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SMART STRUCTURES
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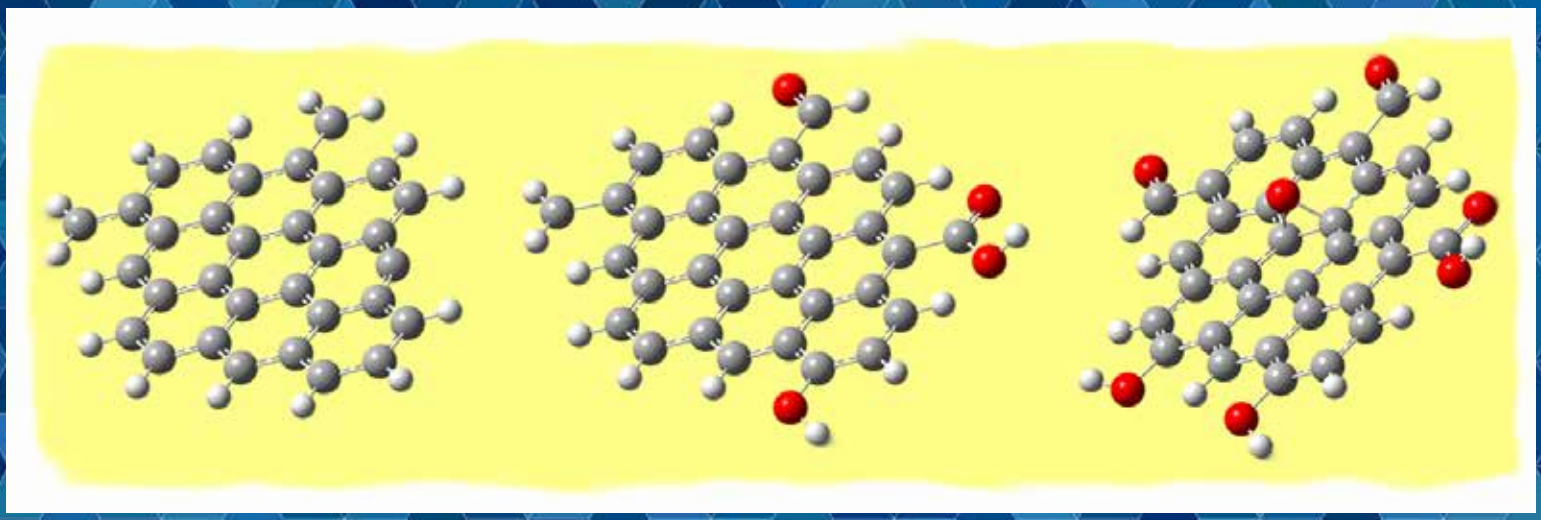

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1 The Editorial

Dr. Nilanjan Chattaraj

Welcome to another issue of Sukshma!

Recently, the ISSS Team has visited the Central Manufacturing Technology Institute (CMTI), Bengaluru. The visit was found extremely valuable considering the aspects of sensor development facilities at the Sensor Technology Development Centre (STDC) in CMTI and finding the scope of collaboration of several institutes with the CMTI from the perspective of contemporary and futuristic sensor development. The interaction of the ISSS delegates with the Director of the CMTI during the visit has opened up several such opportunities. Another exciting aspect of ISSS's activity was the Applied Sensing Conference (APSCON) 2023. The APSCON 2023 was a success. ISSS was designated as the platinum sponsor as per the rules of the IEEE Sensors Council. This association of ISSS with the IEEE through the APSCON 2023 has added a fresh significance to its aim to spread the essence of science and technology among people. We expect that this association of ISSS with the IEEE will go a long way to unfold several future initiatives and opportunities on science & technology. The panel discussion on Challenges of transition of ideas to Start-up and beyond in that conference grabbed a huge attention considering the contemporary importance of entrepreneurship and start-up development. The other panel discussion on Current and Future trends in Applied Sensing was also extremely fascinating since the demand for sensors is exponentially increasing considering the impending trends of IoT and Industry 4.0 standards. We are thankful to all the ISSS members, who actively participated in this event to make this event a grand success. In this issue of Sukshma, we have presented an article on MEMS Community Chip: An initiative to think MEMS beyond just simulation. We are thankful to Dr. Sripadaraja. K, who is the Community Chip Co-ordinator and also the Academia-Industry Coordinator, for contributing such a relevant article. The article has given an insight on the MEMS community chip development through the ISSS's in-house community chip fabrication facility at the Indian start-up InFab Technologies Pvt. Ltd., which is incubated at CeNSE in the IISc campus, Bangalore. This will be extremely beneficial to the motivated researchers and developers. In this issue, we have exhibited another interesting short article on Graphene in Supercapacitor Electrodes written by Ms. Suveksha Tamang and Dr. Joydeep Biswas. A new aspect of this issue of Sukshma is that we have shared several research, career and collaboration opportunities for device development at the Tyndall National Institute at University College, Cork. This is the time to benefit from these opportunities.

We hope that the readers will enjoy reading this issue of Sukshma. We request our readers to share their views, opinions, suggestions and expectations on several aspects of science and smart technology via our email admin@isssonline.in.

Happy Reading!

Sukshmabhilap Prasiksana- 2022

Familiarization and Hands-On Training to Design and Model MEMS Devices for ISSS MEMS Community Chip, Sukshmabhilap Prasiksana- 2022

Nitte Meenakshi Institute of Technology, Bengaluru

The Centre for Nano Materials and MEMS of Nitte Meenakshi Institute of Technology (NMIT), Bengaluru, in collaboration with the Institute of Smart Structures and Systems (ISSS) organized a five-day hands-on training program Sukshmabhilap Prasiksana 2022 on familiarization and hands-on training to design and model MEMS devices for ISSS MEMS community chip during 8th to 12th November 2022. About sixteen participants from all over India participated in the training including students, research scholars, and faculties in hybrid mode. Dr. P N Tengli, Professor of the Aerospace Department of NMIT, Bengaluru welcomed the participants with a keynote address on the MEMS technology and the facilities existing in the center to carry out the research activity. The Resource persons were from in-house and external organizations. The in-house resource persons were Ms. Nithya G and Ms. Sthuthi A, who delivered the training on the introduction to the design and simulation of MEMS devices by using the Comsol Multiphysics tool. The external resource persons were from Infab Technologies Pvt. Ltd. and Project Associates from CeNSE

During the Hands-On Training in Sukshmabhilap Prasiksana- 2022 at Nitte Meenakshi Institute of Technology, Bengaluru

IISc, Bengaluru. The training program covered broadly five aspects of MEMS devices, such as, concept of MEMS design, commercial software for MEMS design, applications of MEMS through case studies, fabrication methods, and scope of industrial collaboration in making MEMS devices. Dr. Sripadaraja K, Managing Partner of Intellisense Software, Bengaluru and Mr. Chandrashekar LN, Project Associate of CeNSE, IISc, Bengaluru discussed on the design aspects of MEMS devices in that training program. Ms. Nithya G, Assistant Professor in the ECE Department of NMIT, Bengaluru and Mr. Michael John Bosco, Project Associate in Multidisciplinary and Multiscale Design and Device (M2D2) Laboratory of IISc, Bengaluru talked about the usages of commercial software such as Comsol Multiphysica and Matlab in the design process of MEMS devices. Dr. Shilpa Raju, Principal Scientist in InFab Tech, Bengaluru, Ms. Sthuthi A, Ms. Nithya G, and Ms. Sthuthi A, Assistant Professors in the ECE Department of NMIT, Bengaluru have discussed on Microfluidic application and MEMS Accelerometer application, respectively. Dr. Sudhanshu, CTO in InFab Tech, Bengaluru and Mr. Litin Vargees, Process engineer in InFab Tech, Bengaluru have discussed MEMS Fabrication & SOI Process flow and MEMS Fabrication Cleanroom Setup. Mr. Muthuraman, Director of InFab Tech, Bengaluru elaborated the scope of INFAB & Academic University Collaboration. The five days training was concluded by having an interactive session for the participants with Dr.Veda SN, Member secretary of ISSS. The interactive session was very fruitful to participants as they convey their further training requirements and support from NMIT and ISSS. Dr. Ramachandra AC of the Department of ECE and Ms. Veena S of the Department of EEE of NMIT took initiative as the convenor, and Ms. Nithya G and Ms. Sthuthi A of the Department of ECE and Mr. Naveen K of the Department of Physics of NMIT took initiated as Faculty Coordinators for organizing such a wonderful event.

3

Institute for Smart Structures and Systems (ISSS) Team Visit to Central Manufacturing Technology Institute (CMTI)

A team from Institute for Smart Structures and Systems (ISSS) consisting of Dr. V. K. Aatre, Dr. Kota Hari Narayana, Dr. Vidyashankar, Dr. Ananthasuresh, Dr. Veda Sandeep Nagaraja, Dr. Anjana Jain, Dr. Natarajan visited CMTI on 29th Dec 2022. The team had a discussion with Dr. Nagahanumaiah, Director, CMTI and visited the Sensor Technology Development Centre (STDC) and Centre for Smart Manufacturing, Precision Machine Tools and Aggregates (C-SMPM) at CMTI. CMTI – STDC highlighted the state-of-the-art laboratory established for Sensors Technology Development. The delegates visited the cleanroom facilities for sensor fabrication, packaging and characterization. The team discussed on possibility of conducting a hands-on workshop

During the ISSS Team Visit to Central Manufacturing Technology Institute (CMTI), Bangaluru

for semiconductor packaging. CMTI-SMDDC has demonstrated smart manufacturing initiatives at CMTI on various activities related to Smart Factory establishment, CMTI Low-cost IIoT implementations, research & developmental projects like Digital Twin, smart foundry, training & skilling initiatives. Dr. Kota Harinarayana, Dr. VK Aatre and other IISc professors were impressed with the CMTI initiatives on Smart Manufacturing. As CMTI is working on emerging technologies, Dr. Kota Harinarayana & Dr. V. K. Aatre suggested CMTI collaborate with IITs to get more enthusiastic students to work on real-time case studies and contribute to the nation's progress on emerging technologies. Dr. Kota Harinarayana and Dr. VK Aatre suggest that CMTI work towards using their sensors fabricated by CMTI for smart manufacturing applications. It would help in sustainability and greatly benefit the Indian industries. Dr. Kota Harinarayana said IIT BHU would be interested in working with CMTI.

4 The ISSS in IEEE Applied sensing conference (APSCON 2023)

The IEEE Applied sensing conference (APSCON) 2023 was held from 23rd January to 25th January 2023 in Bengaluru. ISSS was designated as the platinum sponsor as per the rules of the IEEE Sensors Council. The ISSS members helped in planning the sessions, served as track chairs, reviewed papers, and helped in fund raising. There were over hundred talks and fifty posters presented at that conference during a period of three days, which covered different research areas in the field of sensors and applied sensing, which fall in line with the areas of interest to ISSS. Along with the talks, the conference included demonstrators, a start-up summit, panel discussions, and a networking session for young professionals to find mentors. Prof. G. K. Ananthasuresh, the immediate past President of ISSS, was the Agri-sensor track chair. The Agri-sensor track had several papers presented over the three days. Dr. Vidyashankar Buravalla, President of ISSS, was the in-charge of Day 2, which was on 24th January, for the industry day sessions. There were several industries including GE Healthcare, Applied

materials, Continental, etc. As a part of the industry day, several parallel tracks on infrastructure, health care, and aerospace were arranged. There was also a session on standards for sensors, which was well attended. The industry day also had a Start-up summit, where about five start-ups presented their journeys. The event was followed by a panel discussion on Challenges of transition of ideas to Start-up and beyond with them. The audience participated well in this event by interacting during the panel discussion. The conference also had a Women In Sensors (WiSe) and Young Professionals (YP) session. Dr. Veda Nagaraja, Member Secretary of ISSS, was the co-chair of WiSe session. As a part of this, a Big Idea Pitch competition was held and four participants, who pitched an idea, were awarded a cash prize of $400 each. The WiSe and YP session also included a panel discussion on Current and Future trends in Applied Sensing. There were five panellists from across the globe and also different areas of applied sensing. ISSS also had a stall at the conference that was looked after by ISSS volunteers Mr. Chandrashekar L.N., Mr. Amruth Pawar, Mr. Micheal John Bosco, and Dr. Maligi Anantha Sunil. The stall gave an opportunity for ISSS to showcase its activities. ISSS would like to thank IEEE Sensors council for including ISSS in this event. ISSS is grateful to all the volunteers, speakers, and delegates who accepted our invitation and participated in this event. ISSS had a discounted registration rate of INR 7500. ISSS sponsored the registration of seven people and ISSS also had five complementary registrations. Over all approximately thirty five ISSS members attended the conference.

5

MEMS Community Chip: An initiative to think MEMS beyond just simulation.

Dr. Sripadaraja. K
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The ISSS has initiated in-house community chip activity through an Indian start-up InFab Technologies Pvt. Ltd. incubated at CeNSE in the IISc campus, Bangalore. The goal and vision of this activity is to encourage and support MEMS design engineers in academia to prototype their MEMS device design and support them beyond numerical analysis. First, we should understand that MEMS device development is an interdisciplinary activity (engineers from various disciplines such as mechanical, electronics, material science, chemical, life science are involved) and as MEMS design engineers, it is important to understand the processes involved in the MEMS device development to a greater extent if not in detail. This will enable to build a team and choose our playing field to harness each of our capabilities in the team. The MEMS device design is usually aimed towards a target application. The initial design is made to suite the requirements approximately. It is further optimised. When a design is viewed beyond simulations, it is important to design the device based on the design rules of the targeted foundry. Multiphysics simulations of various 3D models are designed and simulated with a required mesh size in-view of optimising the device. In such cases, the structural parametric simulations help to save a lot of time in design optimisation. Once the design is finalised through the numerical analysis, it is fabricated. The MEMS device fabrication can be done using the standard recipe (process flow) called the Multi-User MEMS Process (MUMPs) or custom recipe. The MUMPs processes are generally more reliable and produces a better yield with minimal number of iterations as the process is standardised. However, the custom recipe demands more iterations for achieving a better yield. In usual practice, as devices are fabricated and tested, the results are plotted in-comparison to simulation and or theoretical results. It is one of the major milestones. In view of commercialising the MEMS device, it is important to know the technology readiness level (TRL). At this stage, it is at 4 (market ready product will have TRL level of 9 in the scale of 1-10). Hence, progressing beyond this stage (TRL 4) is important. This can be achieved with field trials and recording the device-responses in real-time case. It is cumbersome to depend on a sophisticated lab instruments always for such filed trial, and hence this dependence is not always advisable. Therefore, a handy alternative of this constraint is to interface the device with electronic circuits.

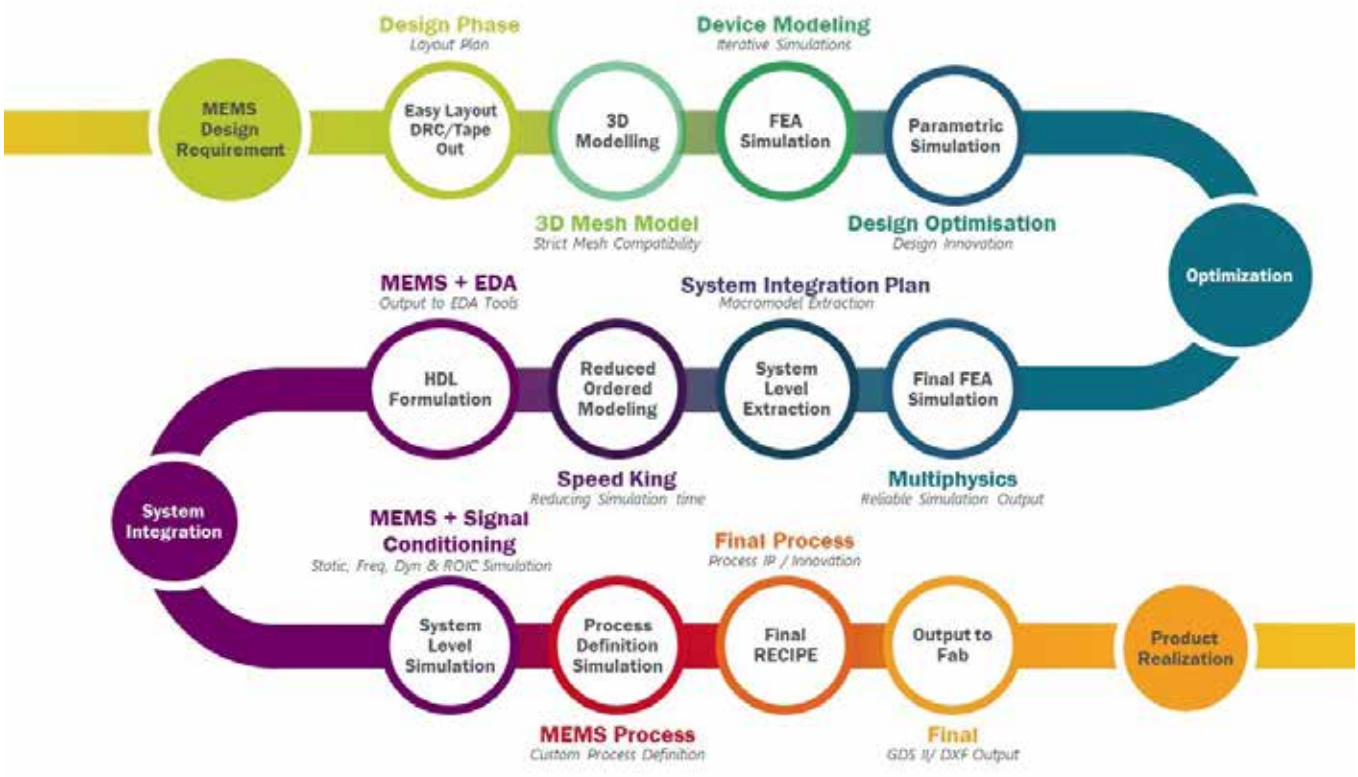

Figure 1. The process-flow illustrating the MEMS design requirement, design optimization, system integration and product realization

Typically, MEMS devices produce low amplitude signals and noises are complimentary. These signals must be processed at various stages such as, signals are to be amplified, noises to be filtered, data to be compared, signal to be converted to digital equivalent to produce data in readable format. Typically, MEMS software can help in designing and interfacing circuits for these MEMS devices. Commercial MEMS devices typically look like an Integrated Chip (IC). It contains the sensors and an IC inside, which processes the signal from the sensor. Therefore, to reach the global market, it is important to build an Application Specific Integrated Circuit (ASIC), which is also called as the Read-Out Integrated Circuit (ROIC). There are Electronic Design Automation (EDA) software tools, which can be used to build such interfacing electronic circuits or ASIC. Interfacing a MEMS design with the EDA tools can be achieved through reduced order model simulations in MEMS software. The behavioural MEMS model goes as a black box in EDA tool and an interfacing circuit/ASIC can be designed and developed. The layout generation of the final ASIC is done and subsequently, the associated CMOS process recipe is developed and finally fabricated. This is another milestone. The integration of the MEMS device with the ROIC/ASIC is made using the wire bonding technique. Finally, the two devices (MEMS and ROIC/ASIC) are hermetically sealed using the standard packaging methods and released to the market.

6

Graphene in Supercapacitor Electrodes

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The ever-emerging industrialisation has necessitated the development of clean, green, and sustainable energy sources globally. The discovery of graphene in 2004 has spawned research in various fields, including energy storage devices. Graphite, the precursor for synthesising graphene, renders sustainability to the application based on this material. Graphene is a 2-dimensional single-sheet derivative of graphite. A few inherent properties of graphene include high electrical and thermal conductivity, flexible structural morphology, exceptional mechanical strength, high specific area (SSA) and low bandgap. The oxidised derivative of graphene is graphene oxide (GO) with a tunable bandgap of 1-3.5 eV. Further reduction of GO results in the procurement of reduced graphene oxide (rGO). The decrease in the oxygen-containing functional groups in rGO restores the π-conjugation in the system, ultimately increasing the conductivity and decreasing the band gap. The chemical structure of graphene, GO, and rGO are shown in Figure 1.

Graphene-based materials are excellent electrode materials for supercapacitor electrodes. The specific capacitance (C) of a supercapacitor is directly dependent on the SSA and shows inversely on the distance between the electrodes, i.e.,

$$C = \frac{SSA}{d} \qquad (1)$$

where d is the distance between the two electrodes. A supercapacitor device is an energy storage device with high charge-discharge rates. Supercapacitor devices can broadly be classified into electrical double-layer capacitance (EDLC), pseudocapacitor and hybrid capacitor. Carbonaceous materials like graphene, CNT, activated carbon, etc., are used for EDLC electrodes. The energy storage involves an electrostatic charge storage mechanism, thus resulting in high power density values (P). Conducting polymers and metal oxides are used in pseudocapacitors-type electrodes. The energy storage mechanism in this type involves Faradic charge storage rendering high energy density (E) values. The third is the hybrid capacitors, where the materials of the EDLC and pseudocapacitor types are combined to form electrode materials. The synergistic effect of the EDLC and pseudocapacitors type materials results in high values of E and P. The EDLC-type materials provide stable morphology and electron transfer path in the combined material. The efficiency of a material as a supercapacitor electrode material

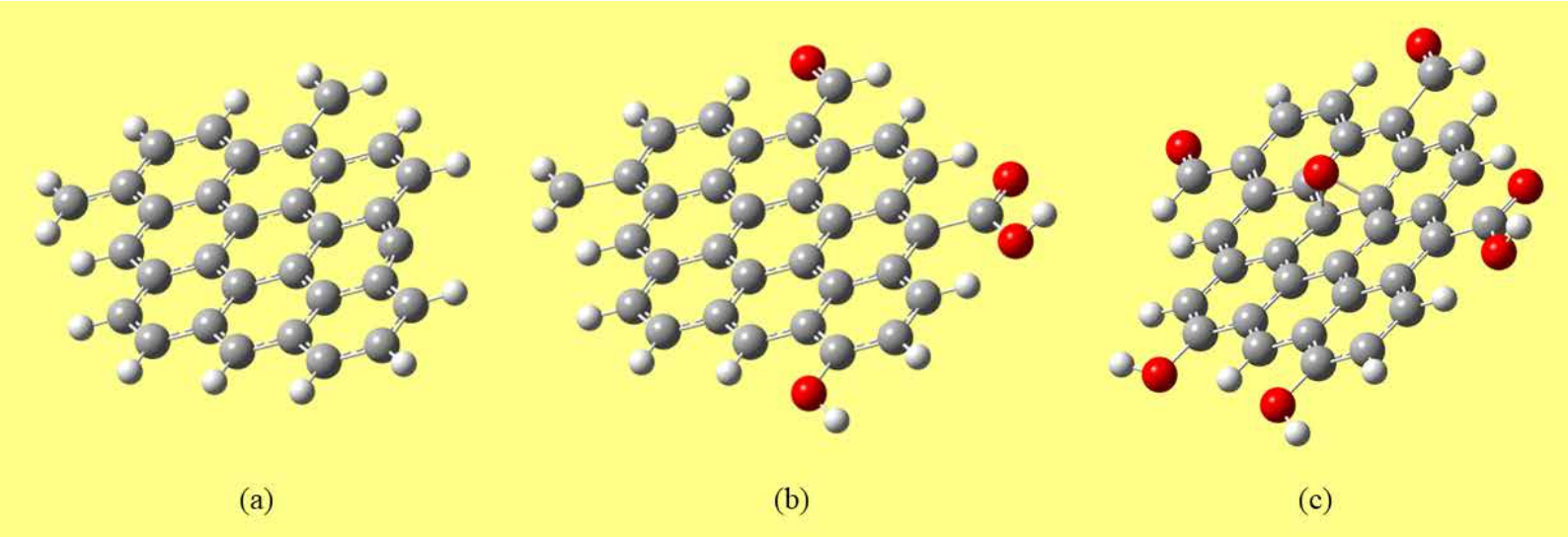

Figure 1: The chemical structure of: (a) graphene, (b) GO and (c) rGO.

is determined by its electrochemical properties. These properties can be determined using C, E and P values. E and P are the ability of energy storage and energy transfer rate to other devices, respectively. The following Eq. (2) determines the C of material through cyclic voltammetry curves.

$$C_s = \frac{\int_{V_1}^{V_2} i dV}{v \times m \times (V_2 - V_1)} \qquad (2)$$

In the equation, the following terms are defined as: $\int_{V_1}^{V_2} i dV$ = integrated area of the curve, m = active mass of material, V_2 and V_1 = high and low potential of the CV, V = scan rate (Vs^{-1}), C= specific capacitance (Fg^{-1}). The values of E, in ($Whkg^{-1}$) and P, in (Wkg^{-1}) can then be determined using the following equations (3) and (4):

$$E = \frac{(C_s \times \Delta V)}{2} \times 3.6 \qquad (3)$$

In the equation, ΔV is the potential change,

$$P = \frac{E \times 3600}{\Delta t} \qquad (4)$$

In the equation, Δt is the discharge time (s).

7

Research and Career Opportunities at National and International Institutes: Tyndall National Institute at University College Cork

Tyndall National Institute at University College Cork (UCC) is one of Europe's leading deep-tech research centres in integrated ICT hardware and systems, and the largest facility of its type in Ireland. They specialise in electronics and photonics - materials, devices, circuits and systems. Tyndall hosts the only full silicon CMOS, micro-electro-mechanical systems (MEMS) and III-V semiconductor wafer fabrication facilities and services in Ireland. Tyndall is a multidisciplinary research community of over six hundred researchers, engineers and support staff of fifty-two different nationalities including more than one fifty full-time postgraduate students. The Institute's total annual budget is competitively won from national research funders, EU Programmes, the European Space Agency and from industry collaborative projects. At Tyndall, they deliver research and innovation in Europe with local and global impact. Tyndall operates under a unique agreement between the Irish Government and UCC.

Tyndall National Institute at University College Cork

Working inside the lab of Tyndall National Institute at University College Cork

The agreement defines the primary role of Tyndall as, providing a national focal point for excellence in deep-tech research, developing graduate trainings at the convergence of micro & nano electronics, photonics, materials, circuits and software, with the objective of having a significant impact on economic development and societal challenges in Ireland. Whether a person will graduate shortly or is an experienced professional, Tyndall National Institute has opportunities for everyone. They offer research and engineering positions and postgraduate opportunities across a wide range of science and engineering disciplines. They also offer a variety of professional support positions across a wide range of disciplines. Tyndall's ambitious 2025 strategy means that they want to attract, support, nurture and enable people to fulfil their potential within a culture of inclusivity, creativity and entrepreneurship. Tyndall takes an active role in developing its staff and facilitating the fulfilment of their career goals. More details on what we do can be viewed on our website.

Tyndall National Institute - Excellence in ICT Research

The Clean room facility at Tyndall National Institute at University College Cork

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