solid state reaction method. X-ray diffraction pattern of the compounds revealed single phase crystal formation, consistent with predominant monoclinic phase of Gd<sub>2</sub>O<sub>3</sub>. Deep level photoluminescence spectra showed multiple emissions in yellow-red region corresponding to transitions of <sup>7</sup>D<sub>0</sub>-<sup>7</sup>F<sub>3</sub>, <sup>7</sup>D<sub>0</sub>-<sup>7</sup>F<sub>2</sub> and <sup>7</sup>D<sub>0</sub>-<sup>7</sup>F<sub>1</sub>, which arise due to europium substitution. Appreciable enhancement in emission intensity is observed at higher doping concentrations. The optical band gap energies are determined from the diffuse reflectance spectra by utilizing Kubelka-Munk theory.

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### 1. Introduction

Mastering the photon sources had been a challenging task in the history of mankind for production of light in desired colors. For decades, enormous studies had been devoted to the synthesis and characterization of rare earth based phosphor materials [1]. Recently, lanthanide oxide nanomaterials have gained potential attention from the luminescence industry due to their appealing properties and advanced applications in various areas of science and technology. To name a few, flat panel displays, optical data storage, luminescent devices, high energy radiation detectors, biomedical diagnostic and treatment applications [2–3]. The unique transition levels associated with the 4f electrons of rare earth materials have brought them to the frontier position in modern luminescence based display industry [4–5]. Gd<sub>2</sub>O<sub>3</sub> an important rare earth compound with high melting point and large energy band gap is considered as a promising host material for luminescence enhancers [6]. A great deal of interest in gadolinium oxide exists because of its physicochemical properties, such as the crystallographic stability up to temperatures of 2325°C, high mechanical strength, excellent thermal conductivity and wide band optical-gap [7]. Europium Oxide is a prominent red emitter in phosphor materials family and is known for the crystal field effects in its D-F transitions [8]. The transitions of Eu<sub>2</sub>O<sub>3</sub> from 5D<sub>3</sub> to 7F<sub>1</sub> belong to the yellow-red region of visible spectra. Based on the symmetry of the crystal structure formed, these J

levels are predicted to split further [8]. In this letter we report the synthesis and characterization of rare earth metal oxide sol solutions of Eu<sub>2</sub>O<sub>3</sub> doped Gd<sub>2</sub>O<sub>3</sub> at different doping concentration. These two compounds are polymorphs with cubic and monoclinic crystal phases. Different crystal symmetry groups associated with the polymorphs, are supposed to create energy sublevels for different J values of 7f states for Eu<sup>3+</sup> ions that are supposed to be at different points of Gd<sup>3+</sup>. Transitions from 7D<sub>0</sub> state to J sub-levels 7F<sub>1</sub> state may split the peaks of red region significantly. Such spectral fine splitting in red region is a prominent property in phosphor applications. To understand this, here, we investigate its structure, surface morphology and optical properties of the synthesized compounds.

### 2. Materials and method

Solid solutions of Eu doped Gd<sub>2</sub>O<sub>3</sub> powder samples were prepared by high temperature solid state reaction technique. The starting materials, Gd<sub>2</sub>O<sub>3</sub> (Gadolinium Oxide, 99.99% purity) and Eu<sub>2</sub>O<sub>3</sub> (Europium Oxide, 99.99% pure) were purchased from Sigma Aldrich Chemical Co. U.S.A. The powder samples were weighed in its appropriate quantities to attain doping in weight percentage. The powders were mixed by means of an agate mortar and pestle for 48–54 h in order to attain uniformity and were calcined initial at 1200 °C for 10–12 h. After the calcination, the samples were allowed to cool down naturally to room temperature and were reground into perfect fine powders and loaded back to furnace for the heat treatment. The powders were then subjected to size by step heating and grinding process between 1250 and 1400 °C

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### Featured Letter

## Microstructure profiling and photoluminescence characteristics of V<sub>(1-x)2</sub>Ni<sub>3x</sub>O<sub>5-δ</sub> compound systems

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V<sub>2</sub>Ni<sub>3</sub>O<sub>5-δ</sub>

### ABSTRACT

V<sub>2</sub>Ni<sub>3</sub>O<sub>5-δ</sub> (V-Ni-O) based multi-cation materials have been prepared by high-temperature solid-state reaction for x between 0.03 and 0.06. The as synthesized V-Ni-O complex ceramic materials were subjected to microstructure profiling and photoluminescence studies. Structural analysis by x-ray diffraction pattern shows preferential growth direction analogous to that of V<sub>2</sub>O<sub>5</sub>. Scanning electron microscopy and energy dispersive x-ray spectroscopy shows dense lattice and the presence of Ni cations. Photoluminescence spectra of the samples exhibited both near band edge and deep level emissions. The optical band gap is found restructured in the compound due to the presence of Ni. The observed band edge emissions are broad with significant Gaussian asymmetry and are deconvoluted for individual components. The luminescent peaks between 2.28 eV and 2.31 eV have been observed for varying mole fractions.

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### 1. Introduction

In recent years, intensive research attention has been paid to the study of materials based on multi-anions [1,2] and multication [1–4] composed of transition metal oxides (TMOs). The multi-cation and multi-anion materials can exhibit enhanced properties that are not available in single anion or single cation materials [5]. Vanadium oxide is one of the transition metal oxide that presents interest for many applications in electrochromic and thermochromic windows, lithium-ion batteries, and supercapacitors [6,7]. Depending on deposition/synthesis conditions, vanadium oxide can consist of multiple phases containing vanadium cations in different oxidation states of 2+, 3+, 4+, and 5+. V<sub>2</sub>O<sub>5-δ</sub> is one of the phases of vanadium oxide that can be non-stoichiometric because some V<sup>5+</sup> or V<sup>4+</sup> ions are invariably present with the predominant V<sup>5+</sup> ions leaving the ion vacancies [7]. In such a material doping with other TMOs will become possible that leads to different types of multiple cation materials. One of such elements is Ni that can be in 2+ oxidation state and have potential for extending functionality of the vanadium oxide. Yan Zhen Zheng et al reported the synthesis of Ni-V<sub>2</sub>O<sub>5</sub> via polyol route and XRD evidenced the formation of orthorhombic V<sub>2</sub>O<sub>5</sub> phase [8]. Benoitia

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Prusty et al synthesized nickel vanadium oxide materials hydrothermally and reported its morphological and electrochemical characterizations [9]. The aim of the present work is synthesis and characterization of V<sub>(1-x)2</sub>Ni<sub>3x</sub>O<sub>5-δ</sub> for x = 0.03 to 0.06, by high-temperature solid-state reaction route. We report structural, morphological, and photoluminescence (PL) properties of V<sub>(1-x)2</sub>Ni<sub>3x</sub>O<sub>5-δ</sub> for x = 0.03 to 0.06.

### 2. Materials and method

The solid ceramic compounds were prepared by mixing up the precursors of NiO (Nickel Oxide, 99.99% purity) and V<sub>2</sub>O<sub>5</sub> (Vanadium Pentoxide, 99.99% pure) purchased from Sigma Aldrich in stoichiometric proportions as per the equation V<sub>(1-x)2</sub>Ni<sub>3x</sub>O<sub>5-δ</sub> for x = 0.03 to 0.06. The mixture was grinded thoroughly with an agate mortar and pestle for 2 h and heated in high temperature furnace between 550 and 630 °C for 52 h through alternate heating and grinding cycles. The samples were coarsely pressed and the obtained pellets were calcinated at 650 °C for 12 h. To ensure maximum phase purity, the pellets were heated for about 12 h. Powder X-ray diffraction pattern (XRD) was recorded by using AERIS-PANalytical diffractometer with Cu-Kα radiation of wavelength 1.5406Å. Scanning Electron Micrographs (SEM) was obtained by VEGA-TESCAN along with Energy Dispersive Spectra (EDS) analyzer with an accelerating voltage of 30 KeV. PL measurements



## Intense, Broad and strongly coupled multiple Photoluminescence in Zirconium doped ZnO thin films

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### Abstract

Zinc oxide (ZnO) and a series of Zirconium doped ZnO (ZZO) thin films are chemically spray coated on quartz substrate at 400°C. The films are further subjected to vacuum annealing at 400°C for three hours in an appropriate air ( $10^{-5}$  mbar) ambience. The X-ray diffraction analysis confirmed the structural purity and Zr addition in wurtzite ZnO matrix. Photoluminescence measurements were used to characterize the materials optically. Intense, broad and strongly coupled multiple photoluminescence were observed. These are indicative of relatively high concentration of defective oxygen and Zn vacancies in the film composition. Simultaneously, the strongly coupled ultraviolet near blue emissions authenticate that the Zr ions are capable of inducing modulated free excitonic (FX), donor acceptor pair (DAP) and longitudinal optical phonon emissions.

**Keywords:** Photoluminescence, Thin films, free excitons, XRD.

### Introduction

Zinc oxide (ZnO) is the most acclaimed wide direct band gap semiconductor with countless applications including blue luminescent devices, low threshold room temperature UV lasers, solar cells, photo catalyst and near UV optoelectronic devices<sup>1-3</sup>. N-type higher valent impurity in wurtzite ZnO at Zn<sup>2+</sup> coordinates and pronounced oxygen deficiencies can lower the electrical resistivity and improve optical transmittance of ZnO thin films. Zinc oxide doped with zirconium; reviewed previously as stable transparent conducting materials (TCM) even at extreme conditions could be a promising candidate in optoelectronic devices, when tuned precisely<sup>4,5</sup>. Besides, rare-earth elements can provide better luminescent centres than the transition metal ions due to their 4f intrashell transitions which give rise to narrow and intense emission lines<sup>6</sup>. Zirconium is a known n-type impurity with a larger ionic radius (0.8Å) than Zn<sup>2+</sup> (0.74Å), however, the ionic radii's are comfortably in the tolerance level for doping<sup>7</sup>. Hence, Zr<sup>4+</sup> can occupy Zn<sup>2+</sup> sites in crystal lattice. In ZnO, Zn interstitials induce a state with two electrons above the conduction band maximum (CBM) and these two electrons can be transferred to the conduction-band offering +2 charge state (Zn<sup>2+</sup>) and thus intrinsically ZnO will always donate electrons to the conduction band by acting as a shallow donor<sup>8</sup>. Along with this, doping in ZnO films with Zr would result in donor electron population and likely to improve transparency in the visible range. This means that Zr doping can be used to alter the intrinsic properties of ZnO. However, the comprehensive discussions in terms of electronic structure, native point defects, impurities and their influence on certain color emissions are necessary to substantiate the role of such materials in certain devices like,

light-emitting and laser emitting diodes that operate in the blue and ultraviolet region of the spectrum<sup>1</sup>. This article presents the results on the intense and broad PL emission at room temperature on spray deposited Zr doped ZnO thin films. The structural and optical properties are measured, analysed and discussed in brief.

### Materials and Methods

Six batches of Zr doped zinc oxide photo emitting transparent electrodes are prepared on quartz substrates using spray pyrolysis method, with Zr dopant concentrations of 0, 1, 2, 3, 4 and 5 at%. Zinc acetate dihydrates dissolved in a mixture of methanol, water and acetic acid in a ratio 65:25:10 to prepare 0.2 molar solutions. Zr doping is achieved by adding zirconium acetyl acetonate in calculated amount to this solution. The solution is ultrasonically stirred for two hours prior to deposition. Quartz plates cleaned ultrasonically and using nitric acid, chromic acid, hydrogen peroxide, acetic acid and water respectively are used as the substrate for deposition. The solution is sprayed on the substrate which is kept at a temperature of 400°C using Holmarc HO-TH 04 spray pyrolysis system. Same program under similar physical conditions are used for the spraying of every solution to assure uniformity of the film. Six samples with Zr atomic percentage varying from 0 to 5 are prepared and annealed for 3 hours at 400°C in air. Samples were further annealed at 400°C in high vacuum of  $10^{-5}$  mbar. The structural properties of the samples are studied using XRD technique, Cu-K $\alpha$ -radiation, using Rigaku-MiniFlex X-ray diffractometer, photoluminescence spectroscopy (Fluorlog III- Jobin Yvon, excited with 325nm laser) were employed to investigate the multicolour luminescence composed

### RESEARCH ARTICLE



## Thermoelectric Properties of Zr<sub>x</sub>In<sub>x</sub>Zn<sub>1-x</sub>O<sub>1.6</sub> Thin Films

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The variation of thermoelectric properties of Zr<sub>x</sub>O<sub>y</sub>-In<sub>x</sub>O<sub>y</sub>-ZnO film system is reported here. The films are fabricated in a chemical composition satisfies the relation Zn<sub>1-x</sub>In<sub>x</sub>O<sub>1.6</sub>, (0.01 ≤ x ≤ 0.04), through spray pyrolysis technique. XRD analysis shows a switching of preferred crystal growth orientation from (002) to (100) and (101) planes as x increases. The quasi-spherical surface morphology was improved on the addition of the cations. A maximum Seebeck coefficient of -159 μV/K was obtained for x = 0.01 at 400K. The decrease in the Seebeck coefficient for higher x values is explained with simplified bandband model. At elevated temperature power factor increased considerably up to 2.33 X 10<sup>-4</sup> Wm<sup>-2</sup>K<sup>2</sup> for x=0.03 which was attributed to decrease in sheet resistance at high temperature.

### Introduction

The energy generation, conversion and regeneration are the crucial steps in the field of energy and technology research paying attention to the suitable materials with high elemental abundance, non-toxicity and conversion efficiencies [1-3]. Considering the energy technology aspects, thermoelectric (TE) properties of materials are regarded as most promising because such materials can convert the waste heat into electricity through a unique phenomenon called the Seebeck effect [3,4]. Large amount of heat is being wasted in industries, automobiles and oil mines and this energy can be harvested and converted to electrical energy by the help of thermoelectric materials. Till date Bi<sub>2</sub>Te<sub>3</sub> and Sb<sub>2</sub>Te<sub>3</sub> alloys are commonly regarded as the best thermoelectric materials due to their higher efficiencies when it is used for room temperature applications [5]. Alloying of tellurides and selenides of bismuth and antimony such as Bi<sub>2</sub>(Te<sub>1-x</sub>Se<sub>x</sub>)<sub>3</sub>, (Sb<sub>1-x</sub>Bi<sub>x</sub>)<sub>2</sub>Te<sub>3</sub> showed excellent ZT and higher n-type carrier concentrations, alongside, p-type (Sb<sub>1-x</sub>Bi<sub>x</sub>)<sub>2</sub>Te<sub>3</sub> compounds are also extensively investigated [6]. Group IV tellurides like PbTe, GeTe or SnTe are widely investigated thermoelectric materials [6-8]. Like photovoltaics, thermoelectricity can also be associated with green technology and this has the capacity to contribute to the energy requirement of the society [9-10]. But even today, organic thermoelectric materials are less studied compared to the photovoltaic materials. However, thermoelectric materials like polypyrrole reported to exhibit excellent thermal conductivity characteristics [11]. But this electric conductivity values need to be improved further for TE applications and most of the current research is directed towards this purpose [12]. In comparison with organic thermoelectric material,

inorganic thermoelectric materials show promising electronic crystal nature, this favors thermal conductivity from the free carrier acquirable from the lattice [13]. Inorganic thermoelectric materials show poor phonon glass character and this can be overcome by introduction of defects in the crystal or by deterioration of crystal quality, doping in crystals is a smart way to implement this. The metal oxides hence become a favorable choice considering the easiness in induced lattice defects [14]. The oxides of metal and its combinations are high temperature thermoelectric materials because of its robustness at higher temperatures in which the other metal alloys melts [15]. Zinc oxide is a wide band gap material which can offer durability in extreme temperature and chemical environments [16]. It has been observed that a reduction in size of materials will reduce the thermal conductivity which in turn will improve the thermoelectric properties of the material. Hence considerable amount of research is focused towards improving the thermoelectric properties of low dimensional materials, especially nano dimensional thin films. Herein, we report the fabrication of Zr<sub>x</sub>In<sub>x</sub>Zn<sub>1-x</sub>O<sub>1.6</sub> thin films at changing the concentrations of zirconium and indium in ZnO thin films by spray pyrolysis technique on quartz substrate. The structure and surface morphology of the films are reported here. The thermoelectric Seebeck effect, thermoelectric power factor and sheet resistance are measured and reported in the article.

### Materials and methods

A 0.2 molar precursor solution was made by ultrasonically dissolving Zinc acetate dihydrate in a solvent containing methanol, deionised water and acetic acid in the ratio 65:25:10. Separate 0.2 molar solutions of zirconium acetyl

## Micro-strain, Dislocation Density, Surface Morphology and Optoelectronic Properties of Indium Zinc Oxide Thin Films

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**Abstract-** The article reports the fabrication of Indium Zinc Oxide (IZO) thin films with different doping concentrations prepared by spray pyrolysis technique at a uniform substrate temperature of 400°C on quartz substrates. The materials fall under the category of transparent conducting oxides, hence to implant oxygen deficiency and improve crystallization the films are subjected to vacuum annealing in air ambience of  $10^{-5}$  mbar base pressure and at 400°C for two hours. The structural profile investigated by XRD technique confirms the growth of particles in hexagonal wurtzite structure. Important structural parameter such as size of crystals, dislocations density and microstrain of thin films were calculated using Scherrer's formula and uniform deformation model (UDM) of Williamson-Hall method. SEM analysis indicated dense and uniform surface morphology for the prepared films. The films show excellent electrical property in terms of sheet resistance, moderate carrier mobility and intermediate carrier concentrations.

**Keywords**—TCOs, Optoelectronics, Thin films, XRD, UDM-Model, UV Vis spectroscopy

### 1. INTRODUCTION

Transparent conducting oxides (TCOs) are unique class of materials that conjugate transparency and conductivity in same material<sup>1-4</sup>. Because of its unique electrical and optical features TCOs has become an inevitable component of all the optoelectronic devices and hence this has been a thrust area of research for the last two decades<sup>5,7</sup>. Among metal oxides, tin doped indium oxide, ITO, is regarded as the most decisive TCO material that shows very promising electrical conductivity and very high optical transparency<sup>7</sup>. Zinc oxide based TCOs such as Al doped ZnO(AZO), In doped ZnO (IZO), Ga doped ZnO(GZO), Er doped ZnO and Zr doped ZnO has proven as potential candidate with TCO behavior<sup>8-10</sup>. Besides, we report the deposition of Indium Zinc Oxide films by spray pyrolysis technique at different atomic concentrations of indium additives in zinc oxide. Many previous reports established that the electronic properties of zinc oxide can be considerably improved when doped with Indium<sup>11,12</sup>. Besides its excellent TCO property, IZO films are crucial materials because of the large work function, comparatively low deposition temperature and very low surface roughness. Hadri

et al. reported a low resistance for Indium doped and fluorine doped ZnO samples deposited by same technique<sup>14</sup>. This study mainly comprises with the effect of doping and variation in doping concentrations on the structural profile of Indium zinc oxide films. We have employed XRD analysis for determination of structural characteristics and uniform deformation model for determination of micro-structural profile of prepared films. Besides, the transparent conducting property of the films was also investigated and is reported here.

### 2. EXPERIMENTAL

Four batches of indium zinc oxide films with 2, 4, 6 and 8at% indium doping were deposited along with pristine ZnO thin films, on fused silica substrate by automated spray pyrolysis technique at a substrate temperature of 400°C. Zinc acetate dihydrate and indium acetate are used as starting solutions sources for Zn and In cations in IZO. 30ml of 0.2 molar zinc acetate dihydrate solution was made in a mixer of methanol, acetic acid and deionised water and is used as the host solution. Similar solutions of Indium acetate is also made in order to use as dopant. Calculated volumes of indium acetate solutions is

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## Micro-strain, Dislocation Density, Surface Morphology and Optoelectronic Properties of Indium Zinc Oxide Thin Films

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## Synthesis, Surface Morphology, Optical Properties and Photocatalyst Activities of TiO<sub>2</sub>/ZnO/Fe<sub>2</sub>O<sub>3</sub> Nanocomposites.

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## Synthesis, z-scan and degenerate four wave mixing characterization of certain functionalized photosensitive polyesters containing ortho-hydroxyazo chromophores

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### ABSTRACT

The preparation and NLO characterization of photosensitive polyesters containing azoaromatic residues in the molecular backbone, functionalized with ortho-hydroxy chromophores is presented. Samples were studied for its UV-vis absorption, FT-IR and intensity dependent nonlinear absorption properties. Nonlinear characterization was carried out with z-scan using frequency doubled, Q-switched Nd:YAG laser operating at 532 nm. The closed aperture z-scan spectra reveal the self-defocusing effects of the samples with negative nonlinearity coefficient ( $n_2$ ) showing values as high as  $-1.28 \times 10^{-16}$  (esu) for certain samples and the corresponding third order susceptibility coefficient of the order of  $29.9 \times 10^{-17}$  (esu). Degenerate four wave mixing technique was employed to substantiate the findings. The numerical fits show that the molecules exhibit reverse saturable absorption. A study of beam fluence dependence of nonlinear absorption coefficient ( $\beta_{NL}$ ) has been presented. All phenomena indicate that molecules are reverse saturable absorbers whose optical limiting property gets enhanced with increasing conjugation length.

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### 1. Introduction

Ever since the discovery of azo dyes in 1863, a wide variety of its physical and chemical properties has been discovered. One of the most intriguing properties of azobenzene (and its derivatives) is trans-cis photoisomerization. Because of the differences in the structure of the isomers, the trans-cis photoisomerization are always accompanied by significant changes of polymer properties, such as the phase, conformation and optical properties. The conformational changes induced by photochemical trans-cis isomerization of the azo groups and their effects on polymer properties or polymer solution properties have been reviewed in 1989 [1,2]. Azobenzene systems exhibit high optical nonlinearities due to photoinduced trans-cis isomerization, molecular reorientation and nonlinear absorption. Azo polymers with photochromic properties offer a vivid panel of linear and non-linear optical properties. The extra ordinary growth and development of nonlinear optical materials are attracting much interest on account of its immense

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applications in photorefractive polymers, programmable optical interconnectors, optical data storage based on photochromism, chemical photoreceptors, non linear optical limiters, and holographic surface relief gratings [3].

In general, organic molecules bearing electron donor and acceptor groups connected by electronic conjugation exhibit large values of second and third order optical properties. Azo polymers provide an attractive possibility for NLO properties because of their processability, good optical properties, wide variety and low cost [4]. In order to provide extended conjugation between donor and withdrawing groups, both main chain and side chain azo polymers have been synthesized and their NLO properties tested [5]. Many synthetic strategies have been developed to incorporate azo groups in a polymer network. These include doping of an NLO chromophore into a polymeric matrix (guest-host system), covalently attaching the NLO chromophore with other polymer systems either as pendant side group to the polymer backbone or into the main-chain backbone [6]. Furthermore, the crosslinking technique has also been used to suppress the reorientation of an NLO chromophore due to molecular motion.

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## Reverse saturable absorption studies in polymerized indole – Effect of polymerization in the phenomenal enhancement of third order optical nonlinearity

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### ABSTRACT

We report our results on the identification of large order enhancement in nonlinear optical coefficients of polymerized indole and its comparative study with reference to its monomer counterpart. Indole monomer shows virtually little third order effects whereas its polymerized version exhibits phenomenal increase in its third order nonlinear optical parameters such as nonlinear refractive index and nonlinear absorption. Open aperture Z-scan trace of polyindole done with Q-switched Nd:YAG laser source (532 nm, 7 ns), shows  $\beta$  value as high as 89 cm/GW at a beam energy of 0.83 GW/cm<sup>2</sup>. Closed aperture Z-scan done at identical energies reveals nonlinear refractive index of the order of  $-3.55 \times 10^{-17}$  m<sup>2</sup>/W. Band gap measurement of polyindole was done with UV–Vis absorption spectra and compared with that of indole. FTIR spectra of the monomer and polymerized versions were recorded and relevant bond formations were confirmed from the characteristic peaks. Photo luminescent spectra were investigated to know the emission features of both molecules. Beam energy ( $I_0$ ) versus nonlinear absorption coefficient ( $\beta$ ) plot indicates reverse saturable type of absorption behaviour in polyindole molecules. Degenerate Four Wave Mixing (DFWM) plot of polyindole reveals quite a cubic dependence between probe and phase conjugate signal and the resulting  $\chi^{(3)}$  is comparable with Z-scan results. Optical limiting efficiency of polyindole is comparable with certain derivatives of porphyrins, phthalocyanines and graphene oxides. © 2016 Elsevier B.V. All rights reserved.

### 1. Introduction

The field of nonlinear optics took its birth when Rev. John Kerr of Freechurch Training College in Glasgow, UK, demonstrated in 1875 the second order electric field induced refractive index changes in number of solids and liquids under suitable DC field [1]. This phenomenon later on happened to be known as DC Kerr effect and was the first observed nonlinear optical effect. Two decades later in 1893, Friedrich Pockels [2] could observe nonlinear electric field phenomena in crystalline materials like quartz. The regime of nonlinear optics got flourished after the invention of laser in 1960 followed by the observation of second harmonic generation (SHG) in quartz performed by Peter Franken et al. [3] of University of Michigan in 1961. The compound 3, 4-benzopyrene developed by Rentzepis and Pao in 1965 [4] was the first SHG

organic molecule to exhibit a nonlinear optical effect. Thereafter, nonlinear optical effects were reported in many other organic materials like azobenzene-based molecular systems [5], various metallo-phthalocyanines [6], porphyrins [7], fullerenes [8], graphene oxides [9] etc and the importance of novel materials were realized through experimentation, theory, models and synthesis. The overwhelming growth and development of nonlinear optical organic materials and its applications in laser cavities, integrated optical devices and optical limiters during the past three decades has rendered photonic technologies an indispensable part of our daily life.

Indole, a white solid at room temperature, is an aromatic heterocyclic molecule which consists of a six-membered benzene ring, fused with five-membered nitrogen-containing pyrrole ring (Fig. 1). It is an abundantly found compound in mother-nature and is produced by a variety of bacteria in its routine physiological process. 2.5% of natural jasmine oil contains indole. It is first

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## Synthesis, Z-Scan and Degenerate Four Wave Mixing characterization of certain novel thiocoumarin derivatives for third order nonlinear optical applications

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### ABSTRACT

The third order nonlinear optical features of certain novel thiocoumarin derivatives have been studied. Single beam Z-scan study on these compounds reveals that the compounds exhibit self defocusing effect upon irradiation with 532 nm, 7 ns pulses of Nd:YAG laser. Nonlinear absorption coefficient, nonlinear refractive index and second-order molecular hyperpolarizability values were estimated. The optical power limiting properties of the compounds are found to be attributable to both two-photon and excited state absorption. Some of the samples show nonlinear absorption coefficient ( $\beta_{\text{eff}}$ ) as high as 24.5 cm/GW. UV–Visible and photoluminescence outputs of these compounds reveal remarkable absorptive and emissive properties. This article also reports extraordinary growth of third order optical nonlinearity in pure coumarin upon certain donor substitutions in lieu of hydrogen. Degenerate Four Wave Mixing (DFWM) signals of the compounds were analyzed to verify the Z-scan results. Electrostatic Surface Potential (ESP) mapping and structure optimization techniques have been employed to interpret the structure-property relationship of each molecule.

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### 1. Introduction

Nonlinear optical processes in conjugated organic molecular systems have led to compelling technological promises in terms of novel high performance materials and devices [1–3]. At the microscopic scale, the  $\pi$ -electron excitations occurring in the individual molecular units are the essential dynamics that control the observed optical nonlinearity in majority of the organic compounds. Vivid strategies have been reported by various research groups to enhance the nonlinear optical features of conjugated organic molecular systems [4]. Each scheme has its own merits and demerits. But, ever since the development of such strategies in the early 1960's [5,6] till date, none has met out with an all pervading solution to the entire specification issues stipulated by the

nonlinear optical (NLO) device fabricators [7]. However, many molecular systems have managed to attain satisfactory levels of thermal, mechanical and chemical stability by offering superlative degree of optical figure of merit in terms of transparency and nonlinear optical coefficients at many wavelengths [8,9].

Among the various classes of compounds investigated, coumarin based molecular systems are a scarcely studied compound for its nonlinear applications, whereas many of its derivatives are widely investigated for various other photo physical applications [10–12]. Many of the coumarin derivatives are extensively used for commercial production of fluorescent dyes, deodorants, skin lotions, and as gain medium in dye laser cavities [13,14]. They show a broad variety of pharmacological activities like anti-inflammatory, antibiotic, antidiabetic, and antidepressant activities [15]. Such compounds are also known for their photochemical and photophysical properties. Especially, pure coumarin can undergo a reversible photo induced cyclodimerisation upon irradiation at wavelength  $\lambda > 300$  nm, leading to cyclobutane based

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## Department's Profile: Research Centers at a glance

Name of the Research Guide	Year of Recognition as a research Guide	Name of research scholars and year of RAC	Details of Publications Year 2019-2020 (Scopus/UGC Care list)	Details of Publications Year 2020-2021 (Scopus/UGC Care list)	No. of Book Chapter/Books/Published or co-authored with (Publisher ISSN)	No of Conference Proceedings In last two years
Dr P Jayaram	2019	Mrs. Sabna M(2019) Mrs. Safna K (2020) Mr. Riyas K M (2021)	International: 2 National : 0 Pre-print: 0	International: 2 National :0 Pre-print:1	1 (Wiley: ISBN: 978-1-119-40754-6)	13
Dr Sudheesh P	2019	Mrs. Sreejalakshmi S	Nil	Nil	Nil	Nil
Dr Pramod K S	2019	Mrs. Shibina T (2020) Mr.Sreejith T (2020) Ms.Ashna Paulose (2021)	Nil	Nil	Nil	Nil
Dr Sailaja U	2019	Nil	Nil	Nil	Nil	Nil

## Department's Profile: Research Centers at a glance

Dr. Mujeeb Rahiman. K.M	2019	Thushara James (2019) Farisha Hassan. P (2020)	International: 1 National : 0 Pre-print: 0	International: 0 National :0 Pre-print:0	1 (Nova: ISBN 9781536170467	1
Dr.Feebarani John	2019	Parvathy Suraj(2020) Dheera P(2020)	Nil	Nil	1 ISBN-978-81- 7255-134-6;	Nil
Dr.M. Nithya	2019	Shabana Ebrahim (2020)	Nil	Nil	Nil	Nil
Dr. V.A. Ayisha	2010	Abdul Nafih P.K (2012) Sakhi T.G (2014) Beegam Feby P (2014) Athira P.G (2016) Jimnisha K (2018)	International :1 National : 0 Pre-print :0	International: 2 National : 0 Pre-print :0	Published: Remote Sensing Applications: Society and Environment, ISSN : 2352-9385	7



## Department's Profile: Research Centers at a glance

Dr. V. Santhosh	2014	Pramod A.K.(2018)	Nil	Nil	Nil	5
Dr. C. Sreejith	2019	Ms. T. Nanditha Nandan (2019)  Ms. M.S. Parvathy (2020)	Nil	International: 1	Nil	Nil
Dr. K.S Arunkumar	2017	Samreena Mohammed (2019)  Jewel John (2019)	Nil	Nil	Nil	4
Dr. Brijesh V K	2018	--	Nil	Nil	Nil	2

The background features a white surface with several light blue rectangular shapes of varying sizes and orientations. A solid red rectangle is positioned in the upper right corner. The text 'Thank You' is written in a grey, cursive font across the center.

Thank You