Synthesis of 2D Materials and Related Application

Yu-Ze Chen
Department of Materials Science and Engineering, National Cheng Kung University
yzchen@gs.ncku.edu.tw

DOI: 10.1039/c9ta05348d

Since 2004, graphene was successfully prepared by mechanical exfoliation, people paid intensive attention to 2-dimensional materials. Among a class of 2D materials family, transitional metal dichalcogenides in 2-dimensional was a potential alternative to graphene due to the transition of band structure from indirect to direct. In addition, the atomic arrangement of the transition metal and chalcogen element will be classified into 1T phase of metal properties and 2H phases of semiconductor properties, and importantly the 1T / 2H ratio will be adjusted, benefitting the subsequent applications. Because of the critical role it plays in boosting the performance of devices, scientists have proposed a number of approaches for phases engineering. Our research utilized the oblique-angle evaporation to fabricate two-dimensional materials with nano-structures with controlling the 1T / 2H ratio by tuning plasma power, improve the sensitivity to detect nitric oxide, and even operating it under atmospheric environment.

Figure 1. Time-resolved response upon NO gas with varied concentration.

Figure 2. Response as a function of NO concentration.
An Alternative Proposal of Electronic and Consumer Plastics

Yu Chi Chang
Department of Engineering Science, National Cheng Kung University
christina780712@gmail.com

With the development of economy and technology, the plastic waste is a growing problem. Also, the plastics can be used in electronic components. The toxic chemicals release through burning of electric or plastic waste, due to these wastes commonly contain toxic and halogen flame retardants. To minimize e-waste, hydrogels and cellulosic substrates were used to develop multifunctional green composite materials. Moreover, to reduce bottlenecks in e-development, seven topics are as follows: (1) development of self-healing materials to enhance the performance and lifetime of soft electronics; (2) using self-healing ability to weave and achieve 3D resistive random access memory array; (3) introducing carbon nanotubes into small dimensions of transistors; (4) fabrication high mobility graphene-based transistors without graphene-transfer processes; (5) using hydrogel and graphene quantum dots to design a new type active channel layer; (6) development of nanostructured hydrogels to enhance the sensing properties of sensors; (7) design a super-thin sensor system that can go inside diapers to inform caretakers.

Figure 1. Applications of self-healing hydrogels for different electronic devices.
An Explicit and Scene-Adapted Definition of Convex Self-Similarity Prior with Application to Unsupervised Sentinel-2 Super-Resolution

Chia-Hsiang Lin1*, J. M. Bioucas-Dias

1 Department of Electrical Engineering, and Institute of Computer and Communication Engineering, National Cheng Kung University
2 Instituto Superior Técnico, University of Lisbon

chiahsiang.steven.lin@gmail.com

DOI: 10.1109/TGRS.2019.2953808

Image super-resolution is a fundamental problem in satellite remote sensing and computer vision. Sentinel-2 satellite, recently launched by the European Space Agency, plays a critical role in several Earth observation missions. As the satellite sensor is far away from the target objects, each pixel of Sentinel-2 image corresponds to an area of hundreds to thousands of square meters. For effectiveness of subsequent classification/identification applications, it is necessary to super-resolve the Sentinel-2 image. Unlike conventional 3-band RGB images, one of the most challenging parts is that Sentinel 2 satellite has a total of 13 spectral bands (ranging from visible to invisible regions). More seriously, the spatial resolutions of the 13 spectral bands are different, making conventional super-resolution methods not applicable. Another challenge is that Sentinel-2 is a new satellite, so big data required for training high-performance neural networks is lacking, making the popular deep learning not applicable.

Intelligent Hyperspectral Computing Laboratory (IHCL) proposed a novel unsupervised algorithm, which significantly outperforms the state-of-the-art ATPRK in terms of both reconstruction accuracy and computational efficiency. We achieve so without relying on model training or big data. What we need is just one single Sentinel-2 imaging data, from which we are able to compute the spatial details. How could this be possible?

It is up to the doer to undo the knot. If what missing is some spatial information, let us seek other information from the spatial domain.

The key lies within the highly-structured spatial patches, i.e., the self-similarity widely observed in natural images. Such prior knowledge about the spatial structure will be used to make up for the missing spatial information. As self-similarity was just a concept that had never been mathematically defined, existing machine learning technologies rely on plug-and-play (PnP) when dealing with the induced optimization problem, and such PnP-driven approaches have no convergence guarantee in general.
For the first time, our IHCL team mathematically defined the concept of self-similarity, allowing us to derive closed-form solutions of the involved optimization problems, leading to a fast algorithm. Besides defining the self-similarity explicitly, it is defined as a convex function. Specifically, we formulate the self-similarity pattern as a weighted graph (which can be directly learned from the texture of the input image, thereby enabling a scene-adapted regularization), followed by embedding such graph into a quadratic term. The resultant convexity allows us to design a fast algorithm (with provable convergence guarantee) by employing powerful convex optimization theory. The algorithmic steps involve two types of high-dimensional matrix inversion, which are efficiently computed by exploiting the so-called BCCB structure and sparsity structure, respectively. The general form of our newly defined super-resolution framework also allows us to compute the basis of multi-resolution imagery like Sentinel-2. Comparing to the computation in the color space, such basis enables a more stable computation of spatial details in a low-dimensional eigenspace. Finally, we conclude the article with a seven-word quatrain:

No worry about lacking of big data.
No need to train any neural network.
Just give us a single imaging dataset.
We then compute spatial details for you!

Copyright 2018 National Cheng Kung University
Nanolaser

Timothy Chou
Institute of Electro-Optical Science and Engineering, National Cheng Kung University
tnc@gs.ncku.edu.tw

In recent years, our demand for data processing has been increasing. As a result, the amount of data generated by applications related to data services, such as cloud services and autonomous driving technologies, is expected to multiply in the next few years. The current data transmission in integrated circuits mainly relies on metal wires; however, as the size of semiconductor devices shrinks, the resistance and capacitance delays and energy losses caused by metal wires limit the data transmission speed. Therefore, the use of integrated optical circuits instead of integrated circuits has been considered as a possible solution to reduce energy consumption effectively. Besides, there will be no interaction between photons, and photons of different frequencies can be transmitted in the same channel so that the data transmission speed will be several orders of magnitude faster than that of electronic circuits. Hence, the goal of our laboratory is to develop novel nanolasers that can be electrically driven at room temperature to break through the limitations of fundamental physics.

Schematic chart of Nanolasers with SEM.
Increased Risk for Hypothyroidism Associated with Carbon Monoxide Poisoning: a Nationwide Population-Based Cohort Study

Chien-Cheng Huang1,2,3, Chung-Han Ho4,5, Yi-Chen Chen4, Chien-Chin Hsu1,6, Hung-Jung Lin1,6,7, Shih-Bin Su8,9, Jhi-Joung Wang4,10, How-Ran Guo2,11,*

1Department of Emergency Medicine, Chi Mei Medical Center, Tainan, Taiwan.
2Department of Environmental and Occupational Health, College of Medicine, National Cheng Kung University, Tainan, Taiwan.
3Department of Senior Services, Southern Taiwan University of Science and Technology, Tainan, Taiwan.
4Department of Medical Research, Chi Mei Medical Center, Tainan, Taiwan.
5Department of Pharmacy, Chia Nan University of Pharmacy and Science, Tainan, Taiwan.
6Department of Biotechnology, Southern Taiwan University of Science and Technology, Tainan, Taiwan.
7Department of Emergency Medicine, Taipei Medical University, Taipei, Taiwan.
8Department of Occupational Medicine, Chi Mei Medical Center, Tainan, Taiwan.
9Department of Leisure, Recreation and Tourism Management, Southern Taiwan University of Science and Technology, Tainan, Taiwan.
10Allied AI Biomed Center, Southern Taiwan University of Science and Technology, Tainan, Taiwan.
11Department of Occupational and Environmental Medicine, National Cheng Kung University Hospital, Tainan, Taiwan.

hrguo@mail.ncku.edu.tw

Scientific Reports. 2019 Nov 11; 9(1):16512

Carbon monoxide poisoning (COP) is the common acute gas poisoning across the globe and will lead to hypoxia in organs and tissues in the human body. If the brain and the thyroid gland are damaged due to hypoxia, hypothyroidism might be introduced. However, related epidemiological literature is limited. From Nationwide Poisoning Database in Taiwan, we identified 24,328 patients with COP diagnosed between 1999 to 2012 and selected 72,984 patients without COP who were matched with the COP patients by the index date and age as the reference group. The two groups were followed up to 2013. After adjusting for age, gender, underlying comorbidities (e.g. hypertension, diabetes mellitus, hyperlipidemia, rheumatoid arthritis, or drug abuse, etc.) and income, we found that COP patients had a significantly higher risk for hypothyroidism (adjusted hazard ratio: 3.8) than the reference. COP patients who have diabetes mellitus, hyperlipidemia, or mental illness had particular higher risks for hypothyroidism, and the adjusted hazard ratios were 9.2, 5.2, and 5.5, respectively. In addition, we found that the increased risk was highest in the first month after the patients have been diagnosed with COP, the adjusted hazard ratio reaching nearly 41.0. Furthermore, and the health effect remained a significant impact even after 4 years.
Comparison of the risk for hypothyroidism between patients with and without carbon monoxide poisoning (COP).

<table>
<thead>
<tr>
<th>Variable</th>
<th>COP n = 24,328 case (%)</th>
<th>Non-COP n = 72,984 case (%)</th>
<th>Adjusted Hazard Ratio* (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall analysis</td>
<td>256 (1.1)</td>
<td>191 (0.3)</td>
<td>3.8 (3.2–4.7)</td>
</tr>
<tr>
<td>Stratified analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>13 (0.5)</td>
<td>13 (0.2)</td>
<td>2.8 (1.3–6.0)</td>
</tr>
<tr>
<td>20–34</td>
<td>87 (0.9)</td>
<td>47 (0.2)</td>
<td>4.6 (3.2–6.7)</td>
</tr>
<tr>
<td>35–49</td>
<td>101 (1.3)</td>
<td>63 (0.3)</td>
<td>4.5 (3.2–6.2)</td>
</tr>
<tr>
<td>50–64</td>
<td>36 (1.2)</td>
<td>46 (0.5)</td>
<td>2.5 (1.6–3.9)</td>
</tr>
<tr>
<td>≥65</td>
<td>19 (1.5)</td>
<td>22 (0.6)</td>
<td>3.1 (1.7–5.8)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>216 (1.8)</td>
<td>153 (0.4)</td>
<td>3.9 (3.1–4.9)</td>
</tr>
<tr>
<td>Male</td>
<td>40 (0.3)</td>
<td>38 (0.1)</td>
<td>3.2 (2.0–5.1)</td>
</tr>
<tr>
<td>Underlying comorbidity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>43 (1.5)</td>
<td>36 (0.5)</td>
<td>3.5 (2.2–5.5)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>28 (1.9)</td>
<td>8 (0.2)</td>
<td>9.5 (4.2–21.1)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>37 (1.9)</td>
<td>20 (0.4)</td>
<td>5.2 (2.9–9.2)</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>5 (1.8)</td>
<td>1 (0.2)</td>
<td>8.2 (0.9–78.5)</td>
</tr>
<tr>
<td>Connective tissue disease</td>
<td>4 (1.9)</td>
<td>3 (0.7)</td>
<td>3.6 (0.7–18.5)</td>
</tr>
<tr>
<td>Vitiligo</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Scleroderma</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Psoriasis</td>
<td>0</td>
<td>1 (0.2)</td>
<td>-</td>
</tr>
<tr>
<td>Drug abuse</td>
<td>15 (1.3)</td>
<td>1 (0.2)</td>
<td>5.2 (0.7–39.6)</td>
</tr>
<tr>
<td>Mental disorder</td>
<td>137 (1.8)</td>
<td>35 (0.4)</td>
<td>5.5 (3.8–8.1)</td>
</tr>
<tr>
<td>Follow-up period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1 month</td>
<td>19 (0.1)</td>
<td>1 (&lt;0.1)</td>
<td>41.0 (5.4–310.6)</td>
</tr>
<tr>
<td>1–6 months</td>
<td>40 (0.2)</td>
<td>10 (&lt;0.1)</td>
<td>10.5 (5.2–21.4)</td>
</tr>
<tr>
<td>7–12 months</td>
<td>26 (0.1)</td>
<td>11 (&lt;0.1)</td>
<td>6.4 (3.1–13.3)</td>
</tr>
<tr>
<td>1–2 years</td>
<td>28 (0.1)</td>
<td>23 (&lt;0.1)</td>
<td>3.1 (1.7–5.5)</td>
</tr>
<tr>
<td>2–4 years</td>
<td>55 (0.3)</td>
<td>48 (0.1)</td>
<td>3.3 (2.2–4.9)</td>
</tr>
<tr>
<td>≥4 years</td>
<td>88 (0.7)</td>
<td>98 (0.2)</td>
<td>2.8 (2.1–3.8)</td>
</tr>
</tbody>
</table>

*Adjusted for sex, hypertension, diabetes mellitus, hyperlipidemia, rheumatoid arthritis, connective tissue disease, vitiligo, scleroderma, psoriasis, drug abuse, mental disorder, and monthly income.
Intelligent Cooperative Object Transportation for Multiple Omnidirectional Automated Guided Vehicles

Yen-Chen Liu, Ji-Xian Peng, Firhan Huzaefa
Department of Mechanical Engineering, College of Engineering
yliu@mail.ncku.edu.tw


Multi-robot systems have received considerable attention from researchers in the past decades. Inspired from the cooperation abilities in small living organisms like ants, birds, and fishes, researchers have been trying to bring out the same level of intelligence in multi-robot systems which is visible from the nature. The concept of multi-robot system have huge potential to be applied in industry. In practice, various loading weight and merchandise sizes lead to difficulties in storages and transportation within warehouses and industrial environment. In this research, we develop control architecture for cooperative transportation without physical link between automated guided vehicle (AGV). This will enable AGVs to contract and expand to different formations depending on object sizes and weight. Consequently, the variation of transporting different types of objects can be solved by adjusting the number and formation of AGV in the system.

The proposed system contains four parts, which are

1. Design and manufacturing of the omnidirectional AGV

The traditional AGVs using differential driving wheels is difficult to implement the concept of cooperative transportation. Thus, in this research we propose a novel design of AGVs by using mecanum omnidirectional wheels with a rotatory platform to provided flexibility of object transportation with various formations and trajectories.

![Figure 1. Design of the proposed omnidirectional AGV](image-url)
2. Synchronized control for multiple omnidirectional AGVs

If AGVs are controller to accomplish cooperative transportation individually, the uncertainties and tracking errors within one of the AGVs would lead to poor performance of the entire system and even mission failed. Therefore, we utilized the idea of synchronization control for networked dynamical system to couple the motion of all AGVs. Hence, the relative distance and orientation are synchronized so that the performance can be guaranteed.

![Figure 2. Cooperative transportation of multiple AGVs with synchronized control](image)

3. External force estimation for AGVs in cooperative transportation

In the design of control algorithms for cooperative transportation, the external force from the transported object is necessary to ensured system performance. However, the requirement of force sensors are expensive and inefficient in practice. Therefore, we present an estimation approach to utilize adaptive control, robust control, and neural network techniques to obtain the distributed force from the object to each of the AGVs. So that the force can be considered in the proposed controller to improve transportation performance.

![Figure 3. Control flow of the proposed adaptive, robust, and neural network estimation for external force in the proposed system](image)
4. Trajectory generation of cooperation transportation

Although the proposed control algorithms can ensure both tracking performance and uncertain object information in cooperation transportation, an accessible and feasible trajectory and orientation are important in implementation. In this research, we utilize rapid-exploring random trees to obtain the desired trajectory of the transportation mission by given only the initial and final position and orientation. This method can generate a collision-free trajectory for the multiple AGVs system to transport the object successfully.

Figure 4. Desired trajectory and orientation for cooperative transportation generated from rapid-exploring random trees
Generation of 3D Hepatic Multicellular Tumor Spheroids for Discovery of Novel Therapeutics

Chiao-Yi Chiu1, Ying-Chi Chen1, Kuang-Wei Wu1, Wen-Chien Hsu1, Hong-Ping Lin2, Hsien-Chang Chang1,3,4, Yung-Chun Lee4,5, Yang-Kao Wang6, Ting-Yuan Tu1,3,4,*

1 Department of Biomedical Engineering, National Cheng Kung University
2 Department of Chemistry, National Cheng Kung University
3 Medical Device Innovation Center, National Cheng Kung University
4 Center for Micro/Nano Technology Research, National Cheng Kung University
5 Department of Mechanical Engineering, National Cheng Kung University
6 Department of Cell Biology and Anatomy, College of Medicine, National Cheng Kung University

* Author to whom correspondence should be addressed

tingyuan@mail.ncku.edu.tw

Materials 2019, 12, 3308; doi:10.3390/ma12203308

Three-dimensional cell culture has revolutionized biomedical research for more than a decade. In the past half century, scientists have mostly cultured cells in two-dimensional plastic dishes for research. However, this culture method is very different from the conditions for the cells to grow inside the human body. Therefore, in order to better simulate the physiological micro-environment of in-vivo diseases, the three-dimensional culture method has gradually emerged. Taking cancer research as an example, a three-dimensional clustering of cells (multicellular tumor spheroids) can recapitulate several key tumor characteristics, such as the transfer of nutrients and oxygen. This study presented a simple and economical microstructure preparation method to produce hepatic tumor spheroids of uniform size, which can be easily incorporated into a conventional laboratory setting and used to develop novel therapeutics for liver cancer. In this study, Huh-7 hepatocellular carcinoma cells could grow into tumor spheroids of 250-520 m within five days of culture. With the combination of concanavalin A and silica carbo hallow spheres, the tumor spheroids could be treated by the photo-thermal therapy.

Schematic illustrations and an image of the rapid laser ablation of microwells integrated with standard culture plasticware for the identification of novel therapeutics through high-throughput screening drug screening and photothermal treatment.
Material Design and Performance Investigation for Developing Advanced High-Energy-Density Rechargeable Batteries

Sheng-Heng Chung
Department of Materials Science and Engineering, National Cheng Kung University
SHChung@gs.ncku.edu.tw

The commercialization of lithium-ion batteries is one of the great successes of modern energy-storage technology. With high reliability and fully-developed battery techniques, lithium-ion batteries currently dominate the market for portable energy storage. Encountering the increasing energy consumption, it is desirable to explore a new, environmentally compatible battery system that has high energy density at an affordable manufacturing and operational costs. Focusing on future energy technology, we are now systemically studying the battery electrochemistry and performance development of high-energy-density lithium-sulfur batteries. The overall goal of this project is to demonstrate practical lithium-sulfur batteries. We propose a new concept in designing lithium-sulfur batteries based on its conversion battery chemistry, such as designing new customized electrodes and developing polysulfides as catholytes. With a more reliable lithium-sulfur battery cathode, we will overcome the scientific/technical challenges by realizing high sulfur loading/content with limited excess lithium in a lean electrolyte cell. The lithium-sulfur cells with practical necessary designed parameters would demonstrate the real lithium-sulfur performance and electrochemical characteristics, which enable the cells to receive essential modification for entering the commercial battery market. Besides the lithium-sulfur battery chemistry, we subsequently will extend our battery design and relative technique to explore new metal-sulfur batteries with high abundant metal anodes (sodium and potassium) and with high valent metal anodes (calcium, magnesium, and aluminum). By conducting this five-year research proposal, our progress will illustrate that the approaches presented in this proposal are inexpensive and offer practically viable solutions for the lithium-sulfur technology commercialization and for the next-generation metal-sulfur battery development.

It is my honor to be granted by the Ministry of Science and Technology and the Ministry of Education for Einstein Program and Yushan (Young) Scholar Program, respectively. We sincerely appreciate the support from all my wonderful colleagues at the Department of Materials Science and Engineering and National Cheng Kung University. We look forward to do better and novel researches in my home country, TAIWAN, and educate outstanding R & D talents in TAIWAN’s energy storage technology.
To Investigate the Effects of 3'UTR Usage Switch and Its Regulator on Causing Resistance of Second-Generation Anti-Androgen Drug in Prostate Cancer

Shih-Chieh Lin
The Institute of Basic Medical Sciences, College of Medicine
Jaylin@mail.ncku.edu.tw

Prof. Shih-Chieh Lin established his lab at The Institute of Basic Medical Sciences since February 2018. His expertise is cancer biology, bioinformatics, translational medicine endocrinology, and reproductive physiology. Now, his current work mainly focuses on study of prostate cancer.

Taiwan has already become an aging society. Prostate cancer is the most common malignancy among elderly men. Metastatic castration-resistant prostate cancer (mCRPC) is a more malignant and lethal type of prostate cancer. Recently, several second-generation anti-androgen drugs are approved by US FDA providing alternative therapies and hopes for treatment of mCRPC patients. However, several critical and emergent issues such as drug selection, treatment sequential order, and drug resistance, are raised subsequently. Especially, National Health Insurance in Taiwan only covers the cost for one kind of those expensive drugs at the initial treatment. Since there is no available drug selection guideline and lack of alternative therapy once resistance to second-generation anti-androgen drugs has developed, it prompts us to investigate the underlying mechanism causing resistance of second-generation anti-androgen drug with a goal to develop novel therapy for mCRPC patients with resistance for second-generation anti-androgen drug. In addition, we also aim to identify biomarkers of drug response to predict resistance for different drugs. Although some reports have investigated the mechanisms of drug resistance for second-generation anti-androgen drugs recently, most of them are still focused on dysregulation of AR and androgen. Herein, we have proposed for the first time that a novel underlying mechanism causing resistance of second-generation anti-androgen drug by analyzing NGS results from enzalutamide-sensitive and -resistant mCRPC clinical specimens. Furthermore, a crucial regulator mediated this novel mechanism and its potential drug have been identified and studied by our research team. Hopefully, results from this grant proposal will have tremendous impacts on academic research, treatment efficacy of mCRPC patients, drug usage selection for clinical doctors, and valuable information for developing policy for the National Health Insurance Program.

There is no miracle for scientific work and accumulation of experience is the only way leading to the success! I am very grateful to receive MOST grant support for my research project. Therefore, our study will have a chance to become leading research in the world. Furthermore, I deeply appreciate all the comments from grant reviewers because their valuable opinions make our research project become better. Most importantly, I also appreciate National Cheng Kung University (NCKU) to provide the excellent research environment for me to perform interesting research based on my expertise. Hopefully, I can train a group of outstanding young researchers for our country in the future. I will try my best to elevate the international visibility of NCKU and Taiwan via our research.