|| SUKSHMA ||

The ISSS newsletter about micro and smart systems in India

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Cover Designed By: Bharathi G.

Future Nano Electronic Materials for SMART TRANSPORT

Prof. S B Krupanidhi

With rapid technological advances, the nature and demands in developing transport are changing rapidly. To realize fully automated transport systems, demands are increasing for electronic control of vehicle-to-vehicle communication, proximity sensing, remote controls and real time image sensing and processing. In addition, operating power economics is taking a front seat, considering the global concern for environment and carbon emission. In an effort to address these issues, a synergized initiative is necessary among industries of automobiles, IT and electronic components.

It is envisioned that a drastically increased number of nano and micro electronic devices will be integrated in embedded chips to help accomplish automated smart driving. For this, it is essential to have electronic devices on ONE chip and establish WIRELESS communication across the devices. The future definitely demands mounting various SMART sensors to monitor engines, power generators, tyre conditions, emission of exhaust gases, image and proximity sensors to assess distances between vehicles, communication devices and real time information processing for an optimal REMOTE CONTROLLED driving. Even though the whole gamut of devices might appear to be making the entire system complex, the primary aim is to make it SIMPLER for human interaction.

Targeted quest for new materials and / or newer ways of materials is a constant demand to assist the innovation of new devices or new configurations of established device concepts. Non-polar GaN, all-oxide thin film transistors, Non-Pb based complex oxides, Hybrids of oxide-semiconductors, combinatorial growth of complex materials systems are a few examples for future nano electronic devices. These have immense application potential not only in the automobile industry but also for a plethora of other avenues that are awaiting new innovations and combinations.

Contents

Contents	Pg No.
Future Nano Electronic Materials for SMART TRANSPORT	02
Latest Trends in SMAs	03
Student Awards	04
Smart Materials and MEMS Activities @ NIT-Tiruchirappalli	05
Practical Guide to RF-MEMS - A Review	07

Latest Trends in SMAs

Vidyashankar Buravalla

In the last edition of Sukshma, I had mentioned that I will provide a quick overview of the trends in SMA technologies. Hence, herein, I would like to provide a flavor of some of the salient advances, opportunities, challenges that SMA technology in general and Industry in particular is making. One of the main purposes of this write-up is to get the interested reader look for further information and get oneself abreast with the relevant developments.

According to several estimates, shape memory industry is now worth at least 10 Billion USD and is expected to exceed 15 Billion in the next 3-4 years. Of this, about 80 % is from the biomedical arena, contributed mainly by the applications in the form of cardiac and brain stents, valves, staples etc.. This predominantly exploits the superelasticity property and one-time shape memory effect. But, what is also noteworthy is that actuation applications that work on the shape memory effect is also fast catching up, maturing rather rapidly. While most of the SMA actuator applications, till a couple of years ago, were restricted to Lab scale demonstrations or numerical models, their realization is a recent phenomenon. And, the trend is showing a rapid increase. Several factors have contributed to this. Firstly, the critical aspects of reliability, durability, cost and operational simplicity have been reasonably well understood or at least addressed by making suitable design choices, prominent among them, being the use of SMA in wire form. Several global suppliers exist today for getting SMA in wire form with consistent and acceptable material properties and reasonable cost. Several recent survey articles have been written that elaborates on several of these aspects.

Developments in SMA material per se, are, as has been the case over the last couple of decades, being largely in the area of identifying alloy combinations that exhibit martensitic transformation, which manifests as superelasticity and shape memory effect. Both completely new alloy formulations and ternary, quaternary additions to well-known NiTi alloy (also called nitinol) are being actively pursued. Alloys with transformation temperatures as high as 600 °C have been identified. Shape memory ceramics, with even higher transformation temperatures have been reported in laboratory experiments, hinting at exciting opportunities. Among the already known SMAs, significant amount of effort is dedicated to two key interdependent aspects viz., processing and durability and reliability. Unlike conventional materials wherein we normally talk of structural or mechanical fatigue, in SMAs fatigue manifests in two distinct forms, namely, functional fatigue and the conventional structural or mechanical fatigue. Understanding these two types of fatigue is critical to effective and efficient use of SMAs. Because SMAs are highly history dependent materials, the thermomechanical processing conditions have a large role to play in determining their fatigue behavior. Hence several studies, mostly experimental, are being carried out on various alloys with different thermomechanical history to assess their durability and reliability. For instance while it is known that adding Cu (up to 10%) reduces the transformation hysteresis, It has been shown that adding about 7% of Cu yields the highest fatigue life. Using fundamental crystallographic theories, it is shown that for this particular alloying combination, the crystal structure is extremely coherent and thereby leads to such enhanced fatigue life. Another recent success is in enhancing the formability of NiTiHf alloys that shows SME at temperatures above 100 °C. It may be noted that while NiTiHf has been around for nearly twenty years, processing the alloy into wire or other such suitable forms had been a challenge.

Another major development in the area of SMA actuators is the gaining interest in bulk form of SMA active elements, in particular the rod or tube form of SMAs. Boeing has demonstrated couple of aero applications on their 737 aircraft and helicopters which uses SMA tubes as active elements. Some applications using SMA bars/strips have also been demonstrated. The next steps would be to establish operable stress-strain-temperature regimes that would lead to a desirable life of the actuator, design features that provide good thermal management and cost reduction. It may be noted that due to thermal actuation, ability to heat and cool the SMA rapidly dictates the actuation and cycle times.

Another interesting development in the area of materials and processing is the production of 'hybrid SMAs' or multiple memory material technology (MMMT) developed by researchers at University of Waterloo, Canada. While conventional SMAs have a well-defined set of transformation temperature range (for instance, a definite Austenite finish temperature), an SMA strip or wire has been made shown to have distinct zones with different transformation characteristics. This has been achieved by controlled altering locally the thermo-mechanical treatments to the material. Several exciting possibilities exist for the use of such alloys.

Coming back to nitinol stents, several new challenges are being addressed. Till recently, the expectation from an implanted stent was that it lasts for about 10 years, translating to roughly 10 Million cycle life. This was arrived at with an expectation that typically the stents are implanted in patients who are 50+ years. Hence a prognostic of 10 years of life for the stent was considered acceptable. With recent trends that significant number of people, as young as 30 years, are showing cardiac related problems and would require stent implantation, the stents are now expected to last 30 years. This implies a whopping 30 million cycles, far more than most of the engineering applications of any structure or a component. Hence, the biggest technical challenge that this poses is that the stent that is manufactured should be free from any flaw (could be even smaller than a micro crack) that can grow to a critical crack size during this ultra-high cycle fatigue conditions. To add to this, there is this inherent environmental highly corrosive condition when the stents are in the blood stream. Though nitinol is known to be very good corrosion resistant material, the effect of such prolonged exposure needs to be ascertained. Another major challenge is to make these stents more affordable, especially in developing countries where, ironically, the cardiac related problems are most prevalent. Newer methods of making stents such as braiding and laser etching are being pursued. Herein too, the challenge is that the method of manufacturing them in such large numbers and in cost effective way does not affect its durability. It probably is not out of context if we note that Indian scientists and technologists have achieved commendable success in developing NiTi SMAs and have set-up infrastructure for large scale production. A significant next step would be to develop and manufacture stents in India and through this indigenization, make them more affordable.

To compliment this work, rapid developments are also seen in the area of characterization both at the material level and at the device level. Surface characterization using SEM and TEM to detect any surface flaws that can affect the performance is an example. Modelling too is helping the development and wider deployment of SMAs. For wire based devices, several 1-D models that are simple and accurate enough to be used to develop design tools exist and with significant test data leading to better understanding of the complex thermomechanical response, design methodologies are being developed to aid the industry. In this scenario it is not surprising that ASM has recently started a new International journal, SMST, dedicated to shape memory and superelastic technology.

ISSS 2014 Student Paper Awards

- By Giridhar M. S.

One of the most popular events at the International ISSS conferences is the student paper award competition. The objective of the competition is to encourage students in their professional development. The competition helps participating students to hone their skills in writing technical papers and making research presentations. Early training in this area will be helpful to the students in their careers as professional scientists. The competition also helps identify and encourage institutions and supervisors who guide students in the area of smart materials, structures and systems.

The competition has three categories: undergraduate (UG), post graduate (PG) and doctoral (PhD). The competition is open to students registered in any educational institution. ISSS 2014 received 8 entries in the UG, 4 entries in the PG and 12 entries in the PhD categories. The entrants were required to submit full papers which were screened by the Technical Programme Committee.

Continued. Pg No. 8

Smart Materials and MEMS Activities @ NIT-Tiruchirappalli

Compiled by Dr. G. Uma, Associate Professor and Dr. M. Umapathy, Professor

MEMS Design Center at National Institute of Technology, Tiruchirappalli was established in the year 2005 in the Department of Instrumentation and Control Engineering. The centre was initially equipped with modeling tools like MEMS CAD tool Coventor-Ware and IntelliSuite purchased from the institution fund and the centreit was subsequently strengthened under grants from NPSM, NPMASS and DST-FIST projectprograms. Several Ffaculty members from the Departments of Instrumentation and Control, Chemical, Electronics, Mechanical, Production Engineering and Physics are involved engaged in the activities related to MEMS and smart materials. The center facilitates UG, PG students and research scholars of the institute and other neighbouring-nearby institutions.

The center has designed, fabricated and tested resonancet based sensors in meso scale with piezoelectric sensing and actuation with associated electronics for sensing mass, thickness of magnetic and non-magnetic materials, conductivity, acceleration, directDC current etc.. Currently, under a DST-SERB sponsored project, a resonant pressure sensor in meso scale is fabricated and tested and the sensor design in micro scale is in progress.

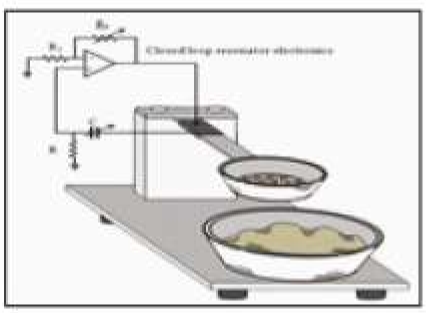
Thickness Measurement

Conductivity Sensor

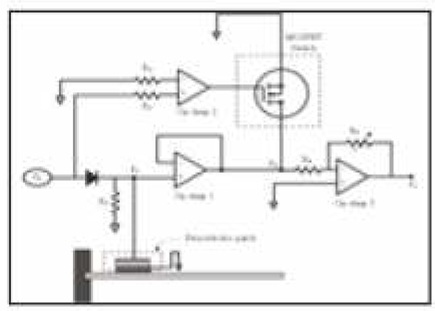
DC Current Sensor

Few novel meso scale piezo actuated devices that have been fabricated include single & two degrees of freedom liquid pumping system, Piezoelectric sifter, Piezo driven motor, SMA actuated ball and beam system and SMA gripper. Self sensing electronics for piezo excited resonance sensors have been designed and tested to be used with micro resonant devices.

Thickness Measurement

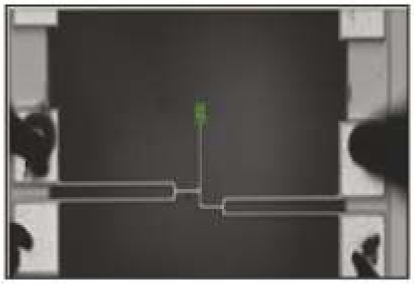


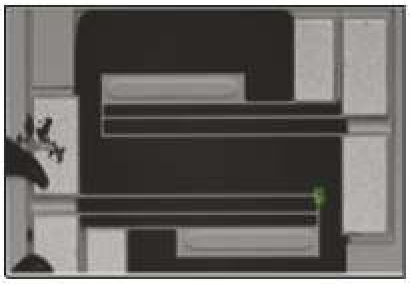
Conductivity Sensor

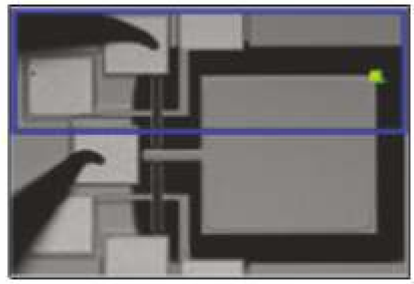


DC Current Sensor

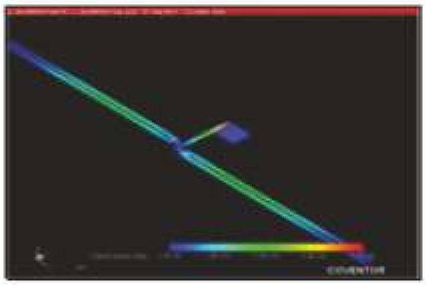
Most of the meso scale resonant based devices fabricated and tested in the centre were also assessed for feasibility of their fabrication in micro domain. This was achieved by simulating themed for its performance in micro domain using modeling tools like CoventorWare and COMSOL Multiphysics. to show the feasibility of fabricating the same in micro domain. Other Apart fromthan these resonance based devices, devices like Electro- thermal actuators, MEMS based logic gates, ADC, DAC, Electro- thermal resonance accelerometer, Chevron micro gripper, etc. were designed and simulated for its performance using MEMS CAD tools. In line with this, the micro fabrication of ETC actuator, ETC resonant accelerometer and Electro- thermally actuated resonator has been attempted in SOIMUMPS process through NPMASS program



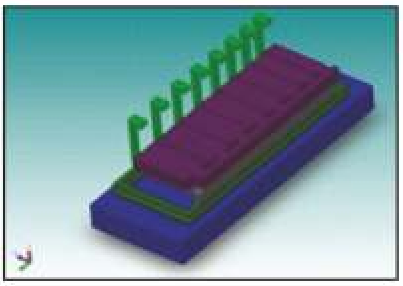




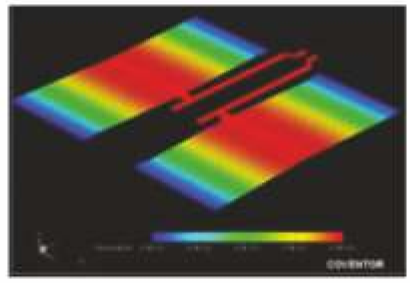
SEM Image of ETC actuators and Electro thermal resonance micro accelerometer



Simulated ETC resonator

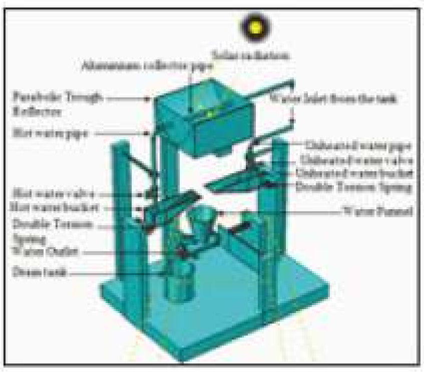


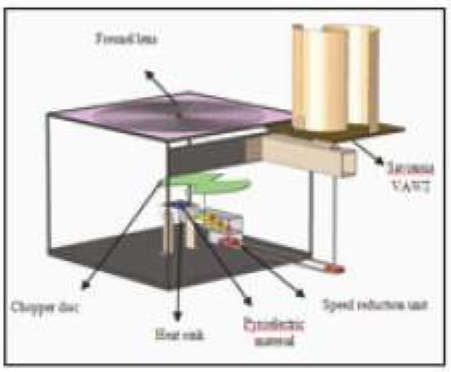
Simulated MEMS ADC

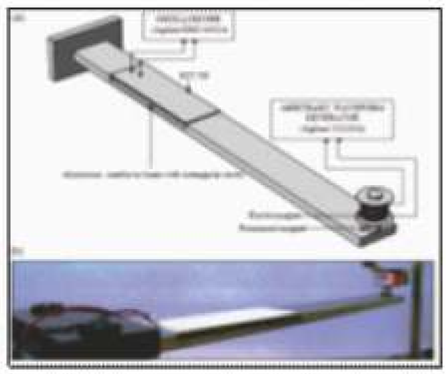


Simulated Chevron Microgripper

In recent years the centre has extended the research work towards Energy Harvesting, with a focus on piezoelectric energy harvesters. Two hybrid energy harvesters utilizing solar, wind and vibration energy are designed, fabricated and tested. Apart from this, research has also been carried out in improving the performance of the beam type energy harvesters by the inclusion of cavity in the regular beam. The effect of dimension, shape and position of cavities and the number of cavities on the magnitude of the harvested voltage has been investigated. The centre is presently working on design, fabrication and testing of broad band piezo-electric energy harvesters.







Facilities available:

Software:
- CoventorWare
- COMSOL
- MEMS+ 5
- IntelliSuite
- MATLAB

Hardware:
- Probe station
- White light confocal ultra-precise displacement measurement system
- Laser displacement sensor
- ER damper with accessories and power supply
- MR damper
- Standard test and measuring equipment

Outcome:

No. of Publications : 25
No. of Patents filed : 3

Community reach:

Courses and workshop on MEMS, its CAD tools & smart materials is organized at regular intervals to educate faculty & students of other institutes

No. of Institutions involved : 15
No. of Faculty trained : 75
No. of Students trained : 100

Practical Guide to RF-MEMS

Author: Jacopo Iannacci
Publisher: Wiley-VHC, Weinheim (2013) ISBN: 978-3-527-33564-0

Book Review
Giridhar M. S.
LEOS, ISRO

Over the past few years, it is heartening to see that several texts devoted entirely to RF MEMS have appeared in the market. Among the most recent of such texts is the "Practical Guide to RF-MEMS" by Jacopo Iannacci. Dr. Iannacci is a well known name in the MEMS literature. He is an active reseacher at the Fondazione Bruno Kessler in Trento Italy, working in various aspects of RF MEMS from design to testing and everything in between.

The author, well aware of other books on this subject, has understandably attempted to write a "different" book. He has set his goal to write a 'practical' book. One can imagine the dilemma in such an endeavour. To be practical, one has to focus on specifics and at the same time not be too specific to lose the interest of the general RF MEMS practioner. This reviewer of the opinion that the book by and large meets these objectives.

The book comprises of seven chapters and two appendices. Each chapter starts with an abstract and introduction, giving a clear overview of its contents.

Chapter 1 is a brief but comprehensive introduction to RF MEMS. It describes the development of the filed briefly giving some historical account of the development of RF MEMS. Mention of Nathonson's work is conspicuous by its absence. Many consider H. Nathonson's invention of the Resonant Gate Field Effect transistor in 1964 as one of the earliest RF MEMS devices.

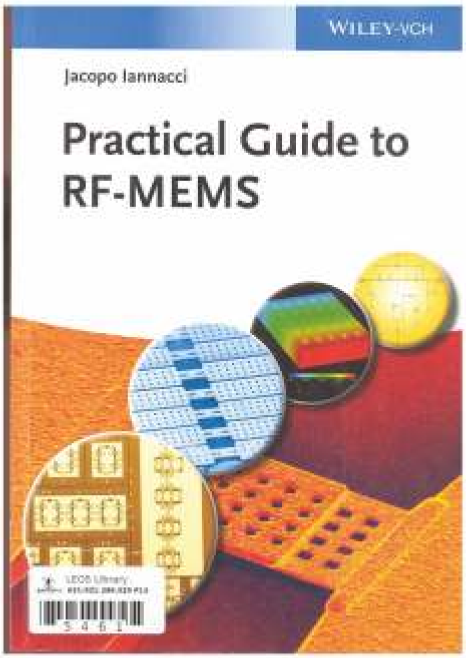
Chapter 2 gives details of the FBK fabrication process which is extensively used in the various case studies discussed in subsequent chapters of the book.

Chapter 3, 4 and 5 delve into design and simulation techniques. It is in these chapters that the book differs from others on the subject. For instance, chapter 3 is named 'Design'. This chapter does not deal with general design principles of MEMS devices, instead, it present a few detailed case studies using a software specific approach of the FBK process. Much of the chapter involves a step by slep description of model development of RF MEMS devices.

'Simulation Techniques' is the name of Chapter 4. This chapter introduces the reader to two of the most commonly used software tools in RF-MEMS viz., ANSYS and HFSS. The material serves as a hand holding guide to ANSYS using its programming language, ANSYS Parametric Design Language (ADPL). The author emphasizes the advantages of using ADPL over the graphical user interface. According to him ADPL offers greater amount of flexibility in model development as compared with the graphical user interface. The chapter has a large number of ADPL code snippets serve as illustrtive examples. HFSS is introduced in a similar fashion with many detailed screen shots to guide the reader.

Chapter 5 is curiously called "On-purpose simulation" tools. This chapter introduces the reader to the power for lumped element simulators. Here, basic mechanical components such as rigid plates and beams are taken from a parts library where specific parameters are defined as required. The author uses Verleg-A programming language to build the parts library within the Cadence simulation environment. The chapter briefly covers the mechanical description of rigid plates and beams that can be used in developing lumped element (compact models). For mathematical details, the reader is referred to Appendix A at the end of the book. The rest of the chapter is devoted to giving detailed examples of models electrostatic switches using compact models and comparing the results with FEM simulators such as Coventorware. The advantage of compact modelling in terms of computation time is emphasized. The chapter concludes with a detailed example of an electrostatic actuator.

The all important topic of packaging and integration is dealt with in chapter 6. The focus is on wafer level packaging (WLP). As in the previous chapters, a typical case studies of WLP are discussed in detail. The examples includes the use of relatively new materials such as anisotropic conductive adhesives (ACA). The detailed description of the use of this material, will be very helpful to readers who would like to explore the use of this materials in their own work. A unique aspect of the material presented is the modeling of the effect of ACAs in packaged device performance using software tools such as HFSS. Conventional WLP techniques such as through silicon vias are also described and modeled. This is a self contained chapter that can be read on its own with a good number of refer-eneces to follow up with.



The subject of chapter 7 is post fabrication modeling. This chapter is yet another unique aspect of the book. It discusses the effects of process tolerances on the simulation results. Very few books in the field given this perspective. Typically, ideal structures are modeled leading to ideal results. But in practice, fabrication and process tolerances introduce departure from design valves during every fabrication step. The accumulated effects of such deviations lead to features such as tapering of beam crosssection, buckling of rigid plates, beams and oxidation RF contacts. If these effects are not accounted for in the models, the simulation results will be far from the observed behavior. The author develops the concept of post fabrication modeling and gives examples of how model parameters are tuned to obtain results that come closer to experimental measurements.

The book contains two mathematical appendices which deal with detailed theoretical analysis of the mechanics of basic structures such as plates and beams. The dynamics of plates under charged conditions and the effects of viscous damping of the surrounding medium are also discussed. The appendices provide a rigorous but lucid theoretical basis for the computational techniques covered in the text.

At first glance, the book appears to specifically address only RF-MEMS. Upon closer reading it comes across as a valuable guide to researchers in the general MEMS area. The material covered in the chapters on modeling, simulation and the appendices take the reader on an enlightening journey. The book assumes some basic familiarity with MEMS devices and fabrication processes on the part of the reader. The reviewer would recommend this book to be kept within easy reach in the MEMS laboratories and design centers.

Student paper award competition ISSS 2014

From Pg No. 3

The papers that were shortlisted were presented as posters at the conference. The screened in posters were judged by a three-member jury and finalists were selected for oral presentations. Candidates selected for poster presentations were required to describe their poster in about five minutes, followed by questions from the jury members. Finalists for the oral presentations were selected from the poster presentations. Assessment criteria included clarity of explanation, contribution to the work presented, and answers to questions fielded by jury members. Oral presentations were made at an enthusiastically attended special session later in the day. One of the candidates in the PhD category made her poster and oral presentation via an internet voice link from USA. The jury had a tough time selecting the winner since all the finalists made high quality presentations in their respective categories. The PhD, PG and UG categories carry cash awards of INR 15000/, 12,000/ and 8000/ respectively. Awards and certificates were given away by Prof. V. K. Aatre, founder president of the ISSS, at a ceremony following the presentations.

UG Category:

1. *(Winner)*
Tharini. T and Shalini. S, "Life saving siren system from dam water discharge" Supervised by A. Suban, Vellamal College of Engineering and Technology, Madurai

2. Dhirendranath Panigrahi and Prasanjeet Nayak, "Zigbee based calling bell for dumb and deaf", Supervised by Sakuntala Mahapatra, Shaik Mohammad Ali, Trident Academy of Technology, Bhubaneswar

PG Category:

1. *(Winner)*
Maj. Krishna Kant Sharma, "Realisation of hyperbolic metamaterial using ferrofluid", Supervised by Suwarna Datar, Defence Insititute of Advanced Technology, Pune
2. Rahul Kumar, "Design, fabrication and characterisation of metamaterial based terahertz filters", Supervised by Enakshi Bhattacharya and Ananth Krishnan, Indian Institute of Technology Madras, Chennai

PhD Category:

1. *(Winner - 1st place)*
V. Mahendran, "Development of magnetically responsive smart nanofluids for optical sensing applications", Supervised by John Phillip, Indira Gandhi Center for Atomic Research, Kalpakkam
2. *(Winner - 2nd place)*
Vijay Kumar Sutrakar, "A computational study of structural and thermomechanical behaviour of metallic nanowires", Supervised by D Roy Mahapatra, Indian Insititute of Science, Bengaluru
3. Vaishnavi Srinivasaraghavan
"Microelectrode-based impedance spectroscopy as a tool for studying adherent and suspended breast cancer cells", Supervised by (name not known), Virginia Tech, Blacksburg, USA.