# **Advanced Nano materials for Clean Energy Applications**

A Joint collaborative project between

# Bergen University College, Norway and Coimbatore Institute of Technology, India

Title of the project : Advanced Nano materials for Clean Energy Applications

Project number INCP-2014/10045

#### **Institution in Norway : Bergen University College (NO-HiB)** Institutional responsible: Rivedal, Audun - Director General Project coordinator - Velauthapillai, Dhayalan

#### Institution in India : Coimbatore Institute of Technology (IN)

Institutional responsible: Velappan, Selladurai - Principal Project coordinator : Natarajan ,Muthukumarasamy

Project period : January 2015 – December 2017

#### **Project Objectives**

The main objective of this joint project is to strengthen and expand the existing research collaboration between the partner institutions resulting in close ties in educational activities and increase in student and staff mobility within the field of nanomaterials for clean energy applications. The main objective also includes

- The preparation of variety of semiconductor nanomaterial structures which can be used in solar cell applications. Special emphasis will be given to our research on Dye Sensitized Solar Cells. The research will also focus on simulation studies on nanomaterials which could compliment the experimental studies on design of the new-generation of solar cells.
- Increased mobility of master students, PhD research fellows and academic staff.
- Increased supervision of Master and PhD students.
- Building and teaching a research-based course.
- Exchange of knowledge within nanomaterial research for clean energy applications by organizing joint workshops and conferences.

The preparatory work for the project started already in November/December 2014 and the project leader Prof. Dhayalan Velauthapillai from HiB visited India in December 2014 and had a number of meetings with the project coordinator, other members of the project committee at CIT and the administration at CIT.

A delegation of seven People from CIT of the project committe visited HiB in March 2015 (9.3.2015 – 15.3.2015)

Dr. V.Selladurai – Principal Dr.N.Muthukumarasamy - Project Coordinator Dr.S.Agilan Dr.N.Murugan Dr.K.Marimuthu Dr.R.Rajesh Dr.G.Sureshkannan

Joint Meetings and workshop were conducted at HiB and the delegation made visits to the laboratories at HiB and UiB. Meetings were also arranged with industries and other organizations such as Statoil (Mongstad), Haukeland Universitets sykehus etc. The delegation had also opportunities to meet faculty heads and staff from the Engineering and Health faculties at HiB.





#### A MoU between HiB and CIT were signed by the Principal of CIT and the Dean of the Faculty of Engineering in the presence of SiU delegates on 14.3.2015 at Norway





A Webpage has been created for the this INCP project such that all the activities are updated regularly at this site. (http://www.cit-hib-incp2014.com/)

#### **Student mobility**

- Three PhD students from CIT (Mr.G.Rajesh, Mr.R.Venkataraman, Mrs.Y.Akila) who are supervised by Professor Dhayalan Velauthapillai had two months of research stay at HiB from May 2015 to July 2015. These students have been working on synthesis of nano materials at HiB during their research stay. They have also contributed in building the laboratory facilities at HiB for the characterization of solar cells.
- One MSc student from HiB had a research stay at CIT from July 2015 to September 2015 and one PhD research scholar from HiB has had one month research stay at CIT during Nov/December 2015. Both students were working on the computer simulation models and were involved in assisting students at CIT in computational material Technology.









Professor Dhayalan Velauthapillai had a research stay at CIT during Nov/December and was involved in conducting seminars and lectures on Nano materials for solar cell Applications. Dean of the Faculty of Engineering, Prof. Geir Anton visited CIT together with Dhayalan and held several meetings with the Vice Chancellor of CIT, Principal and heads of the departments at CIT on enhancing the collaboration in research and higher education between the two institutions. With the facilitation from CIT, the delegation from HiB visited also the PV industry and held meetings with a few companies in Coimbatore area to identify potential for future research collaborations with the industry.





#### **Conferences/ Workshops/ Seminars**

We had a Indo-Norwegian workshop on the 11th of March 2015 entitled Indo-Norwegian Collaboration Program on Research and Higher Education at D110, Kronstad Campus, Bergen University College (HiB)

International Conference on Advanced Nano Materials for Frontier applications (ICNFA 2015) was jointly arranged by HiB and CIT in collaboration with IFE, UiO and University of Exeter (UK) from Dec 2. to Dec 4. 2015 at Coimbatore, India

This Conference was arranged under the INCP Project and also got the support of NFR.

The conference was successful with 144 presentations and 14 invited talks. Dean from HiB, Prof. Geir Anton Johansen and a number of researchers from HiB, UiB, UiO, IFE from Norway attended the three-day conference. Recognized researchers from UK, South Korea, Turkey, Spain, Estonia, Norway and India participated at the conference.





An extra seminar was arranged in June 2015, which was not in the original plan. When 3 PhD students of cit were at HiB between May and July 2015, we had an open seminar at HiB. Nearly 25 researchers from HiB and UiB participated and the PhD students related to the INCP program along with the project coordinator had presentations.

- 1. State of the art of Solar Cell Technology Research and future developments / Dhayalan Velauthapillai
- 2. Natural Dye Sensitized Solar Cells based on TiO2 / Akila Yuvapragasam, CIT
- 3. A study on recombination effects in Dye Sensitized Solar Cells / Venkatraman Ramakrishnan, CIT
- 4. Environmental friendly CZTS materials for future PV technology / Rajesh Govindaraj, CIT
- 5. Computational simulation studies on nano materials for solar cell applications / Murugesan Rasakkannu, HiB

Mr.R.Venkataraman PhD student from CIT who is supervised by Professor Dhayalan Velauthapillai had two months of research stay at HiB from 14<sup>th</sup> January 2016 to 21<sup>st</sup> March 2016

Mr.R.Venkataraman carried out synthesis of  $TiO_2$  and transition metal doped TiO2 nanoparticles by microwave assisted solvothermal Synthesis. The synthesized nanopowders were coated over FTO substrate by doctor blade method and were used as photo anodes in dye sensitized solar cells and which yielded an efficiency of nearly 8%.

Mr.G.Rajesh PhD student from CIT who is supervised by Professor Dhayalan Velauthapillai is presently at Norway for nearly three months of research stay at HiB from 24<sup>th</sup> April 2016 to 14<sup>th</sup> July 2016 and is working on CZTS thin films for solar cell applications





In April 2016 a team from CIT visited HiB Norway and had discussions and made strategic plan for the following years



Sondr Sandberg from Bergen University college Norway, will be at CIT and work for his PhD in the area of dye sensitized solar cells from September 2016

#### Research work so far from January 2015 ...

- The project so far is progressing well with the research scholars involved in the project working on TiO<sub>2</sub> and other semiconductor oxides for solar cell applications. Dye sensitized solar cells have been fabricated using the prepared oxide semiconductors and their characteristics have been studied. The performance of the fabricated solar cell has been very encouraging as it exhibited an efficiency of nearly 8%.
- CZTS semiconductor thin films have also been prepared and the deposition conditions have been optimized to obtain device quality thin films.
- Perovskite materials have been prepared and are being studied for solar cell applications

• Joint research is also carried out on Computer modeling of nano structures for PV applications.

- Before the project started the laboratory facilities at HiB was nonexisting, There were risks in building new, viable technical environment at HiB. But, the project coordinator succeeded in getting additional funding for building laboratory facilities at HiB.
- Collaboration between different institutes at HiB has helped in creating an effective technical environment for the experimental research on nanomaterials for clean energy applications. This project has also contributed in expanding the experimental facilities at CIT.

#### **Publications**

# This INCP project has resulted already in 12 peer-reviewed publications in highly reputed journals and 9 presentations at international conferences.

- Enhanced performance of natural dye sensitised solar cells fabricated using rutile TIO2 nanorods Y. Akila, N. Muthukumarasamy, S. Agilan, Tapas K. Mallick, S. Senthilarasu, Dhayalan Velauthapillai, 10.1016/j.optmat.2016.05.009
- Synthesis and characterization of zeolite NaA and NaY coating on mild steel, S. Keerthana S. Agilan N. Muthukumarasamy R. Balasundaraprabhu Dhayalan Velauthapillai, Journal of Sol-Gel Science and Technology, DOI: 10.1007/s10971-016-4094-0
- 3. Magnesium incorporated Hydroxyapatite Nanoparticles: Preparation, Characterization, antibacterial and larvicidal activity, Gayathri Udhayakumar, N. Muthukumarasamy, Dhayalan Velauthapillai , Shanthi Bhupathi Santhosh , Vijayshankar asokan, Arabian Journal of Chemistry, DOI: 10.1016/j.arabjc.2016.05.010
- Effect of reaction time on the formation of TiO2 nanotubes prepared by hydrothermal method Ranjitha Arumgam; Muthukumarasamy Natarajan; Thambidurai Mariyappan; Velauthapillai Dhayalan; Agilan Santhanam; Balasundaraprabhu Rangasamy Optik (Stuttgart) ISSN 0030-4026
- Effect of Chromium and Cobalt Addition on Structural, Optical and Magnetic Properties of NiO Nanoparticles, Pothapalayam Mahali Ponnusamy, Santhanam Agilan, Natarajan Muthukumarasamy, and Dhayalan Velauthapillai, Zeitschrift fur physikalische Chemie (Munchen. 1991) ISBN/ISSN: ISSN 0942-9352

- Natural dye sensitized TiO2 nanorods assembly of broccoli shape based solar cells, Yuvapragasam Akila;
   Muthukumarasamy Natarajan; Agilan Santhanam; Velauthapillai Dhayalan; Senthil Thottipalayam Subramaniyam;
   Sundaram Senthilarasu, Journal of Photochemistry and Photobiology. B: Biology, ISSN 1011-1344
- Enhanced photovoltaic performance of quantum dot-sensitized solar cell fabricated using Al-doped ZnO nanorod electrode, Raja Mohan Dinesh; Muthukumarasamy Natarajan; Velauthapillai Dhayalan; Balasundrapraphu Rangasamy; Senthil Todari S.; Agilan Santhanam, ISSN 0749-6036 Superlattices and Microstructures
- Influence of Dietary Selenium Nanowires on Growth Performance of Broiler Chicken, Senthil Kumaran C K;
   Sugapriya S; Velauthapillai Dhayalan; Rajamani R; Chandrasekhar, Bellan, International Journal of Biosciences and Nanosciences ISSN 2349-5251.
- Effect Solution-based synthesis of high yield CZTS spherical quantum dots, Rajesh G.; Muthukumarasamy N.;
   Subramanian E. P.; Venkatraman M R; Agilan S.; Ragavendran V.; Thambidurai M.; Velumani,S.; Yi Junsin;
   Velauthapillai Dhayalan Superlattices and Microstructures, ISSN 0749-6036
- 10. Solvothermal synthesis of TiO2/CNT composites and its physical and chemical properties, Venkatraman M R; Muthukumarasamy N.; Balasundaraprabhu R; Agilan S.; Velauthapillai Dhayalan, AIP Conference Proceedings
- Structural and optical properties of Ga-doped CdO nanocrystalline thin films, Thambidurai M.; Muthukumarasamy
   N.; Ranjitha A; Velauthapillai Dhayalan, Superlattices and Microstructures, ISSN 0749-6036
- Studies on Cobalt doped NiO nanoparticles prepared by simple chemical method, Ponnusamy PM; Agilan S;
   Muthukumarasamy N; Raja M; Velauthapillai Dhayalan, Journal of materials science. Materials in electronics, ISSN 0957-4522

#### **Utilized amount details in NOK**

<b>Amount Disbursement from SIU 2015</b>	-	384 499
Available amount	-	384 499
Expenditures	-	374 129
Balance	-	10 370
Return to SIU		
New balance	-	10 370
Transfer to 2016	-	10 370

# **EXPERIENCE GAINED**

As anticipated, collaboration between HiB and CIT has progressed smoothly. Understanding the cultural codes between the working atmospheres at the two institutions has been one of the challenges.

CIT has an effective structure and the high level involvement from the leaderships at HiB and CIT has been very helpful for the successful implementation of this project. Both institutions have solid, flexible managing system which has enabled the project to progress smoothly.

The collaborating atmosphere has been exemplary and students and the staff involved in this project from both institutions have developed mutual understanding.

Acquiring travelling visas quickly for the mobility of the students and staff involved in this project was anticipated as one of the challenges. But the Norwegian Embassy in India and the Indian Embassy in Norway have been very helpful with speedy visa arrangements that made the mobility program to proceed according to the plan. The project coordinator has been in constant touch with the embassies and the authorities have been well informed of the project.

#### Plan for July 2016 to December 2017

**Student mobility** 

- PhD student from HIB to CIT From Aug Sept 2016, Aug Sept 2017
- Two PhD students from CIT to HIB From Feb Apr 2017
- Two master students from HIB to CIT From Aug Sep 2016, Aug Sep 2017
- One master student from CIT to HIB From Feb Apr 2017

#### **Staff mobility**

- HIB to CIT July 2015, Aug 2016, Aug 2017
- CIT to HIB Mar 2016, Mar 2017

Joint Master and PhD supervision - From Jan 2015 to Dec 2017

Joint lectures on computer modelling of nano materials at CIT - Aug 2017

Joint lectures on nano material structures, synthesis and characterization methods at HIB - Mar 2017

Indo –Norwegian Collaborative Workshop with other research collaborators from UiB, UiO, IFE Mar 2017

International Conference on Advanced Nano Materials for Frontier applications (ICNFA 2017) Aug 2017

#### Sustainability plans after INCP funding

- Through mobility program, inter-institutional and inter-cultural understandings are developed. It results in building a sustainable partnership that holds the potential to continue independent of funding.
- The project brings a critical mass of expertise dedicated to different aspects
  of computational and experimental materials science and an integrated
  approach will provide contributions beyond the state of- the-art in
  computational and experimental knowledge available in the field of
  photovoltaics.
- The experience and expertise gained from this project will help to generate external funding's from Indian, Norwegian and European research funding institutions.

# **THANK YOU**