

# **FIEXE**

**National Centre for Flexible Electronics**

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# **ANNUAL REPORT 2015**

Joint Initiative of  
Department of Electronics and Information Technology  
Government of India &



**Indian Institute of Technology Kanpur**

**FIEXE**  
National Centre for Flexible Electronics



MESSAGE FROM  
PROF. INDRANIL MANNA, DIRECTOR IIT Kanpur

It is indeed a matter of great pride and pleasure to provide you an update on the National Centre for Flexible Electronics in the form of this annual report.

I want to thank Department of Electronics and Information Technology (DeitY) for funding this initiative and IIT Kanpur is very proud to have this very important centre. I may add that IIT Kanpur is now extremely keen and committed to translate knowledge into technology (commercially viable product or process). I strongly believe NCFlexE will greatly facilitate that ambition in the area of flexible electronics.

NCFlexE has three major objectives:

- To establish a National Centre of Excellence in Flexible Electronics and interact with national and international academic/research institutions and industry.
- To conduct research and development in the area of flexible electronics with commercialization of technology as the main goal. The centre will develop prototypes in active collaboration with industry partners.
- To train manpower in the new area of Flexible Electronics keeping the future needs of the country in mind.

I want to emphasize that networking with academic institutions as well as industry is key to achieving these goals. Our team is actively engaged in reaching out to the industry and trying to identify applications for flexible electronics that will serve the needs of our country.

I am very confident of the track record of the team and its strength in the field of Organic Electronics which will lead towards the success of this centre. The opportunity cannot be missed and the Institute will proceed with full commitment.

With best wishes,



Indranil Manna,  
Director, IIT Kanpur,

Date: 13<sup>th</sup> February, 2016

## **Executive Summary:**

National Centre for Flexible Electronics (NCFlexE) came into existence formally on 14<sup>th</sup> November, 2014 at Indian Institute of Technology Kanpur. The centre has been initiated with an outlay of Rs. 133 crores sanctioned by the Department of Electronics and Information Technology (DeitY), Government of India and support from IIT Kanpur. The functioning of the centre will be coordinated by the executive committee headed by the centre coordinator. The executive committee will operate under the guidance of a national advisory committee (NAC) that has been set up under the chairmanship of the Director, IIT Kanpur.

Due to the use of new materials and methods of manufacturing, flexible electronics represents a break from the past and provides India with a fresh opportunity to become a significant manufacturer of electronics. Centre's objectives include development of a national technology roadmap in coordination with other academic and industrial partners in the country, establishment of a broad research program that leads to development of a critical set of electronic components and partner with industry to develop prototypes and commercialize the technology.

In the first year, NCFlexE has adopted a proactive strategy for publicity and branding to reach out to the existing and potential industrial partners within and outside India. Three 'roundtables' to listen to the relevant industries for inputs, were held at Delhi, Bangalore and Ahmedabad. A few industry workshops, press meets and other activities to raise awareness among potential partners on flexible electronics and NCFlexE were organised at IIT Kanpur. Centre has also actively participated in national and international level interactions at industrial exhibitions and other events. Till December, 2015, seven calls for the expression of interest (EOI) were floated for collaborative projects with the industry. The areas targeted were – anticounterfeiting, flexible photovoltaic technologies, gas sensors, near-field communication tags, OLED for lighting and displays, printable inks and printed batteries.

In the first year, five companies have signed up for the partnership with NCFlexE with more than Rs. 1 crore funds for the projects. A project approval mechanism has been put in place at the centre to approve and monitor proposals for the development and prototyping activities. Each project is encouraged to involve at least one partner industry. The proposals are peer reviewed by experts from around the country. Based on the peer review, a sub-committee setup by the NAC Chairman, approves them.

The building construction and equipment purchase for the centre are on track. In the first year, after institute space committee approval, building plan approval and construction tendering, construction started in May 2015 and by the end of the year, the roof of the ground floor is constructed. The equipment needed for successfully running the centre are being procured in a systematic matter.

Having started the journey on a firm footing in the first year of its existence, NCFlexE looks forward to the coming years to grow into an international centre of excellence to help establish a flexible electronics ecosystem in India.

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## I Branding & Publicity Activities

In its first year, NCFlexE activities for branding and publicity included the following

- Personal Networking and References (Corporations, Centres in this field etc.)
- Industry Associations – IESA, ELCINA, AIMED, IPCA, Smart Card Manufacturers Association, ACMA, FICCI, CII etc.
- Events organized in conjunction with CII, AIMED etc. (Table I)
- Industry Workshops (Table I)
- Sector Wise Roundtables in various cities – Healthcare, Packaging and Printing etc.
- Govt. organizations – DBT, DST, GITA, CII, etc.
- Attending Workshops and Conferences in relevant areas (Table II)

**Table I. Exhibitions and Events – Organized by NCFlexE**

Event	Date	Venue	Outcome
Launch and Laying of the Foundation stone (as part of Digital India Launch)	1 <sup>st</sup> July, 2015	IIT Kanpur	Publicity and awareness created
Short course on Flexible Electronics	6-11 July, 2015	IIT Kanpur	Awareness & human resource development
Workshop on Flexible Electronics	10 <sup>th</sup> July, 2015	IIT Kanpur	Publicity and awareness
Roundtable for sensors	22 <sup>nd</sup> September 2015,	New Delhi	Awareness created. Preliminary leads obtained
FLEXE 2015, Industry Workshop	12 <sup>th</sup> October, 2015	IIT Kanpur	Identified several companies for second stage discussions
Roundtable - Healthcare	8th December, 2015,	Bangalore	Identified potential partners for Healthcare and Diagnostics
Roundtable- Flexible electronics for Healthcare and packaging	29th January, 2016	Ahmedabad	Identified potential partners for Healthcare and Diagnostics

**Table II. Exhibitions and Events – Attended by NCFlexE**

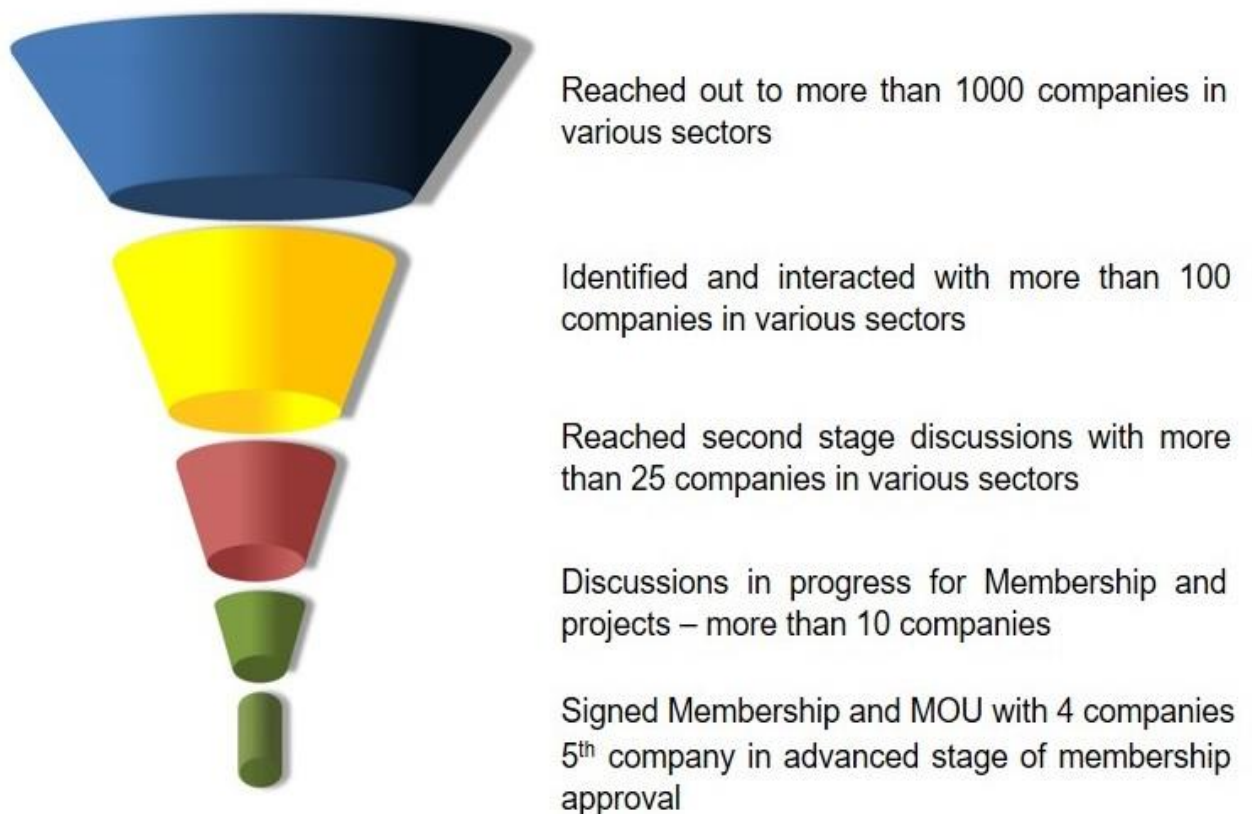
Event	Date	Venue	Outcome
TAITRONICS	6th-9th October, 2015,	Taipei, Taiwan	Awareness created. Preliminary leads obtained
AIMED Roundtable	6th November 2015, New Delhi	New Delhi	Contacts established with Medical Equipment makers
Indo Japan CWG	30th November, 2015	New Delhi	Invited Japanese academic and industry players for possible collaboration
PAMEX 2015	9th-12th December,	Mumbai	Awareness for printing industry
IESA –VS 2016	3-4 February, 2016 at	Bangalore	Contacts established with PCB and Semiconductors manufacturers

Through a combination strategies, websites, industry association mailings, industry association mass mailings and our own personal networking, we have reached out to more than 1000 companies in a variety of sectors. In addition to creating awareness about our focus, the exercise has been useful in gauging the level of demand, interest and preparedness for the technology in the wider industry circles.

Calls for Expression of Interest (EOI) were prepared for the following focus areas and widely circulated:

- Anti-counterfeiting
- Flexible PV
- Gas and Thermal Sensors
- NFC Tags
- Printable Inks
- Smart Tags
- Printed Batteries
- OLED for Lighting and Displays and
- Flexible PCB.

**Industry Membership & Project Approvals:**



Through a series of roundtables and sector wise workshops, we have interacted with more than a hundred companies specifically for collaboration/co-development. Finally, 28 companies are at the level of second stage discussion

Out of these efforts, we have FIVE Industry members this year (Table III) that have signed the NDA cum membership document with NCFlexE this year. Projects proposals with three of them have been written. As per the decided mechanism for project approval (Annexure 2: Project Approval and Monitoring procedure), the proposals were sent for external peer review and at least two appraisals for each proposal were obtained. Project Approval and Monitoring (PAM) Committee met on 13<sup>th</sup> Oct 2015.

**Table III. Industry Partners and Project Approval Status**

Sl. No	Item	Activities	Status
1	Manipal Technologies	Security Tags for Packaging	Project approved. Ready for Industry membership. MOU for project to be signed.
2	Chain Electronics	Seven segment OLED and flexible PCB	Membership signed. Project proposal in progress.
3	Applied Materials	Processing equipment	NDA and Membership agreement signed.
4	Murata Manufacturing*	Flexible sensors for breast cap	NDA signed. MOU under review for signature.

**The total funds committed by these partners in the first year has crossed Rs. 1 Cr.**

*\* Advanced stage of approval of membership.*

**Branding and Publicity Activities up to March 2016**

**Table IV. Exhibitions and Events – To be organized by NCFlexE**

<b>Roundtable – Packaging, Pharma, PV and OLED</b>	<b>4<sup>th</sup> March, 2016</b>	<b>Mumbai/Pune</b>
<b>Roundtable – Healthcare and Medical Equipment</b>	<b>28<sup>th</sup> March, 2016</b>	<b>Bangalore/Hyderabad</b>



## II NCFlexE Projects

### PAM Approved Projects

#### **Brand Protection Labels: Phase I: Contact-based Tax Stamp Tags**

Product counterfeiting is a thriving multi-billion dollar global industry and hurt many of the brands and products badly. There are many anti-counterfeiting solutions available but either they are not cost effective or can be easily copied. Thus the development of a printed electronic version of anti-counterfeiting device which offers good anti-counterfeiting protection while being cost efficient would be attractive to businesses whose valuable brands or evasion of taxes are constantly challenged.

The basic aim of this project is to address the need of developing anti-counterfeiting features for protection against spurious products. Another advantage of this development is towards upgradation of the technology for creating a niche in the market (taking a strategic lead over competitors). In this genre, this project specifically intends to develop an additional electronic security feature solution for Tax Stamp labels. The label should empower the Tax inspector to verify a unique identity by reading the label pasted on the product using a contact electronic reader. Being a large volume application, it needs to be manufactured (printed) at a high speed (so that it can be integrated into existing lines for tax stamp) within acceptable limits of additional cost.

In Phase-I, we are targeting development of tags based on contact reading as an example of a generic effort towards in expensive tags.

#### **Prototype WOLED based lighting tiles**

In India, 16% of the total generated electrical power is consumed for lighting. Still 25-30% of the total population of India lives without access of electricity (approximate 400 million) and largely depend on the kerosene oil for lighting. Considering the fact that the present lighting devices have low efficiency (5-20%) and environmental hazards (contain mercury), there is great potential for substantial energy saving as well as environmental protection (by reducing green house gases emission) by switching to more energy efficient and eco-friendly lighting devices.

Alternative SSL technologies exist that have the potential to compete with the inorganic white LEDs in the future. These are called white organic light emitting diodes (WOLEDs) and white polymer light emitting diodes (WPLEDs). WOLED is the only technology that can create large "area" lighting panels (as opposed to point or line lighting enabled by LEDs and Fluorescent bulbs). These OLED devices are made by amorphous polymers semiconductors that can be deposited on large area, flexible and lightweight substrates and offer significant advantages as polymers can be directly processed from solution by spin coating, ink-jet printing, and blade coating. WPLEDs can be made using roll-to-roll printing process with high throughput which reduces the cost of the lighting panels further for general lighting application. OLEDs can be used to make flexible and transparent panels, and can also be color-tunable. OLEDs emit soft

diffused light - in fact OLED lighting is the closest light source to natural light (with the exception of the old incandescent lamps).

The objective is to develop prototype WOLED lighting tile on glass that can be arranged to make flexible luminaires. In the second phase, the technology will be transferred to flexible substrates.

### **Breast cap for detection of breast cancer**

It is reported that by 2020, 70% of the world's cancer cases will be in developing countries, with a fifth being in India. The previous year, the Indian Council of Medical Research provided an analysis of cancer cases among women in various cities - Delhi, Mumbai, Chennai, and Bangalore from 1982 to 2005, showing that until about 10 years ago, 10 per 100 000 women got breast cancer, compared with 23 per 100 000 now; and by 2020, breast cancer is set to overtake cervical cancer as the most common type of cancer among all women in India

There is a need for early detection of the disease for facilitating effective remedial measures. This has been highlighted in a recent case study conducted in India which found that women in developing countries survive roughly 10 years shorter after a breast cancer diagnosis compared to women in developed countries, and a reason for this among others is late detection. A vast population not having an easy access to the diagnostic centers, due to the prohibitive costs and to the locational issues, adds to the burden of the disease in India. According to a 2008 WHO report, there is one doctor for every 10,000 Indians. Moreover, in cities, 80% of India's medical staff works in the private sector.

The objective of the work is to develop a low-cost breast cap using flexible temperature systems capable of providing the skin temperature mapping of the breast to be analyzed using algorithms for detecting abnormalities attributed to breast cancer. A successful technology could help make breast cancer diagnosis accessible and affordable.

### **Technology Development for Commercialization of Low Cost Anti-counterfeiting Tags**

Counterfeiting is a continuously increasing problem, especially in the developing world. In one case, counterfeit books, CDs, electronic equipment, or consumer durables in general are available which impacts the business conditions in the country. The other case is even more serious, which involves fakes in foods and pharmaceuticals, creating an additional health risk. So manufacturer, producer and even end users want a high level of security to protect their products. The World Customs Organization reported that approximately 6% of global goods are fake. In many cases, it is very difficult to identify counterfeit goods from genuine ones.

We are identifying counterfeiting of medicines as the most severe risk, hence focus of this work would be on development of anti-counterfeiting strategies in general and for medicine packages in particular.

### ***Objectives***

To develop and demonstrate a physical method of printing on a package that

- (a) has potential to prevent or severely mitigate counterfeiting of the packages (not the contents inside),
- (b) offers verifiability in the hands of consumer without a need to carry an extra detector or access to communication networks,
- (c) Is produced with bill of materials below Rs. 1 per tag.

### **Projects related to EOIs**

#### **Synthesis, characterization and formulation of conductive silver nanoparticle (NP) ink for inkjet printing**

A tremendous interest in printable electronics has been developed in the last decade which is also evident in the literature. Printed electronics refers to the fabrication of electronic circuits and devices using printing process, especially on flexible substrate. Conventionally, manufacturing of electronic devices can only be realized by expensive multistage processes such as photolithography, vacuum deposition, and electroless plating. These processes are not eco-friendly and create mostly toxic and hazardous chemicals. The motivation behind the printed electronic is to create large scale manufacturing of electronic devices in a faster and cheaper way. Inkjet printing is very attractive method for manufacturing organic solar cell electrode, RFID tags, OTFT, flexible LEDs and displays. Inkjet printing is favorable for automation and enables patterning with high resolution line and space dimensions can be small as 20 micron. Due to the complex nature and very challenging requirements for inkjet inks, preparation of such inks is often very complicated. The ink must meet out the physicochemical requirement of print head such as viscosity and surface tension.

### ***Objectives***

- a) Development of methodology for making stable conductive metal nanoparticles (Ag/Au/Cu).
- b) Ink formulation of conductive inks using suitable solvent preferably eco-friendly solvent
- c) Process development for inkjet printing and sintering.
- d) Performance development of the printability over flexible substrates like paper/PET/PEN/PI using inkjet printer.
- e) Development of business plan for the low cost conductive inks as a commercial product

#### **Printed Organic Solar Cells on Flexible Substrate**

Organic solar cells use organic semiconductors for the active layer of the solar cells. They have the potential to be manufactured on a large scale at low cost per unit. With proper

product development, the fabrication process and the products developed may be ecologically friendly. Moreover, their fabrication on flexible substrate such as appropriate plastics or paper can help implement solar modules that are lightweight, can be conformal to the structure on which they are mounted and may be folded or rolled up for ease of storage and transportation.

In this project, we will be building organic solar cells on flexible substrates such as paper or plastic (PET) by the printing techniques. Some of the main challenges in this project will be developing a printing process and the inks needed for that to build the solar cell; to design the sub-modules and test them effectively for efficiency and stability; and to build a stable process line so as to fabricate sub-modules of size 10 cm × 10 cm or more that have efficiencies above 3% which last for at least six months.

### ***Objectives***

- The primary objective would be to develop a printing technology that will allow us to print an organic solar cell sub-module onto a flexible substrate such as paper or plastic.
- Another objective would be to develop sub-modules of size at least 10 cm x 10 cm on a substrate size of 15 cm x 15 cm and integrate them with chips / circuits that will help charge a battery or deliver power to any suitable and practical electrical load.
- Another objective would be to work with industry partners to integrate the sub-module of appropriate size on a system to form a commercial product.

### **Flexible sensors**

#### ***(i) Sensors for detection of heavy metals in water***

Providing clean drinking water to the population has become an increasing challenge with depletion of water sources and pollution of water bodies. The pollutants in the water can be broadly classified as metals, organics and pathogens with a large variety of species in each of these classes and the pollutant profile could be area specific. The types and concentrations of these pollutants have increased, all leading to serious health consequences. There is a need for monitoring the quality of the water at all stages, from the source till the end user. The goal of the proposed activity is to develop low-cost chemical sensors for detecting pollutants in drinking water. The market for these sensors not only includes the general populace, but also the regulatory agencies and the water purification industry. Initial focus would be on detection of heavy metal (e.g. cadmium, chromium, manganese, arsenic) ions.

### ***Objectives***

1. Generate the knowledge, by formulating and executing pertinent research problems, as provided in the proposed work modules, needed to design and fabricate a sensor for detecting heavy metal ion pollutants in water
2. Setting up of the design specifications for the FlexE team to develop the device.

***(ii) Breathalyzer for non-invasive disease diagnostics***

Exhaled breath while primarily comprises nitrogen, oxygen, carbon dioxide and water vapor (75%, 16%, 4%, and 4% by volume, respectively), also contains trace levels of other gases which can be markers of the disease status. For example, acetone could indicate diabetes, ammonia could indicate kidney problems, toluene could indicate lung cancer. The use of breath analysis is a promising field for non-invasive detection. However, the breath analysis poses significant challenges to specifically identify components at low detection limits.

***Objectives***

1. Generate the knowledge, by formulating and executing pertinent research problems, as provided in the proposed work modules, needed to design and fabricate a breathalyzer.
2. Setting up of the design specifications for the FlexE team to develop the device.

***(iii) Disease diagnostics from body fluids***

Biomarkers present in body fluids (blood, saliva, urine) can indicate the pathological condition of the body. For example: blood urea nitrogen (BUN) and creatinine are biomarkers for impaired renal function, levels of the prostate specific antigen are biomarkers for prostate cancer. Detection of disease biomarkers in the fluids can be utilized for early disease detection. Also, these can be used to monitor the response to therapies.

Utilization of microfluidics based platforms has the potential of rapid and low-cost detection techniques with point-of-care applications, which could be very relevant to the Indian context.

***Objectives***

1. Generate the knowledge, by formulating and executing pertinent research problems, as provided in the proposed work modules, needed to design and fabricate a microfluidic sensor array.
2. Setting up of the design specifications for the FlexE team to develop the device.

**Printed Batteries**

Every electric device needs to be powered. Low-cost, wearable, flexible electronics e.g. in the form of smart watches, sensors embedded in clothing, activity trackers, and health-monitoring tags are anticipated to be widely adopted. Future generations of these devices would be thin, conformable to the human body, ubiquitous, and almost imperceptible to the user. Powering these devices while retaining their mechanical properties will be a challenge.

Batteries are essential for powering portable electronic devices. A battery is a closed system in which energy is stored in chemical form, and it is converted to electrical energy by connecting the battery to an external load to complete the circuit, causing electric current to flow between the anode and cathode.

The standard batteries (coin cells, can cells etc.) are bulky and do not provide the flexibility in shape and design required by new printed electronics. By printing the battery itself too, all advantages of the printed, flexible electronics can be utilized.

An electrochemical cell consists of active layers supported on conductive substrates (current collectors) to form the anode and cathode of the battery. The electrolyte provides ionic contact between the electrodes and helps to complete the redox reactions within the cell. Printing processes such as screen, stencil, and blade printing are well established and they can be used to deposit battery components by designing printable inks for the active layers, current collectors, and electrolyte. Batteries fabricated using printing processes have the advantage of low cost, flexible form factor, ease of production, and integration with electronic devices. The term “printed battery” is used to describe a battery for which at least one of the components is solution processed and deposited using a printer.

### ***Objectives***

- development of printed batteries
- development of free – form batteries / printed on demand
- development of disposable batteries

### **Development of Organic Diode Array for Temperature Sensing**

Temperature is a fundamental physical parameter that needs to be measured for a wide range of applications. Low cost temperature sensor arrays are required for applications ranging from electronic skin, biomedical thermal imaging, and structural temperature monitoring. Organic electronics offers the prospect of high density of sensors through monolithic fabrication on flexible and cheap plastic substrates. There are a number of ways of realizing a temperature sensor using organic materials including resistors, transistors etc. Resistors have the advantage of being simple but in an array their density is limited by the requirement of direct addressing where each sensor has its own individual set of external terminals. Transistor based temperature sensors can be used to fabricate an active matrix type large sensor array but they are more complicated to fabricate and are likely to be expensive as well. Although, Silicon Diodes are widely used for sensing temperature, there are very limited reports of use of organic diodes for this purpose. Diodes offer the prospect of building a fairly large array of sensors through passive addressing scheme and represent a solution that is intermediate between simple direct addressed resistive array and complicated transistor based active matrix array. The aim of this research proposal is to develop a sensitive and reliable organic semiconductor based diode temperature sensor and a proof-of-concept 3 x 3 passive matrix array.

### ***Objectives***

1. Development of an organic diode based temperature sensor in the range 0-50 °C on glass substrate using spin coating/vacuum deposition techniques
2. Development of proof-of-concept 3 x 3 sensor array with associated external readout electronics

3. Development of a of fully inkjet printed diode and its evaluation as a temperature sensor

### **Development of dielectric inks for printing**

The proposal is aimed at developing dielectric inks for various printing processes and wide range of applications such as printed TFTs, RC component in smart tags and as printed insulators in flexible circuits.

This project will investigate various polymer dielectrics properties and their ink properties with different solvents for printing applications. Phase I of the project will aim at developing polymer dielectric inks of different properties as per specific application and printing process. In phase II, nanostructure – polymer composite dielectric inks will be developed for enhanced properties.

Dielectric inks development will be in-line with specifications of various components under development at FlexE (such as printed TFTs) and prototypes (such as RC circuits in smart-tags).

#### ***Objectives***

Dielectric inks are integral component of printed and flexible electronics. Development of dielectric inks would be in two phases

##### Objectives of Phase – I

- i. Processing of polymer dielectric inks with different solvents
- ii. Study repeatability, and stability of the inks using MIM structures.
- iii. Rheological study of inks and formulation as per printing process specifications.
- iv. Ink-jet printable dielectric inks with specifications as per application(s).

##### Objectives of Phase – II

- i. Study of dielectric properties of nanoparticle – polymer composites.
- ii. Stability and repeatability of composite dielectric inks.
- iii. Ink formulation for different printing processes (such as ink-jet, screen, slot-die etc.)
- iv. Tuning of dielectric properties of ink as per application(s).

Beyond the 2-year period (October 2017), ink properties will be continuously upgraded to follow a roadmap based on internal requirements and international standards.

### **Development of TFT backplane for QVGA flexible AMOLED displays**

Indian market for hand-held display devices is poised for a steep growth. Currently smartphone user penetration is only at 17% of Indian population, in contrast to > 40% in China. Even if a small fraction of hand-held devices go flexible, overall volume for such devices in India will be huge. In absence of a technology know-how in this field, chances of indigenous manufacturing of flexible display devices are very meagre. Absence of technology and skilled manpower will also act as a barrier for foreign industries to manufacture in India. Furthermore, various technology components developed in the course of this project, i.e. flexible TFT backplane, flexible thin film encapsulation (TFE),

top emission OLED, substrate handling solutions, and process integration can be disseminated to the manufacturing of other flexible electronics devices, such as TFT technology for circuits and backplane for sensors, memories, imager etc. and TFE for any flexible electronics device susceptible to moisture. Therefore, this project will serve as a foundation to many other flexible electronics applications.

In this project we will develop a flexible AMOLED display fabricated on a polymer substrate with metal-oxide TFT backplane and OLED frontplane technology. The project involves bringing together technology groups mainly involved in TFT arrays, barriers and encapsulation, and OLED development in order to achieve a monolithic integration of backplane and frontplane on a polymer substrate. Driver IC integration and flexbonding expertise will be inherited from the passive matrix OLED display project earlier executed by SCDT.

***Objectives:***

Flexible AMOLED display is a technology integration project involving various components being developed in the FlexE Centre. This project will serve to following objectives:

1. Development of metal-oxide TFT backplane technology
2. Development of top-emission OLED frontplane technology
3. Developing thin film barrier and encapsulation
4. Developing flexible substrate handling solution (bonding/debonding)
5. Display driving infrastructure

**Flexible white OLED for lighting and display**

The traditional sources of lighting are incandescent bulbs and florescent tubes with luminous efficiency of 15 lm/W and 90 lm/W, respectively. Solid state lighting is considered the next generation lighting technology because of its improved efficiency and life-time, but technological breakthrough is required to reduce its cost. There are two approaches – inorganic LEDs (GaN based) and white organic LEDs (WOLEDs). Inorganic LEDs have a definite advantage of high efficiency (at device level), and life time, but they are still very costly when one compares the equivalent luminaire cost (INR/kLm) of lighting. This is why WOLED is considered a good alternative, but considerable improvement of efficiency, lifetime, and cost is required. Internationally, EU (EUROPE), DOE (USA) and Japan are funding several OLED lighting projects. There have been few commercial products, by Osram and Philips, introduced at efficiency less than 20Lm /W, although the highest efficiency reported is >100 Lm/W.

R&D on WOLED at Flex-E center will continuously work on the following aspects:

1. WOLED stack (for evaporation and for solution processed devices) with two objectives: maximize device efficiency and minimize the cost of substrates, coatings, organic compounds
2. Light extraction techniques
3. New device structures: transparent WOLED for building integrated lighting



There will be efforts to find possible products along the way and to improve manufacturability of WOLED for commercialization.

There will be WOLED sub-teams in the Flex-E center to (i) reduce the BOM, (ii) improve OLED stack for thermal evaporation on flexible substrate, (iii) improve OLED stack for printing techniques, (iv) increase light extraction (v) develop encapsulation to enhance life-time, (vi) design novel products.

### **III NCFlexE Infrastructure and Manpower**

#### **Manpower hiring:**

Substantial progress has been made in the area of team building. The COO joined the centre in May, 2015. Three team leaders (RE) have already joined the team and started contributing significantly to the development activities. More candidates have been identified and interviewed to fill the remaining positions. Project staffing is also well under way. In summary, about 60% staffing is now complete.

#### **Building:**

The ground clearing work started in May, 2015. During excavation, there were several challenges faced related to underground cables which were diverted before excavation could proceed. Since then, work progresses rapidly and the plinth level Foundation work has now been completed. The sequence of photographs below shows the development of the construction of the building. Construction is on schedule and target completion is by Dec 2016.



**MAY 2015**



**JUNE 2015**



**JULY 2015**



**AUGUST 2015**



**SEPTEMBER 2015**



**OCTOBER 2015**



**NOVEMBER 2015**



**DECEMBER 2015**

***Equipment purchase:***

The equipment list was divided into 2 phases based on immediate requirements as well as the space availability. Some of the equipment, which are large in size and needed at a later stage, were moved into Phase II category (to be in line with the completion of the new clean room in the new building).

**Summary: First phase Equipment defined and orders being placed.**

# Academic Report

2015-2016

## IV FUNDED PROJECTS



### *List of Other Projects*





Sl. No.	Project Name	Funding Agency	Amount (Rs. In Lakhs)	Duration	Project Investigator
01	Design and Development of Organic Solar Cell sub-Modules	MNRE	663.52	2011-2015	Dr. S.S.K. Iyer
02	Research and Development of InGaZnO <sub>4</sub> (IGZO) Large Area Electronics and its Application to Active Matrix Flat Panel Display	DST	686.95	2011-2014	Dr. Deepak Gupta
03	Organic/ Polymer Light Emitting Diodes Fabrication and Characterization	DRDO	10.00	2012-2014	Dr. Y.N. Mohapatra Dr. Ashish
04	Stand –off detection of explosives based on immunochemical Techniques	Office of the Principal Scientific Advisor Government of India	567.00	2011-2014	Dr. Siddarth Panda
05	Flexible Printed Integrated Disposable Electronics (FLEXIPRIDE)	Indo-German Science & Technology Centre	107.25	2012-2015	Dr. Y.N. Mohapatra Dr. B. Mazhari

## V PERSONNEL

### *Core Faculty @ SCDT*

Sl No	Name	Department	Designation
01	Dr. Deepak Gupta	MSE, SCDT	Professor
02	Dr. Y.N.Mohapatra	Physics, SCDT	Professor
03	Dr. B.Mazhari	EE, SCDT	Professor
04	Dr. Monica Katiyar	MSE, SCDT	Professor
05	Dr. S.Sundar Kumar Iyer	EE, SCDT	Professor
06	Dr. Siddhartha Panda	CHE, SCDT	Professor
07	Dr. Anshu Gaur	MSE, SCDT	Assistant Professor

	<p><b>Deepak Gupta</b> <b>Professor, Materials Science and Engineering</b></p> <p><b>Experience</b> Ph.D., Materials Science and Engineering, UC Berkeley, 1993 Argonne National Laboratory, Motorola, IIT Kanpur</p> <p><b>Research Interest</b> Organic Semiconductors, Displays, Electronic and Optical Materials</p>
	<p><b>Y. N. Mohapatra</b> <b>Professor, Physics and Materials Science Programme</b></p> <p><b>Experience</b> Ph.D., IISc, 1988 IIT Kanpur</p> <p><b>Research Interest</b> Semiconductors, electronic and photonic , materials, OLED/PLED</p>
	<p><b>Baquer Mazhari</b> <b>Professor, Electrical Engineering</b></p> <p><b>Experience</b> Ph.D., Electrical Engineering, U. Illinois, Urbana-Champaign, 1993</p> <p><b>Research Interest</b> Organic Semiconductors, Semiconductor device modelling and analog circuits</p>

	<p><b>Monica Katiyar</b> <b>Professor, Materials Science and Engineering</b></p> <p><b>Experience</b> Ph.D., Materials Science and Engineering, U. Illinois, Urbana-Champaign, 1994, Motorola, IIT Kanpur</p> <p><b>Research Interest</b> Organic Electronics(OLED/OTFT),Printable Electronics Thin Films, Material Characterization</p>
	<p><b>S. Sundar Kumar Iyer</b> <b>Professor, Electrical Engineering</b></p> <p><b>Experience</b> Ph.D., Electrical Engineering, UC Berkeley, 1998 IBM Microelectronics (NY), IIT Kanpur</p> <p><b>Research Interest</b> Organic solar cells, Photovoltaic systems, Printable electronics, VLSI technology, devices and circuits</p>
	<p><b>Siddhartha Panda</b> <b>Professor, Chemical Engineering</b></p> <p><b>Experience</b> Ph.D., Chemical Engineering, U. Houston, 1999 IBM Semiconductor R&amp;D Center, IIT Kanpur</p> <p><b>Research Interest</b> Chemical sensors, Lab-on-a-chip, Micro/nano fabrication, Microfluidics, Materials processing for microelectronic and display technologies</p>
	<p><b>Anshu Gaur</b> <b>Assistant Professor, Materials Science and Engineering</b></p> <p><b>Experience</b> Ph.D., Materials Science, University of Illinois at Urbana-Champaign, USA, 2008 Applied Materials Inc., USA</p> <p><b>Research Interest</b> Electronic and opto-electronic materials, thin films, device physics, carbon based nanostructures</p>

***Core NCFlexE Members***

#	Name	Department	Designation
01	Dr. Sudhindra Tatti	SCDT	Chief Research Engineer & COO
02	Dr. Ashutosh K Tripathi	SCDT	Sr. Research Engineer & Team Leader
03	Dr. S.J. Tripathi	SCDT	Sr. Research Engineer & Team Leader
04	Dr. Ashish	SCDT	Sr. Research Engineer & Team Leader

	<p><b>Dr. Sudhindra Tatti</b> <b>Chief Research Engineer</b></p> <p><b>Experience</b> PhD:: MSE, UT, Austin, 1989 PEGASUS SEMICONDUCTOR, AmberWave Systems, Chartered Semiconductor, SubMicron Technology, MOTOROLA</p> <p><b>Research Interest</b> <i>Organic solar cells, Photovoltaic systems,</i></p>
	<p><b>Dr. Ashutosh K Tripathi</b> <b>Senior Research Engineer</b></p> <p><b>Experience</b> PhD: Physics, University of Stuttgart, Germany (2008) Holst Centre, Netherlands</p> <p><b>Research Interest:</b> <i>Organic and oxide semiconductors TFTs, Flexible Electronics (flexible displays, TFT backplane technology, flexible circuits, NFC etc.)</i></p>
	<p><b>Dr. Sabine Juliane Tripathi</b> <b>Senior Research Engineer</b></p> <p><b>Experience</b> PhD: Chemistry, TUD, Germany 2006 Holst Centre, Netherlands IFW Dresden, Germany</p> <p><b>Research Interest:</b> <i>Flexible Electronics, Thin film Batteries, Electrochemical Sensors, R2R Processing</i></p>
	<p><b>Ashish Gupta</b> <b>Senior Research Engineer,</b></p> <p><b>Experience</b> Ph.D.(Chemistry) University of Allahabad, 2004</p> <p><b>Research Interest:</b> <i>Conjugated Polymers &amp; Nanomaterial Synthesis</i></p>

## VI COMPLETED THESES

### *Ph.D. Theses*

1. Polymer blend based white light emitting diode: Study of electrical and optical characteristics, Asit Prakash, (MSE), 2016
2. Effect of electric-field annealing during solvent drying step of active layer in organic solar cell devices, Anirban Bagui, (PHY), 2015.
3. Annealing in the presence and absence of electric field of copper phthalocyanine based thin films and their applications in organic solar cells, Anukul Prasad Parhi, (PHY), 2015.
4. Trap Controlled Charge Processes in Organic Semiconductors Studied using Transient Techniques, K Sudheendra Rao, (PHY), 2014
5. Charge particle beam interaction with matter from a perspective of lithography, Mihir Sarkar, (PHY), 2014
6. Study of nanomagnetism in NiO single layer and Co/Cu multilayer films, Mr. Vikram Verma, (MSE), 2014.
7. Opto-electronic analysis of planar, bulk and hybrid planar-mixed heterojunction organic solar cells, Suman Banerjee (PHY), 2014
8. Surface engineering and flow characteristics in pressure driven silicon based microfluidic immunosensors, Ramchander Chepyala (ChE), 2014
9. Carrier Transport in Organic Semiconductor Diodes with Doped/Undoped Interfaces, Durgesh Chand Tripathi (PHY), 2014

### *M. Tech. Theses*

#### 2015

1. Thin Film Formation and Morphology of Organo-Lead Halide Perovskite suitable for Solar Cells, Raghunandan B. Iyer, (MSP), 2015
2. Effect of encapsulations on the steady and transient response of thermal sensing nanoscale PANI-CSA films, Hima Suram, (ChE), 2015



3. Fabrication of temperature sensor using conducting polypyrrole film deposited on flexible substrate, Aprita Saha , (ChE), 2015
4. Fabrication of Polymer Memories Based on P(VDF-TrFE) and its Blends,.Amruth C, (MSP), 2015
5. Correlation between Dark & Light Characteristics of Bulk Hetero-Junction Organic Photo-Voltaic Cells, Mohd. Imamuddin, (EE),2015
6. Simulation Dual Gate Ion Sensitive Field Effect Transistor, Abhay Prakash Tiwari, (MSP), 2015
7. Optimization of parameters for sensing glucose in sandwich immunosensors using screen printed electrodes, Mr. Mohd. Ibrahim Faruqi, (ChE), 2015
8. Fabrication and Characterization of CZTS Nanocrystals, Ink and Thin Films for Solar Cell Applications, Balaji Adothu, (MSE), 2015
9. Time Dependent Studies on P3HT:PC60BM and PTB7:PC70BM Organic Solar Cells, Jyoti Yadav , (EE), 2015
10. Effect of annealing poly 3-hexylthiophene layers in the presence of pulsed electric field, Anshik Gangwar, (EE), 2015
11. "Study of suitability of four imidazolin-5-one derivatives for active layers in organic solar cells, Raghav Gupta, (EE), 2015
12. Vanadium Pentoxide Nanostructures: Growth Kinetics, Synthesis and Characterization, Sujata Senapati, (ChE), 2015
13. Compact Modelling Approach for Organic Thin Film Transistors, Aditya Upadhyay ,(EE), 2015
14. Analysis of Photo-Response of Top-Contact OTFT, Smriti Kumari, (EE), 2015
15. Extraction and Modeling of Threshold Voltage of Organic Thin Film Transistors, Swati Tiwari, (EE), 2015
16. Study of suitability of four di-keto-pyrrolo-pyrrole derivatives for active layers in organic solar cell, Kumar Saurav, (EE),2015
17. Simulation and Modeling of Organic Light Emitting Diodes, Raja Kirana Saraba, (EE), 2015

18. Effect of Various Reaction Conditions on Aminosilane Thin Films Formed on Silanol Terminated Silicon Surfaces, Pranay Mehta, (ChE), 2014
19. Fabrication of Vertically Aligned Nanorods of Zinc Oxide on Si/SiO<sub>2</sub> Substrate for Sensing Membrane in Electrolyte-Insulator-Semiconductor Sensors, Harsh Vardhan, (MSP), 2014
20. Temperature Sensor Using Organic Diode, Nitin Kumar, (EE), 2014
21. Organic photodiode array for image scanning applications, Naimatullah, (EE), 2014
22. Light and Temperature Sensitivity of High Injection Barrier Diodes, Anupam Kumar, (EE), 2014
23. Analysis of Photo-Response of Top Contact Organic Thin Film Transistors, Anurag Dash, (EE), 2014
24. Implementation of Organic Resistor and its application as temperature sensor, Amit Barjatya, (EE), 2014
25. Graphitic Carbon Nitride (g-C<sub>3</sub>N<sub>4</sub>): Synthesis and Characterization of Bulk and Thin Films For Device Applications, Vivekanand Shukla, (MSP), 2014
26. Simulation of an OLED device, Balasubrahmanyam E, (MSE), 2014

## VII PUBLICATIONS

### Journal Articles

#### 2016

1. Effect of the electric field during annealing of organic light emitting diodes for improving its on/off ratio, Rahul K. Sharma, Monica Katiyar, I. V. Kameshwar Rao, K. N. Narayanan Unni and Deepak, *Phys. Chem. Chem. Phys.*, 18, 2747-2755, 2016
2. Effect of aging of V<sub>2</sub>O<sub>5</sub> sol on properties of nanoscale films, S Senapati and S Panda, *Thin Solid Films*, 599, 42-48, 2016
3. Correlation of Capture Efficiency with the Geometry, Transport, and Reaction Parameters in Heterogeneous Immunosensors, Dharitri Rath and Siddhartha Panda, *Langmuir*, 32 (5), 1410–1418 2016, 2016
4. Signal Amplification in Field Effect-Based Sandwich Enzyme-Linked Immunosensing by Tuned Buffer Concentration with Ionic Strength Adjuster, Satyendra Kumar, Narendra Kumar and Siddhartha Panda, *Appl Biochemistry and Biotechnology*, 2016
5. Trap Kinetics in Solution-Processed Organic Thin-Film Transistors, Subhash Singh and Y. N. Mohapatra, *IEEE ELECTRON DEVICE LETTERS*, 37, 1, 2016
6. A Current-Induced Channel Organic Thin-Film Transistor, A. Gangwar and B. Mazhari, *IEEE TRANSACTIONS ON ELECTRON DEVICES*, 63, 1, 2016

#### 2015

7. Channel Pinchoff Near Drain in Top Contact Organic Thin-Film Transistor, Ashish K. Agarwal, Rajesh Agarwal, and B. Mazhari, *IEEE ELECTRON DEVICE LETTERS*, 36, 9, 2015
8. Enhanced pH sensitivity over the Nernst limit of electrolyte gated a-IGZO thin film transistor using branched polyethylenimine, Narendra Kumar, Jitendra Kumar and Siddhartha Panda, *RSC Adv.*, 6, 10810–10815, 2015
9. Solar Photovoltaic Energy Harnessing, S. Sundar Kumar Iyer, Review, Article in *Proceedings of the Indian National Science Academy*, "81, 4, 100-1021, 2015.
10. Understanding the formation of PEDOT:PSS films by ink-jet printing for organic solar cell applications, Arjun Singh, Monica Katiyar and Ashish Garg, *RSC Adv.*, 5, 78677-78685, 2015

11. Origin of intrinsic ferromagnetism in undoped antiferromagnetic NiO thin films, Vikram Verma and Monica Katiyar, *J. Phys. D: Appl. Phys.* 48, 235003 (10pp), 2015
12. Zeta potential and Reynolds number correlations for electrolytic solutions in microfluidic immunosensors, R Chepyala, S Panda, *Microfluidics and Nanofluidics*, 18 (5-6), 1329-1339, 2015
13. Effects of thickness, dopant type and doping levels of flexible nanoscale polyaniline films on responses to gases, M Sinha, S Panda, *Materials Research Express*, 2 (7), 076401, 2015
14. Highly sensitive explosive sensing by "aggregation induced phosphorescence" active cyclometalated iridium(III) complexes, Alam, P., Kaur, G., Kachwal, V., Gupta, A., Roy Choudhury, A., Laskar, I.R. *Journal of Materials Chemistry C*, 7, 21, 5450 -5450, 2015
15. Low temperature annealed amorphous indium gallium zinc oxide (a-IGZO) as a pH sensitive layer for applications in field effect based sensors, N Kumar, J Kumar, S Panda, *AIP Advances*, 5, 6, Article No.67123, 2015
16. An organic device with thin film transistor merged with light emitting diode through use of an accumulation layer in TFT as an electrode, A Gangwar, B Mazhari, *ECS Transactions*, 67, 1, 199-204, 2015
17. Growth and characterization of nanocrystalline CdSe thin solid films, Singh, A.K., Deo, S.R., Deshmukh, L., Pandey, G.P., Singh, R.S., Gupta, A., *Research on Chemical Intermediates*, 42, 2, 535-548, 2015
18. Sensitivity enhancement mechanisms in textured dielectric based Electrolyte-insulator-semiconductor (EIS) sensors, N Kumar, J Kumar, S Panda., *ECS Journal of Solid State Science and Technology*, 4,3, N18 -N23, 2015
19. Structure of clusters of pentacene molecules and their polarizabilities, Divya, Tankha, A., Prasad, R., Deepak, *Journal of Physics and Chemistry of Solids*, 76, 184 – 194, 2015
20. Sensitivity Enhancement of Electrolyte–Insulator–Semiconductor Sensors Using Mesotextured and Nanotextured Dielectric Surfaces, Subham Dastidar, Abhishek Agarwal, Narendra Kumar, Vivekananda Bal, and Siddhartha Panda, *IEEE Sensors Journal*, 15, 4, 2039- 2045 2015
21. Enhanced capture efficiencies of antigens in immunosensors, D.Rath and Siddhartha Panda, *Chemical Engineering Journal*, 260, 657-670, 2015

## 2014

22. Interface morphology driven control of electrical properties of P(VDF–TrFE) and PMMA blend M–I–M capacitors, Deepa Singh, Deepak, Ashish Garg, *Organic Electronics*, 15, 3811-3817, 2014

23. S. M. H. Rizvi, P. Mantri, and B. Mazhari, Traps signature in steady state current-voltage characteristics of organic diode, *Journal of Applied Physics*, 115, 24, 2014
24. K. Sudheendra Rao and Y.N. Mohapatra, Open circuit voltage decay transients and recombination in bulk-heterojunction solar cells , *Appl. Phys. Lett.* 104,203303, (2014).
25. Mihir Sarkar and Y.N. Mohapatra, Self-aligned electron beam lithography of metallic layer sandwiched in a polymer multilayer: Facilitation of vertical organic transistor fabrication, *Microelectronic Engineering*, 115, 16-20, (2014).
26. Nanda Shakti, Asit Prakash, Tapendu Mandal, Monica Katiyar, Processing temperature dependent morphological and optical properties of ZnO nanorods, *Materials Science in Semiconductor Processing*, 20, 55–60, 2014.
27. K. Sudheendra Rao, Y.N. Mohapatra, Disentangling degradation and auto-recovery of luminescence in Alq<sub>3</sub> based organic light emitting diodes, *Journal of Luminescence*, 145, , Pages 793–796, 2014.
28. Anirban Bagui , S. Sundar Kumar Iyer , Increase in hole mobility in poly (3-hexylthiophene-2,5-diyl) films annealed under electric field during the solvent drying step, *Organic Electronics* 15, 1387–1395, 2014
29. N. Nagarajana, Asit Prakash, G. Velmurugan, Nanda Shakti, Monica Katiyar, Corresponding author contact information, P. Venuvanalingama, Corresponding author contact information, R. Renganathana, Synthesis, characterisation and electroluminescence behaviour of  $\pi$ -conjugated imidazole–isoquinoline derivatives, *Dyes and Pigments*, 102, 180–188, 2014
30. Mihir Sarkara, b, Y.N. Mohapatra, Self-aligned electron beam lithography of metallic layer sandwiched in a polymer multilayer: Facilitation of vertical organic transistor fabrication, *Microelectronic Engineering*, 115, 16–20, 2014.
31. Natarajan Nagarajan, Gunasekaran Velmurugan, Asit Prakash, Dr. Nanda Shakti, Monica Katiyar, Ponnambalam Venuvanalingam, Rajalingam Renganathann, Highly Emissive Luminogens Based on Imidazo[1,2-*a*]pyridine for Electroluminescent Applications, *Chemistry - An Asian Journal*, 9 (1), 294-304, 2014
32. Deepa Singh, Ashish Garg, Deepak, Cooling rate controlled microstructure evolution and reduced coercivity in P(VDF–TrFE) devices for memory applications, *Organic Electronics*, 15 (1), 82–90, 2014

### **Conference Proceedings**

#### **2015**

1. Study of charge carrier mobility and electroluminescence performance in polymer blend based white light emitting diodes Asit Prakash, Monica Katiyar, 2015, MRS Spring meeting, San Francisco, USA 2015.

2. Variations in spectral response behaviour in single layer organic solarcells with active layer thickness and bias”, Sandeep Kumar and S. SundarKumar Iyer, Proceedings of 42nd Photovoltaic Specialists Conference June14-22, 2015, New Orleans, LA, USA, [ieeexplore.ieee.org](http://ieeexplore.ieee.org)
3. “Optimization of MoO<sub>3</sub> buffer layer thickness for short circuit currentenhancement in Ag nanoparticle incorporated CuPc solar cell”, DevikaKataria and S. Sundar Kumar Iyer, Proceedings of 42nd PhotovoltaicSpecialists Conference June 14-22, 2015, New Orleans, LA, USA,
4. “Persistent photocurrent quenching study in TIPS-Pentacene Organic Thin Film Transistor”, Subhash Singh and, Y.N. Mohapatra, Proceedings in ICMAT-2015 , 28<sup>th</sup> June, 2015 to 3<sup>rd</sup> July, 2015 at Suntec, Singapore.
5. Role of sulfide treatment on electrical properties of contacts on magnetron sputteed ZnO thin films, Shikha Srivastiava and Y.N Mohapatra, Proceedings in ICMAT-2015 , 28<sup>th</sup> June, 2015 to 3<sup>rd</sup> July, 2015 at Suntec, Singapore.
6. Photocapacitance –Voltage Characteristics of Organic Bulk Heterojunction Solar Cell, Upkar Verma and Y.N. Mohapatra, Proceeding of ICOE-2015, from 15-18 June, 2015 at Erlangen, Germany.
7. Label Free Prostate-Specific Antigen Detection using Electrolyte Insulator-Semiconductor Device, Narendra Kumar and Siddhartha Panda, MRS Spring 2015, from 6-10 April, 2015 at San Francisco, California, USA
8. Tubable Sensitivities and Selectivities of Hierarchical Polyaniline Nanostructures Grown on Flexible Substrates for Sensing Difference Gases, Mousumi Sinha and Siddhartha Panda, AIChE Annual meeting at Atlanta, GA, USA
9. Enhancement of current efficiency of white polymer light emitting diode by blending of electron transport material, Asit Prakash, Monica Katiyar DAE-BRNS conference on Organic Devices: The Future Ahead (ODeFA - 2014), March 3-6, 2014, Bhabha Atomic Research Center Trombay Mumbai 400085, India
10. White polymer light emitting diode for lighting -An Overview, Asit Prakash, Monica Katiyar, International conference on energy efficient LED lighting & solar photovoltaic systems 27-29 march -2014, IIT Kanpur
11. Improvement of rectification ration of organic light emitting diodes by electrical biasing during annealing, Rahul K. sharma, Deepak, Monica Katiyar, ICMAT, Singapore, 28 June 2015-03 July 2015
12. Light extraction from organic light emitting diodes - a review, Rahul K. Sharma, Deepak, Monica Katiyar, International conference on energy efficient LED lighting & solar photovoltaic systems 27-29 march -2014, IIT Kanpur

## VIII PATENTS

1. An apparatus for shadow-mask deposition and method thereof”, Anukul Prasad Parhi and S. Sundar Kumar Iyer,EE, **201611002575**, 22-01-2016, 2016
2. Utilizing glove box ante-chamber for electric-field annealing purpose, Anirban Bagui, Anukul Parhi, and S. Sundar Kumar Iyer, EE, **33/DEL/2015 6/1/2015**, 2015
3. An Organic Devices with thin film transistor merged with light emitting diode through use of an accumulation layer in TFT as an electrode, Ankita Gangwar and B Mazhari, EE, **708/DEL/2014**, 12/3/2014, 2014

## IX AWARDS

- Dr. S. Sundar Kumar Iyer awarded SBI Chair Professor at IIT Kanpur (2015)

# ANNUAL REPORT 2015

**FLEXIBLE ELECTRONICS: LARGE AREA  
ELECTRONICS FOR EVERYONE, EVERYWHERE**

