NUS National University of Singapore

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Newsletter of Engineering Science Programme

Message from New ESP Director, A/Prof Anjam Khursheed

Changes in ESP

It is my pleasure to take over from Professor CM Wang as Director for the NUS Engineering Science Programme (ESP) starting January 2017. Professor CM Wang was director of ESP from Jan 2008 to December 2016, and I would like to place on record, heart-felt thanks on behalf of all our ESP team for his enthusiastic leadership, efficient yet open style of management over the last 8 years. Professor CM Wang, thank you for all the great services that you have rendered NUS ESP, we will miss you.

There are many changes occurring in ESP at this time. One piece of good news is that we have received full EAB accreditation for the next 5 years. Our programme was examined by an international panel of experts, and we passed with flying colours! Heartfelt thanks for all those who helped in the accreditation exercise over the last one to two years. The EAB feedback is that our programme is in a very healthy state, more on the EAB report is given on *page 3* in this Pulse issue.

Another major change to our programme is in the new management structure. ESP is now co-owned and supported by the three host departments of Physics, Electrical and Computer Engineering, and Mechanical Engineering. This is different from the previous arrangement where ESP was managed more directly by the Science and Engineering Deans. All our academic staff are pooled from these new host departments. While the day to day running of ESP is expected to continue as normal, policy decisions will now be made jointly together with the heads of our three host departments. Staff teaching duties and the running of labs will be coordinated together. One opportunity of this new management arrangement is to redesign ESP so it is better able to supply MEng/PHD students to our host departments. Another line of development is for us to develop joint labs, creating a greater variety of cutting-edge multi-disciplinary hands-on projects. I will be exploring these kinds of opportunities in the months ahead.

The Mission of ESP

The Engineering Science Programme (ESP) was launched in April 2006 as a flagship educational initiative from the faculties of Engineering and Science at NUS. The main mission of ESP is to prepare students for careers in Research and Development, whether be it in industry or academia. The programme aims at combining strong science fundamentals with cutting edge engineering applications, so that ESP graduates can effectively contribute to solving the many complex multi-disciplinary challenges of our time, such as problems in communication, transportation, energy production, health, security, and environmental pollution.

Job Opportunities with an ESP degree

According to a recent Ministry of Education surveys, our ESP graduates have relatively high starting salaries [1]. There is currently, a great demand for all kinds of engineers. Beyond the traditional engineering disciplines, such as civil, electrical, mechanical, chemical, industrial, engineering is rapidly growing in new fields, such as medicine, biology and the environment. All are needed, and there are plenty of jobs to go round. Our Engineering Science graduates have been successful in finding jobs in a wide-variety of different ways. Some find jobs in traditional engineering disciplines, such as electrical power distribution. Others go to the newer high tech multi-disciplinary industries, companies in alternative energy technologies (eg, solar cells), in medical, communications and semiconductor industries. Quite a few ESP graduates have found jobs with government research centres such as DSO and A*STAR research institutes. A significant number of ESP graduates have started up their own companies, and many have gone on to do further studies, both in Singapore and prestigious universities such as Harvard university and MIT. Our graduates have found jobs in a wide variety of places.

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Prospective ESP students should bear in mind that employers take into account many factors when deciding whether to employ a university graduate, beyond which courses he or she has studied. Since the cohort size of ESP is deliberately kept small (limited to approximately between 30 to 50), the programme has built up a closely -knit team of high quality academic staff, ESP students receive a lot of personal attention, and this helps them have greater hands-on experience and develop their own individual passion and interest. ESP students will receive an ungraduate education that is strong in the following areas.

First-hand experience and a hands-on education

An employer will ask students about the hands-on things that they have done, the things that are in their first-and experience. Employers can easily tell the difference between **second-hand** knowledge and **first-hand experience**. They will ask students about their projects, they will generally not ask too much about specific courses and grades.

Passion and interest

Employers want to have employees who are passionate and interested in what they do. Passion and interest is the most secure strategy for a successful career, students should take the time to develop passion and interest in a field of study during their university career.

Strong scientific fundamentals

In a landscape of fast changing technologies, it is very important to be strong in scientific fundamentals. This is essential if you intend to work in the R&D sector, this is often required in order to innovate in engineering.

A multi-disciplinary approach

More and more employers these days are requesting for a multi-disciplinary education. Graduates must be prepared to be more flexible in what they can work on, graduates are now expected to change jobs several times during their careers. Also, engineering devices and products are becoming more and more multi-disciplinary in character, and confidence/ experience in several different disciplines is very much appreciated by employers.

Engineering Science Programme and STEM

The acronym, "STEM", which stands for Science, Technology, Engineering and Mathematics is becoming increasingly used in the fields of education and the job market. It was first used in the context of developing a broader type of primary/secondary school education in the US [2], but is now widely used in the context of highlighting the kind of education graduates need in order to be prepared for the future.

In a speech made by Prime Minister Lee Hsien Loong on 8th May 2015, he stressed that in order to develop its economy and to become a modern and technologically advanced society, Singapore will need to grow its talent and capabilities in the fields of Science, Technology, Engineering and Mathematics or STEM. He said: "... For the next 50 years, we need strong STEM capabilities to be what we should be – a vibrant, exciting, advanced society. Recently I launched the Smart Nation programme to make Singapore a nation where technology and innovation strengthens our community and society, and enables people to live meaningful and fulfilled lives. There will be many opportunities for STEM graduates to make your mark and shape how we live, work and play. We are also upgrading our living environment – building greener homes, connecting our waterways and parks, expanding our public transport networks, embarking on complex engineer projects like the High Speed Rail link between Jurong East and Kuala Lumpur. All these require expertise and skills in engineering, technology and design." [3]

The Engineering Science Programme at NUS is focused on providing a hands-on engineering multi-disciplinary "STEM" type of education that is founded on strong scientific/mathematical fundamentals. There are clear indications that a graduate with this kind of education will do well in the job market now and for the foreseeable future.

[1] https://www.moe.gov.sg/docs/default-source/document/education/post-secondary/files/nus.pdf

[2] http://whatis.techtarget.com/definition/STEM-science-technology-engineering-and-mathematics

[3] http://www.pmo.gov.sg/newsroom/transcript-prime-minister-lee-hsien-loong-speech-sutd-east-coast-campus-opening-8-may

ESP Receives International Accreditation for the next 5 years (2016-2021)!

Our programme has officially received the news that it will be accredited for the next 5 years. The Evaluation Team of the Engineering Accreditation Board (EAB) of the Institution of Engineers, Singapore (IES) conducted a 2-day accreditation on-site visit to assess the Bachelor of Engineering (Engineering Science) program on 18th and 19th October 2016 against the criteria set out in the EAB Accreditation Manual. The result, ESP has passed with flying colours. The EAB summarised their report as follows.

Main strengths:

- The mission and programme educational objectives of the Engineering Science program are periodically reviewed based on discussions with ESP's Industry Advisory Committee.
- In addition to the above, the SLOs and MLOs are periodically reviewed for improvement.
- Staff and ESP Associates show great enthusiasm and passion for teaching and conducting hands-on experiments.
- The student intake profile is good – attracting many good students primarily from both the Junior Colleges and overseas with equivalent qualifications.
- The academic qualifications of the ESP associates are of high standard and their resources are supplemented by postgraduate students from their respective departments.
- Teaching quality assurance is achieved via student feedback and a detailed review of teaching and examination results at the end of each semester

Area for Improvement

We recommend the cross-disciplinary aspect of the program be more clearly articulated to the students.

THE INSTITUTION OF ENGINEERS, SINGAPORE

CERTIFICATE OF ACCREDITATION

This is to certify that in February 2017

The Institution of Engineers, Singapore
through its Engineering Accreditation Board

has granted Accreditation to the Degree Programme for

Bachelor of Engineering
(Engineering Science)

conducted by

National University of Singapore

for graduating class in academic years 2009/2010 to 2020/2021

Er. Edwin Khew
President
The Institution of Engineers, Singapore

Er. Ong See Ho
Chairman
Engineering Accreditation Board

The Institution of Engineers, Singapore is a Signatory to the Washington Accord.

This report is an international recognition of the high quality of our programme, with particular emphasis on the "enthusiasm and passion" of our academic staff for "hands-on experiments". There is only one minor weakness mentioned, which can be easily corrected. Congratulations are in order for the whole ESP team, especially to those academic/support staff directly involved in the accreditation exercise. Special thanks go to the ESP accreditation committee, consisting of Profs CM Wang, A. Khursheed and E, Birgersson, with inputs from J. Shailendra and J. van Kan. Also to the support staff who gathered information and helped compiled the final report, Violet, Priya, Anna and our ESP alumnus, Kwok Hoe.

A Revolutionary Renewable Air Treatment System to Enhance Energy Efficiency for Singapore's Buildings

by A/Prof Ernest Chua

Is it possible to develop and engineer a totally sustainable renewable system to address the challenges of Singapore's buildings indoor air quality during the annual BAD Haze season while reducing energy consumption for Heating Ventilation and Air Conditioning?

At the Mechanical Engineering Department and Engineering Science Programme, NUS, we have developed a revolutionary air treatment system (ATS), employing renewable resources, to reduce energy consumption of any Air Conditioning Mechanical Ventilation (ACMV) systems by up to 30% and markedly improve Indoor Air Quality (IAQ). This ATS is truly a "game-changing" solution to significantly improve energy efficiency of ACMV systems for existing and new buildings. It entails an innovative state-of-the-art air treatment system (ATS) to treat buildings' recirculated and supply air. It reduces the needs for large-volume outdoor air intake while providing the highest IAQ. It further enhances heat exchange at air handling unit (AHU) and consequently reduces energy consumption due to chilled water cooling.

The ATS comprises an ozone generation system is capable of dualistic function of air treatment and cleaning of chilled water heat exchanger. It has evolved an integrated "plug-and-play" game-changing ATS that can be tailored (based on building's needs and constraints) and easily retrofitted to any new or existing ACMV systems to realize immediate improvement in energy efficiency and human thermal comfort with added health benefits coming from enriched oxygen Levels in the supply air. It is also noteworthy that this research has pushed the boundary of science in its focus to developing cheap means but highly energy-efficient and sustainable oxygen production system and ozone-air treatment processes. The entire ATS is highly sustainable since it employs solar irradiation, PV panels and rain-water to produce oxygen which converts to ozone for treating pollutants (such as VOC, formaldehydes, benzene, radon, asbestos) and enrich the supply air with higher oxygen content. Besides, air treatment and enriching the supply air with oxygen, the CO_2 from occupants is judiciously managed through highly active CO_2 scrubbing agents coated on membranes.

The developed ATS presents a leap forward in energy-efficient ACMV technology. It will contribute towards Singapore's targets and goals of improving energy efficiency through better indoor air quality and reduced outdoor air intake. The technology could also have applications beyond buildings' ACMV. For example, health care centre that requires oxygen enriched air for patients' recovery; the compact plug-and-play system can be integrated to any existing ventilation to allow more widespread application of enhanced IAQ. The ATS could also be applicable in Bringing high-quality treated air to underground military bunkers.

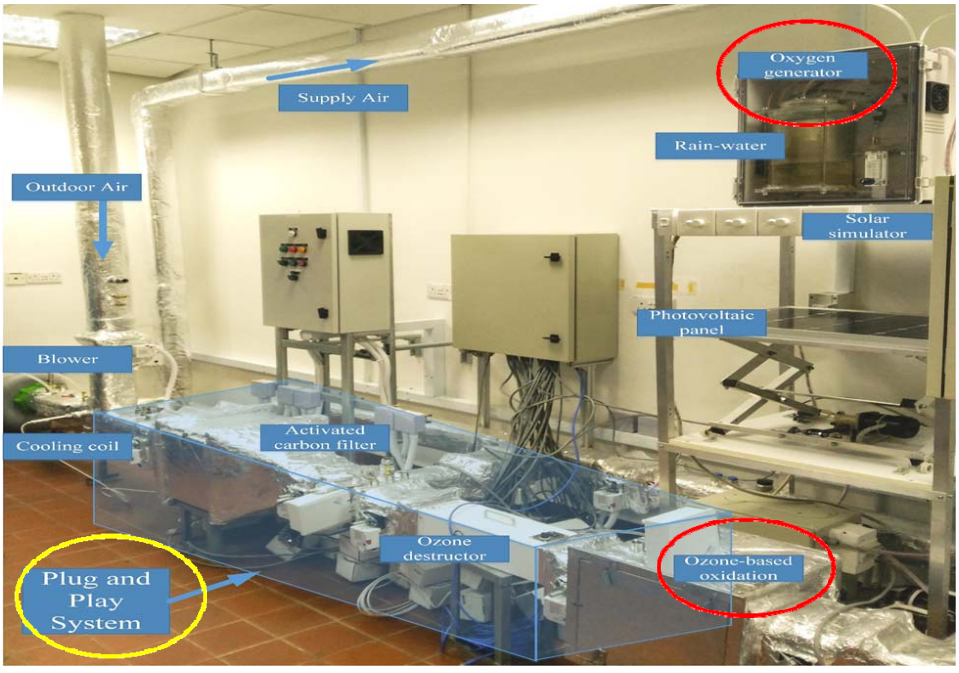


Figure: A pictorial of the PLUG-&-PLAY air treatment prototype incorporating renewable energy (sunlight, PV & rainwater) for ozone generation.

This project will contribute significantly to energy-savings and IAQ enhancement in particular adept during a period when Singapore faces periodic bad haze situations and when existing plans are in place to consider future under-ground residency.

"A/P Chua gratefully acknowledges the generous funding from the National Research Foundation Singapore under the Energy Innovation Research Programme Funding Scheme (R-265-386 000-515-279) managed on behalf by Building and Construction Authority."

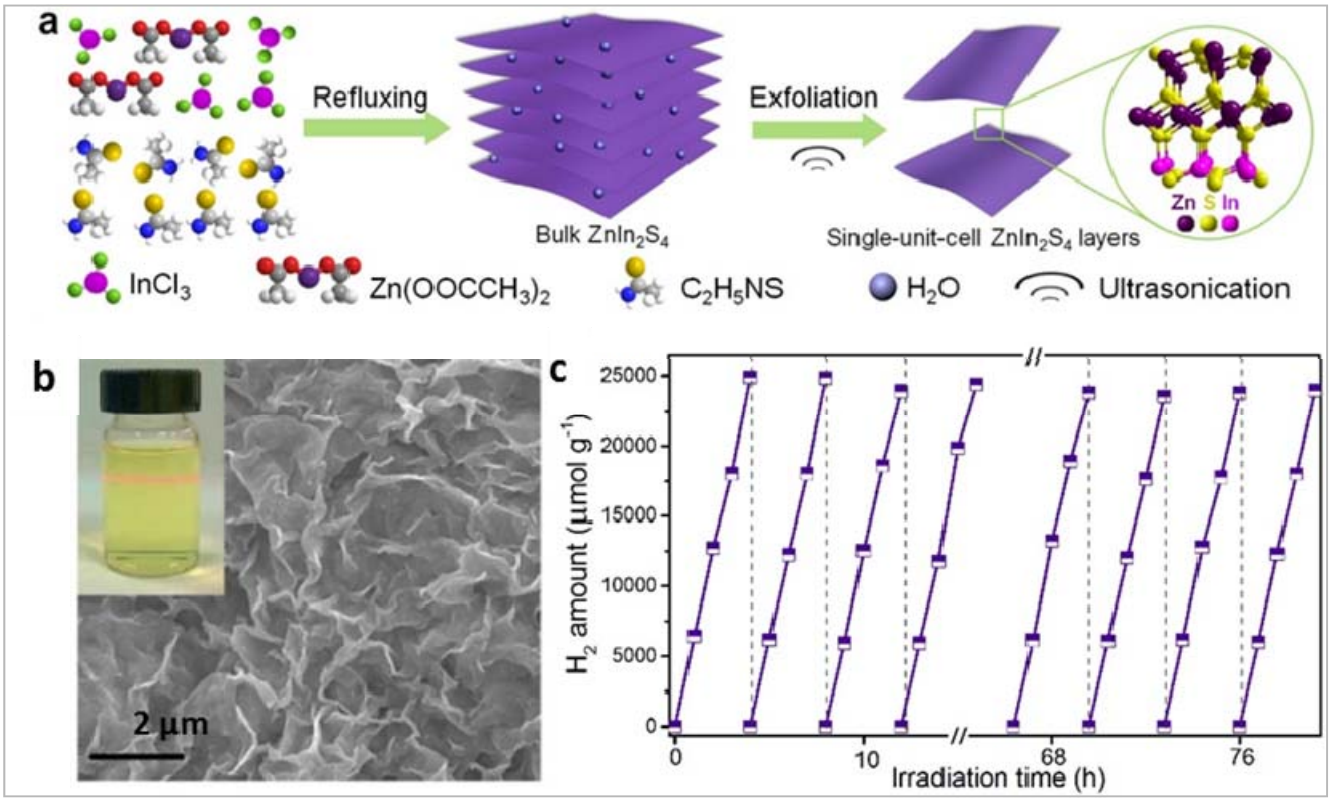
Nanoscale Engineering of 2D Materials for Clean Fuel Energy Harvesting

By A/Prof Ho Ghim Wei

At present, technological groundwork of atomically thin 2D hetero-layered structure realized by successive thin film epitaxial growth is in principle constrained by lattice match prerequisite as well as low yield and expensive production. Here, we have readily exfoliated *metal chalcogenide* semiconductor, $ZnIn_2S_4$ into single-unit-cell layered structure (ca. 2.5 nm) via self-surface charge exfoliation in pure water medium. Successive electrostatic coupling with other *transition metal chalcogenide (e.g.,* $MoSe_2$) enables construction of arbitrary ultrathin hetero-layered hybrids in a large-scale. Such approach offers salient features, i.e. independent thickness and composition control of individual layer assembly, unconstraint by lattice matching prerequisite into functional ultrathin heterostructures. Distinct emission lifetime reduction and photoluminescence quenching of the hetero-layered hybrid ascertain strong interlayer coupling and efficient charge transfer. Correspondingly, surface and interfacial -dominated photocatalysis, a promising way for solar energy conversion, is adopted to demonstrate the reliability of the catalytic rich 2D ultrathin $ZnIn_2S_4$/$MoSe_2$ hetero-layered material.

The ultrathin $ZnIn_2S_4$ nanosheets can significantly shorten the charge carrier transfer distance and inhibit charge recombination. Meanwhile, the few-layer $MoSe_2$ considerably decrease the activation energy/ overpotential of water reduction and provide rich catalytic H_2 evolution sites. Therefore, the $ZnIn_2S_4$/$MoSe_2$ hetero-layered composite is expected to concurrently realize efficient separation and transfer of photogenerated charge carriers, acceleration of surface proton reduction with abundant active sites as well as enhanced visible light absorption, which circumvent the limitations of conventional photocatalyst. Consequently, the $ZnIn_2S_4$/$MoSe_2$ displays high-performance visible-light-driven H_2 evolution activity approximately 15 and 4 times higher than that of bulk and bare $ZnIn_2S_4$ nanosheets, respectively. Importantly, the 2D hetero-layered hybrid shows high stability with prolong cycling and remarkable catalytic reactivity retention over a few months which further attest the integrity of the constructed 2D materials for prospective advanced applications. Furthermore, we tested the applicability of this approach on other 2D metal sulphides, namely $CdIn_2S_4$ and In_2S_3 which also shows scalable self-surface charge exfoliation. Similarly, the constructed hetero-layered hybrids of $CdIn_2S_4$/$MoSe_2$ and In_2S_3/$MoSe_2$ testify enhanced photocatalytic activity and stability.

This work is published in Nature Communications 8, 14224, (2017) authored by Yang M-Q, Xu Y-J, Lu W, Zeng K, Zhu H, Xu Q-H, Ho G. W.



a) Schematic illustration of the synthesis of single-unit-cell $ZnIn_2S_4$ layers. b) Scanning Electron Microscopy image of the $ZnIn_2S_4$ nanosheets (inset: digital photograph of the colloidal product). c) Photocatalytic H_2 production of the $ZnIn_2S_4$ nanosheets.

A Graphene Coated Ring Cathode Electrode Gun for Ring Electron Beam Lithography

by A/Prof Anjam Khursheed

An important challenge facing the microelectronics industry today is how to continue the trend of making integrated circuit features smaller and smaller. One way to do this would be to use focused electron beam technology to define and write patterns on a semiconductor, a method called Electron Beam Lithography (EBL). Unlike photolithography, the resolution of EBL is not restricted by wavelength. On the other hand, EBL is relatively slow compared to the photolithography. The problem is that it takes time to move the electron beam from place to place, it must in some way be scanned. The great advantage of UV lithography is that it exposes an entire image of patterns at one time. EBL is typically over a thousand times slower than photolithography. One way to overcome this limitation is use a shaped electron beam, one that is shaped to a desirable pattern, such as a circle or ring.

All electron guns at the moment consist of a point cathode, this means the beam needs to be scanned in order to define a pattern, but what if we break with tradition, and emit from a ring shaped cathode directly? This could then, in principle, directly write ring patterns on the integrated circuit, greatly speeding up electron beam lithography. This is precisely what has been achieved by the research group working under ESP director, Anjam Khursheed [1]. For the first time, successful electron emission from a ring-cathode cold field emission electron gun has been obtained using a method of coating sharpened nickel wire with graphene, as shown in Figure 1. These promising results have the potential to revolutionize the subject of EBL and make it much more competitive.

Acknowledgement: this research was funded under the National Research Foundation (NRF) Competitive Research Programme (CRP) award # NRFCRP13-2014-04 titled "Micro-fabricated Ring Carbon Nanotube electron/ion sources.

[1] X. Shao, A. Srinivasan, Y. Zhao, and A. Khursheed, Carbon 110, 378 (2016).

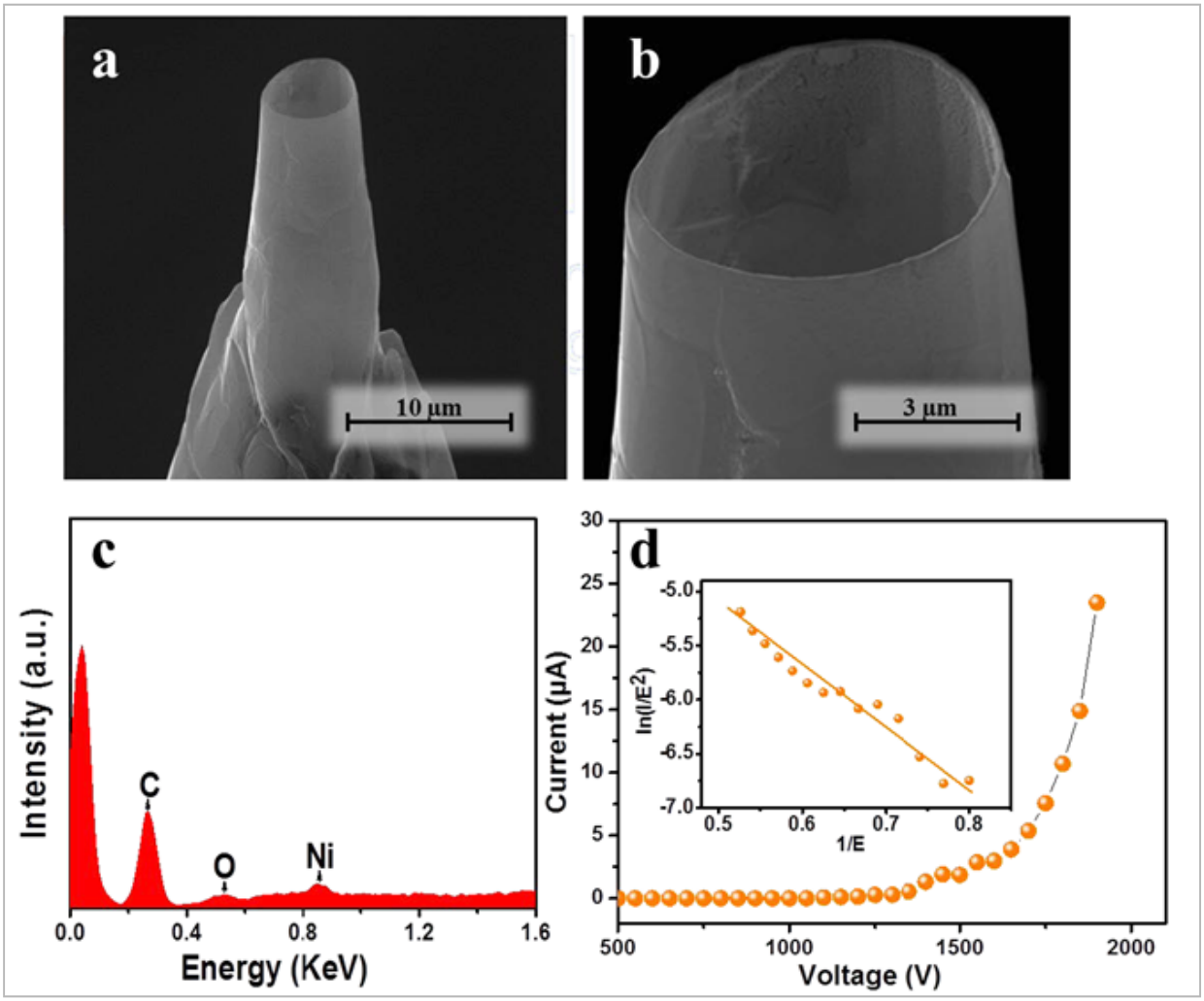


Figure 1: A graphene ring-cathode field emitter (a) SEM image of a Ni-nanoparticle enriched graphene microtube structure. (b) High magnification SEM micrograph of the ring-cathode. (c) EDS spectrum acquired on the surface of the fabricated structure. (d) Field emission I-V curve obtained from the Ni-GRC emitter (inset shows the F-N plot).

Thank You ESP!

Reported by Anna Robinson

A few International students from Engineering Science Programme put their heads together to publish their views on ESP studies in Singapore. In their own words some of the students bring to life their dreams, expectations and aspirations gained through this new environment with double edged Undergraduate Programme.

After two years of study in Engineering Science Programme, I personally think that ESP has truly given me and my friends' ample opportunities to explore and improve! I am glad I am able to take up modules from various engineering and science courses. This I feel will enhance and broaden my knowledge. I feel very confident in understanding and carrying out the multi-disciplinary projects without much difficulty. As an international student, I get to know my course mates better as we interact together both at our residences and at the University in small class sizes. I also realized we get close proximity to our ESP lecturers who are experts in their own field and hence an opportunity to learn a lot from them straightaway. I must mention they are friendly, helpful and truly mentor to guide me along the fascinating journey here.

..... *Fang Zhihao of Yr 2.*

As a science student who is passionate about frontier technologies, I feel that ESP is undoubtedly the best Programme I could choose in Singapore. The hardest and most pressing engineering problems in the world often require solutions which involve multiple fields, and the multidisciplinary nature of the ESP curriculum allows me to acquire a large knowledge base to deal with the issues I am interested in. More importantly, I have become a independent learner and developed a love for science and engineering.

..... *Zhang Ji of Year 2*

My international experience as a Malaysian student from Johor Bahru (not far from Singapore), I must admit I got a firsthand probe into the different aspect of Engineering and Science combination studies through this competitive learning environment. Some projects were very difficult and time consuming but the ends were certainly rewarding. Luckily for me, I could go home every weekend to unwind as against my other international friends, so much so I used to think I am in a boarding school rather than studying abroad:) I did

in a boarding school rather than studying abroad. I did learn quite a lot of Hokkien from my Singapore friends friends as they use them quite often. Overall I made good progress and positive strides in my studies here.

The unforgettable memories gathered here is precious and I am looking forward to more of them! ESP has surely taught me to become more self-reliant and now I feel very confident that I will succeed on the global scene!

.....*Stella of Year 3*

ESP has been not been an easy Programme for me where we were tasked with learning scientific concepts while simultaneously applying them to engineering scenarios. But as curious students, we did realise our inherent capabilities surfacing as we were constantly being pushed to overcome boundaries we thought we could not cross! The close-knit community of students has been a great support and this is my expression of gratitude to my fellow friends, staff and professors for always being there and believing in us!

..... *Sandeep from Year 4*

As a global traveler, I was enthralled by the idea of moving to Singapore to pursue my university degree. Cultural diversity always fascinated me and I was convinced that my Singapore experience would live up to my expectation. I was not disappointed, the experience has been truly rewarding and fulfilling! I have enjoyed the university setting and have assimilated well into the local environment.

In particular, ESP provided me the platform for easier accumulation of knowledge with a lot of hands on experiences. With a relatively smaller cohort size, I constantly felt guarded and protected by my peers, who never made me feel the absence of home. In these four years, the ESP community that I have become a part of, has served as family and I couldn't be more grateful to the experience and the people who made it all happen.

..... *Anisha from Year 4*

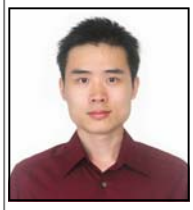
I would like to join the students above to thank Prof Wang, Prof Khursheed, All ESP Associates and my lovely ESP colleagues and students for cooperating and teaming with me to produce ESP Newsletters; PULSE from last 8 years! With this, my last contribution, I proceed to say goodbye to the ESP family as I am retiring soon! THANKS AGAIN and I will miss you and PULSING It was a joy to be a member of this family :) *Anna*

ESP Graduates continue to conquer on the PhD scene to become successful R&D Engineer Scientists!

Following on the footsteps of ESP pioneer graduates, Dr Teoh Hao Fatt (NGS), Dr Zhang Teng (NUS), Dr Liu Licheng (NUS), Dr Siah Sin Cheng (MIT), Dr Danny Chua (Harvard), Dr Wang Pai (Harvard), Dr Wang Ying (NUS), Dr Liu Nannan (NUS) completing their doctorates in 2014, 2015, ESP is proud to announce Dr Kevin NY (Yale), Dr Lim Fang Jeng (NUS), Dr Liu Haohui (NGS), Dr Set Ying Ting (NUS), Dr Feng Jingduo (NUS) and Dr Chun Yu as new set of ESP doctorates in their chosen fields.

Kevin NY's research was in the area of Solar Energy. He is currently working on an energy startup and says he is forward to the transition.

Lim Fang Jeng's research was in the area of Organic Solar Cells. He is currently working at SERIS as research fellow in Solar Energy Systems .



Liu Haohui's research area was in solar energy and solar cells. He says, It was a collaboration project with SMART and MIT and finds it an enriching experience.

Set Ying Ting completed his Doctor of Philosophy in Chemical and Biomolecular Engineering by NUS. He is currently working as a post-doctoral researcher at RWTH Aachen University in Germany.

Feng Jingduo majored in Computation. She hopes to become a Mechanical Resident Engineer for a Multinational Corporation.

Chun Yu completed has graduated in January 2017 in Chemical Engineering @ NUS. He is currently working in the area of Clean energy.

More than 35 ESP graduates are now reading their PhDs in reputed universities and some of them poised to complete in a year or two. Also in the pipeline are some more graduates intending to join the bandwagon!

Happy Chinese New Year

by Liu Xuecong

On 16 January 2017, ESP professors, staff and students gathered together to celebrate the Year of the Rooster with delicious fun games and Lo Hei dinner outside LT7 in the FoE premises.

ESP Sub club members welcomed the guests with much enthusiasm and distributed the traditional CNY oranges and chocolate coins. A/Prof Anjam Khursheed opened the event and wished everyone a joyful evening and A fruitful Lunar New Year!

As games round rolled in, the evening picked up momentum. Lucky guests who found Red Ang Pow packets in their goodie bags were invited to play the darts game. Guests who participated in bingo rounds and won, received vouchers as prizes, Hurray!!!

With the delicious dinner at the end, the celebration came to an end quite abruptly. The sub club president thanked all the ESP family who showed up for the evening and participated in the CNY festivities. Exchange of Lunar New Year wishes and warm fellowship continued into late evening amongst students and some of the staff members .

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