Living Electronics for Bio-interfacing

Speaker: Prof. Xiaocheng Jiang, Tufts University
Date: Nov 15, 2019; **Time:** 2:30pm **Location:** UTEB 175

Abstract: Electronic and biological systems represent two limiting thermodynamic models in terms of functioning and information processing. By converging the dynamic and self-adaptable features of bio-machinery and the rationally defined/programmed functionalities of electronic components, there is potential to evolve new capabilities to effectively interrogate and direct biologically significant processes, as well as novel bio-inspired systems/device concepts for a range of engineering applications. The intrinsic mismatches in physiochemical properties and signaling modality at biotic/abiotic interfaces, however, have made the seamless integration challenging. In this talk, I will present our recent effort in forging their structural and functional synergy through the design and development of: (1) bio-hybrid electronics, where living transducers, such as functional biomolecules, organelles, or cells, are integrated with electronic transducers using spatially-defined, biocompatible hydrogel as the interfacing material; and (2) biosynthetic electronics, where biogenic electron pathways are utilized to naturally bridge the gap between internal biological and external electrical circuits. Blurring the distinction between livings and non-livings, these efforts have the potential to facilitate the cross-system communication and broadly impact how complex structures/functions may be designed/engineered.

Biographical Sketch: Xiaocheng Jiang is an Assistant Professor in the Department of Biomedical Engineering at Tufts University. He received his Ph.D. in physical chemistry from Harvard University with Professor Charles Lieber, with a focus on the design and application of nanoscale materials and nanoelectronic devices. Prior to joining Tufts, he was an American Cancer Society postdoctoral fellow at Massachusetts General Hospital, where he worked with Prof. Mehmet Toner on functional microfluidics for early cancer diagnostics. His current research concentrates broadly at the interface of materials and biomedical science, with specific interests in bio-inspired/bio-integrable electronics. He is a recipient of NSF CAREER award (2017) and AFOSR young investigator award (2018).

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Detail record view

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Previous

- **Healing codes for the biological apocalypse /Leonard G. Horowitz and Joseph Puleo.**

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9 March 2017

Innovative Supply Chain Information Platform Will Help Prepare For The Next Pandemic

TOKYO - The United Nations World Food Programme (WFP) and NEC Corporation today announced their collaboration for the development of the first ever information platform to provide end-to-end visibility of supply chains for pandemic interventions, on behalf of the Global Pandemic Supply Chain (PSC) Network. The government of Japan has provided US$1 million for the PSC Network, which will be used as seed funding for the new information platform.

The Global Pandemic Supply Chain Network was formed in response to lessons learned from the 2014 West Africa Ebola outbreak and discussions that followed at the World Economic Forum in Davos in 2015, where the need for a collaborative, multi-stakeholder response became clear. The founding members of the Network, representing the public sector, include WFP, the World Health Organization (WHO), and the World Bank, and representing the private sector, Henry Schein, Inc., Becton, Dickinson & Co., and UPS Foundation.

The challenges faced during the West Africa Ebola outbreak included severe warehousing and distribution capacity constraints, limited visibility of the overall supply and demand of critical items, access constraints caused by border closures, and a lack of public-private sector coordination resulting in duplicate efforts and an inefficient

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response.

These challenges are being answered by organizations including WFP, WHO, UNICEF, the Food and Agriculture Organization of the United Nations, the Office for the Coordination of Humanitarian Affairs, the World Bank, World Economic Forum, U.S. Agency for International Development, University of Minnesota, GS1, and Centers for Disease Control and Prevention, in collaboration with private sector companies, including Henry Schein, Inc., Johnson & Johnson, UPS Foundation, Becton, Dickinson & Co., and NEC. They have worked together in an unprecedented fashion to develop a framework for improving pandemic preparedness and response.

Supply chain logistics are fundamental to any emergency intervention. Inadequate preparedness and response capacity leads to critical delays, costs lives and wastes precious resources. By bringing together information on supplies and logistics and enabling analysis of supply chain inefficiencies, the new information platform, which will be part of the Global Pandemic Supply Chain Network, will promote timeliness and cost efficiency as well as aid in continuous improvement.

“In order to achieve any one of the Sustainable Development Goals (SDGs) by 2030, we must all do our part, lending our unique expertise and experiences to innovating solutions to global problems,” said Ertharin Cousin, Executive Director of WFP. “I am proud of the work being done by the PSC Network. The creation of this new platform is a prime example of the amazing endeavours that are possible when the public and private sectors work together.”

NEC was the first Asian company to join the PSC Network and remains the only

can reach the world's most vulnerable people in times of crisis, NEC will focus on gning a logistics visualization system that will enable end-to-end tracking of pandemic response items, such as protective clothing and medical equipment within a country facing an outbreak, helping to ensure quick and appropriate delivery of supplies to people in need. Other key functions of the system include reporting, data integration with existing logistics systems and in-country warehouse management.

“We are honoured to collaborate with WFP and the other members of the PSC Network to strengthen the global supply chain for pandemic preparedness and response in order to more effectively fight the next disease outbreak,” said Dr. Nobuhiro Endo, Chairman of the Board, NEC. “This is a perfect example of our commitment to creating safe,

secure, efficient, and equal societies through the provision of innovative information and communications technologies such as Artificial Intelligence, which also contributes to the United Nations' SDGs."

As members of the PSC Network jointly advocated the need for more efficient pandemic supply chain, the Japanese government has since committed US$1 million to development of the Network, allowing NEC and WFP to begin work.

"It is widely recognized that the global health architecture could be reinforced with improved supply chain platform to enable better preparation and faster response time for pandemics," said Mr. Hideaki Chotoku, Director of Humanitarian Assistance and Emergency Relief Division, Ministry of Foreign Affairs of Japan. "The Japanese Government welcomes and is proud to support the PSC Network which also involves Japanese IT technology. We look forward to monitoring its progress in designing this innovative tool."

# # #

About the Global Pandemic Supply Chain Network

The Global Pandemic Supply Chain Network is a public-private initiative that seeks to increase supply chain and logistics capacities and develop an information platform to more equitably match supplies with demand. By focusing on supply chain logistics to support the response to large-scale health emergencies, the partnership complements other efforts that are underway to strengthen national and international systems that prevent and manage future pandemics.

About WFP

WFP is the world's largest humanitarian agency fighting hunger worldwide, delivering food assistance in emergencies and working with communities to improve nutrition and build resilience. Each year, WFP assists some 80 million people in around 80 countries. Because of its strong capacities in logistics WFP also serves as coordinator of the Humanitarian Logistics Cluster and as manager of the United Nations Humanitarian Air Service (UNHAS) and the United Nations Humanitarian Response Depots (UNHRD). Follow us on Twitter @WFP @WFP_Media @WFP_JP

About NEC Corporation

NEC Corporation is a leader in the integration of IT and network technologies that benefit businesses and people around the world. By providing a combination of

benefit businesses and people around the world. By providing a combination of products and solutions that cross utilize the company's experience and global resources, NEC's advanced technologies meet the complex and ever-changing needs of its customers. NEC brings more than 100 years of expertise in technological innovation to empower people, businesses and society. For more information, visit NEC at http://www.nec.com

# # #

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Seiichiro Toda/Shinya Hashizume, NEC Corporate Communications Division

Profusa and Partners Receive DARPA Award to Speed Detection of Disease Outbreaks

Profusa's Lumee Oxygen Platform Selected as Part of Comprehensive Monitoring Platform

NEWS PROVIDED BY
Profusa, Inc. →
Aug 08, 2019, 08:30 ET

SOUTH SAN FRANCISCO, Calif., Aug. 8, 2019 /PRNewswire/ -- Profusa, an empowered health company that is pioneering the next generation of personalized medicine, today announced in collaboration with RTI International and Duke University the award of a DARPA (Defense Advanced Research Projects Agency) award to develop an early identification system to detect disease outbreaks, biological attacks and pandemics up to three weeks earlier than current methods. The RTI DARPA SIGMA+ funded effort is based on evaluating monitoring platforms including Profusa's first-of-its-kind, minimally-invasive injectable biosensor technology, the Lumee™ Oxygen Platform, to measure tissue oxygen levels as a potential indicator of human response to infection or exposure.

Unlike current efforts, which among other methods track and predict outbreaks via public health network data of patients that seek medical care once already experiencing symptoms, this program will assess the ability to collect real-time physiological data including oxygen status through Profusa's injectable biosensor, and other measures to detect impending distress before symptoms are present.

"We believe that data collected by monitoring real-time changes in body chemistry will allow us to make an important shift towards preventative care and away from costly sick-care needed after a pandemic, like the flu, has taken hold," said Ben Hwang, Chairman and CEO of Profusa. "This could lead to advances like more effective vaccines and disease prevention plans that improve health outcomes and potentially reduce healthcare costs. We are honored to receive this DARPA grant and excited to work alongside our partners towards a healthcare ecosystem that is focused on true personalized care."

The data collected by this program will be used to develop new algorithms for the detection of respiratory infections using machine-learning techniques with the goal of optimizing predictive capabilities. The collaborative effort will monitor patients simultaneously, so the technology can provide real-time, geospatial information on the spread of an infectious disease in an urban environment, to derive more effective countermeasures and mitigation strategies.

The project is part of DARPA's SIGMA+ program in the Defense Sciences Office (DSO).

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About Profusa

Founded in San Francisco, Calif., Profusa is an empowered health company led by visionary scientific founders, an experienced management team and a world-class board of directors who share the long-term goal of improving health and well-being for patients worldwide. With its long-lasting, injectable and affordable biosensors and its intelligent data platform, Profusa aims to provide people with a personalized biochemical signature rooted in data that clinicians trust and rely upon. These data may allow people to act as an active and educated participant alongside their care team and understand how their choices and decisions impact health and well-being, day-in and day-out. For more, visit https://profusa.com.

About the Lumee™ Oxygen Platform

Profusa's first clinical offering, the Lumee™ Oxygen Platform, which is CE marked for use in the European Union, is indicated for use in patients with potential acute and/or chronic changes in tissue oxygen levels who may benefit from monitoring. The sensors provide continuous and long-term monitoring of the oxygen in subcutaneous tissue. After a single injection, measurement thereafter are obtained non-invasively. In contrast to external pulse oximeters which measure oxygen bound to the hemoglobin in larger blood vessels, the Lumee™ platform measures dissolved oxygen at the tissue level in the fluid that bathes our cells.

About DARPA SIGMA +

The DARPA SIGMA+ program aims to expand SIGMA's advance capability to detect illicit radioactive and nuclear materials by developing new sensors and networks that would alert authorities to chemical, biological, and explosives threats as well.

SIGMA+ calls for the development of highly sensitive detectors and advanced intelligence analytics to detect minute traces of various substances related to weapons of mass destruction (WMD) threats. SIGMA+ will use a common network infrastructure and mobile sensing strategy, a concept that was proven effective in the SIGMA program. The SIGMA+ chemical, biological, radiological, nuclear and high-yield explosive (CBRNE) detection network would be scalable to cover a major metropolitan city and its surrounding region.

Planned execution of SIGMA+ will occur in two phases. Phase 1 will focus on developing novel sensors for chemicals, explosives, and biological agents while Phase 2 will focus on network development, analytics and integration.

Disclaimer

Funding from the Defense Advanced Research Projects Agency (DARPA). The views, opinions and/or findings expressed are those of the author and should not be interpreted as representing the official views or policies of the Department of Defense or the U.S. Government.

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SOURCE Profusa, Inc.

Related Links

http://www.profusa.com

AO 91 (Rev. 11/11) Criminal Complaint

UNITED STATES DISTRICT COURT

for the

District of Massachusetts

United States of America
v.
CHARLES LIEBER

Case No. 20-mj-2158-MBB

Defendant(s)

CRIMINAL COMPLAINT

I, the complainant in this case, state that the following is true to the best of my knowledge and belief.

On or about the date(s) of April 28, 2018 & January 10, 2019 in the county of Middlesex in the _____ District of Massachusetts, the defendant(s) violated:

Code Section	*Offense Description*
18 U.S.C. § 1001(a)(2)	Making false statements to the agency of the United States Government

This criminal complaint is based on these facts:

See attached affidavit of FBI Special Agent Robert Plumb.

☑ Continued on the attached sheet.

Complainant's signature

Robert Plumb, FBI Special Agent

Printed name and title

Sworn to before me and signed in my presence.

Date: 01/27/2020

Judge's signature

City and state: Boston, MA

Hon. Marianne B. Bowler

Printed name and title

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AFFIDAVIT IN SUPPORT OF APPLICATION FOR CRIMINAL COMPLAINT

I, Robert Plumb, being sworn, depose and state as follows:

1. I am a Special Agent with the Federal Bureau of Investigation ("FBI"), and have been so employed since June 2016. I am currently assigned to one of the FBI's Counterintelligence Squads in the Boston Field Office. My responsibilities include investigating violations of federal criminal laws relating to espionage and theft of trade secrets, the mishandling of classified and defense information, and export control laws. Previously, I was employed at the FBI as an Intelligence Analyst. I worked in this capacity for six years. I have participated in numerous investigations, during the course of which I have interviewed witnesses, conducted physical surveillance, executed search warrants, and used other investigative techniques to secure relevant information regarding various federal crimes.

2. I submit this affidavit in support of a Criminal Complaint charging Dr. Charles Lieber ("LIEBER") with making materially false, fictitious and fraudulent statements in a matter within the jurisdiction of the Executive Branch of the United States, in violation of Title 18, United States Code, Section 1001(a)(2). Specifically, based upon the evidence gathered thus far in this ongoing investigation, I have probable cause to believe and do, in fact, believe that LIEBER made materially false, fictitious and fraudulent statements regarding his participation in China's Thousand Talents Plan to the U.S. Department of Defense ("DoD") on or about April 24, 2018. I also have probable cause to believe and do, in fact, believe that, on or about January 10, 2019, LIEBER made and caused to be made a series of materially false, fictitious and fraudulent statements to the National Institutes of Health ("NIH") about his involvement in the Thousand Talents Plan and his affiliation with Wuhan University of Technology ("WUT") in China.

3. Based on the evidence gathered to date, LIEBER was a "Strategic Scientist" at WUT and a contractual participant in China's Thousand Talents Plan for significant periods between at least 2012 and 2017. The terms of LIEBER's Thousand Talents contract called for LIEBER to be paid up to $50,000 per month in salary and approximately $150,000 per year for living and personal expenses by WUT. LIEBER was also awarded more than $1.5 million by WUT and the Chinese government to establish a research lab and conduct research at WUT.

4. The information in this affidavit is based upon my training and experience, my personal knowledge of this investigation, information conveyed to me by other law enforcement agents and officials who assisted in the investigation, and the other sources of information described herein. This affidavit is submitted for the limited purpose of establishing probable cause to believe that LIEBER has committed the offenses described above. Accordingly, I have not included each and every fact known to me and other law enforcement officers involved in this investigation. I have set forth only those facts that I believe are necessary to establish the requisite probable cause.

FACTS SUPPORTING PROBABLE CAUSE

Background

5. LIEBER is a full-time faculty member and Chair of the Department of Chemistry and Chemical Biology at Harvard University in Cambridge, Massachusetts. He has been affiliated with Harvard since approximately 1991. According to LIEBER's biography on Harvard's website, LIEBER's primary area of expertise and research is nanoscience.

6. At all times relevant to this complaint, LIEBER served as the Principal Investigator of the Lieber Research Group at Harvard University. According to its website, the Lieber Research Group "is focused broadly on science and technology at the nanoscale, using novel synthesized

building blocks to push scientific boundaries in diverse areas from biology/medicine to energy and computing." The Lieber Research Group's website identifies its principal sponsors as NIH and DoD, including the Office of Naval Research ("ONR") and the Air Force Office of Scientific Research ("AFOSR"). Based upon records maintained by NIH, DoD, and Harvard University, I know that the Lieber Research Group has received more than $15,000,000 in grant funding from NIH and DoD since 2008.

7. A component of the United States Department of Health and Human Services, NIH is a government agency responsible for biomedical and public health research. The NIH conducts its own scientific research through an intramural research program, and also provides major biomedical research funding to non-NIH research facilities through an extramural research program. Many of the non-NIH research facilities that receive funding through NIH's extramural research program are colleges and universities, including Harvard University.

8. In order to receive NIH funding, non-NIH research institutions must submit a detailed application describing, among other things: (a) the purpose and scope of the proposed research; (b) the amount of funding requested; and (c) how the funding will be used. Both during the application process and periodically after an award is made, the institution must also disclose to NIH all foreign collaboration and foreign sources of research support, including, but not limited to, research grants, cooperative agreements, contracts and/or institutional awards. Additionally, NIH requires research institutions to identify and disclose to NIH significant (typically greater than $5,000) financial conflicts of interest by investigators (that is, the person or persons responsible for the design, conducting the research, and publishing or reporting the research performed pursuant to the grant), including those related to funds received from a foreign institution of higher education or the government of another country. Although it is the research institution itself that

submits the grant application and all other grant-related disclosures to NIH, the individual investigator(s) must certify to the institution and NIH that the information contained in grant applications, post-award submissions and all other grant-related filings is accurate and complete, and also acknowledge that any false, fictitious or fraudulent statements or claims made to NIH may subject the investigator to criminal, civil and/or administrative penalties.

9. WUT is a university located in Wuhan, China. It is considered a top-tier Chinese university recognized for its studies of science and technology.

10. The "Chinese Talent Programs" refer collectively to various plans designed by the Chinese Government to attract, recruit, and cultivate high-level scientific talent in furtherance of China's scientific development, economic prosperity, and national security. Implemented in 2008, the "Thousand Talents Plan" is the most prominent Chinese talent recruitment plan designed by the Chinese Government to incentivize individuals engaged in research and development in the United States to transmit the knowledge and research they gain here to China in exchange for salaries, research funding, lab space, honorary titles, and other incentives. The Thousand Talents Plan is designed to lure both Chinese overseas talent and foreign experts to bring their knowledge and experience to China. The so-called "World Recruitment Plan of Renowned Experts in China" is part of the Thousand Talents Plan. The Chinese Talent programs have rewarded individuals for stealing proprietary information and violating export controls.

Lieber's Affiliation with WUT and China's Thousand Talents Plan

11. According to records maintained by Harvard University, LIEBER traveled to WUT in mid-November 2011 ostensibly in order to participate in a Nano-Energy Materials Forum being hosted by WUT. Just days before LIEBER's trip, a professor at WUT (hereafter the "WUT Professor") emailed LIEBER a "Contract for Strategic Scientist's Appointment" (hereafter the

"Strategic Scientist Agreement"). He also informed LIEBER that LIEBER had been recommended for the "The Recruitment Program of Global Experts," which I know to be part of China's Thousand Talents Plan. In subsequent communications on or about November 11, 2011, both LIEBER and the WUT Professor acknowledged that LIEBER would sign the Strategic Scientist Agreement at WUT on November 15, 2011.

12. According to the agreement, which was written in both Chinese and English, LIEBER was appointed as a Strategic Scientist at WUT for five years from on or about November 15, 2011, until on or about November 14, 2016. LIEBER's objectives and tasks under the agreement were as follows:

> **Article Two Employment Objective and Tasks for Party B**
>
> 1. Make strategic, visionary and creative research proposals to guide the advancement of disciplines or scientific research institutes to become first class disciplines or scientific research institutes in China or the world, especially in frontier areas.
> 2. Supervise young teachers or receive them as visiting scholars, guiding or co-guiding postgraduate students (including post-doctoral students), leading them to the international forefront of related fields, jointly publishing academic papers in top international journals (in the name of WUT, and WUT faculty or students as the first author) or publishing high-level academic monographs and guiding young teachers to win national awards or influential international academic awards.
>
> 3. Build up a Discipline Innovative Team, introducing and cultivating high-level talents to be as qualified as those of China's 1000 Young Talents Plan, Distinguished Professors of Chang Jiang Scholars and winners of National Science Fund for Distinguished Young Scholars.
>
> 4. Conduct national important (key) projects or international cooperation projects that meet China's national strategic development requirements or stand at the forefront of international science and technology research field.
>
> 5. Carry out international exchanges and cooperation, and host or jointly host prominent international academic conferences in the name of WUT.

13. According to the contract, WUT agreed to pay LIEBER $50,000 U.S. Dollars ("USD") per month, prorated according to LIEBER's "actual work time" at WUT. WUT also

agreed to provide LIEBER with round-trip, business-class airfare to and from WUT. Finally, the agreement alluded to LIEBER's future involvement with China's Thousand Talents Plan, and allowed for seemingly greater monthly compensation to LIEBER in the future:

> 4. Once Party B gains a Chinese government-sponsored position through successful application for various Chinese talent-related projects, Party A shall adjust its payment terms to ensure that Party B enjoys more benefits on the principle of "taking the higher pay", but the same benefit terms will not be paid twice.

14. LIEBER returned to Massachusetts from WUT on or about November 16, 2011. Two days later, in an email to the WUT Professor, LIEBER wrote, "I very much appreciate the effort that you put into making my visit a good one. I also agree that it would productive, and hope that we can push forward as per discussions to build up the joint laboratory to a truly world-level facility." Approximately one month later, on or about December 19, 2011, the WUT Professor emailed portions of a proposed website for the "WUT-Harvard Joint Nano Key Laboratory," which, according to the website, was established in 2009. The website prominently featured LIEBER's name, photograph and biographical information, and it identified him as the "Laboratory Director." In his email to LIEBER about the website, the WUT Professor noted that "the Chinese version [of the website] will be made after your approval for [sic] the English version."

15. On or about April 5, 2012, approximately five months after executing the Strategic Scientist Agreement with WUT, the WUT Professor wrote an email to LIEBER informing him that he had been selected to participate in China's Thousand Talents Plan. At that time, LIEBER's selection entailed awards by WUT and the Chinese Government of approximately $158,000 USD in "personal benefits" and nearly $800,000 USD in "research funding." Specifically, the WUT Professor wrote,

> I am very happy to let you know that, in the **World** Recruitment Plan of **renowned** experts in China (also called as one thousand plan of foreign experts), you have been approved and awarded as invited strategic foreign expert by Chinese government because of your **world-leading** achievements, the **good collaboration basis** between you and WUT, and your great **contribution** to national academic exchange between China and USA. You are provided with personal benefit of one million RMB (~158,800 USD), a research funding of 5 million RMB (~794,000 USD) for development of WUT-Harvard joint nano key lab and collaboration research This plan is the highest plan/program for famous foreign scientists in Chinese scientific field and only 40 famous experts from the world were awarded. (Emphasis original.)

16. Nearly three months later, on or about June 27, 2012, the WUT Professor shared with LIEBER a contract titled "Employment Contract of 'One Thousand Talent' High Level Foreign Expert" between LIEBER and WUT (hereafter the "Thousand Talents Agreement"). The WUT Professor asked for LIEBER's "ideas/comments/suggestions" within "one week when your schedule allows (of course, the sooner the better)." The first page of the agreement appeared as follows:

“千人计划” 高层次外国专家工作合同书
EMPLOYMENT CONTRACT of “ONE THOUSAND TALENT” HIGH LEVEL FORTIGN EXPERT

聘任方：武汉理工大学（简称甲方）

受聘方：“千人计划”高层次外国专家、美国哈佛大学教授 Charles M. Lieber 博士（简称乙方）

Employer (Party A): Wuhan University of Technology

Employee (Party B): “One Thousand Talent” high level foreign expert, professor **Charles M Lieber** from Harvard University, USA.

为保证“千人计划”高层次外国专家项目的顺利实施，保障甲乙双方的合法权益，根据中华人民共和国的有关文件精神和政策规定，经双方平等协商，订立本合同。

Both sides, in line with the principles of legality, fairness, equality, and mutual agreement, to ensure the implementation of “One Thousand Talent” high level foreign expert plan, and to guarantee the legal rights and obligations of both sides, on the basis of Chinese laws and rules concerned, agree to sign this contract.

第一条 聘期

“千人计划”高层次外国专家岗位首次聘期为三年，该合同自签订之日起生效。聘任期满，经双方协商后，报上级主管部门审批，可续签下一期合同。

1. Duration of the Contract

The term of this contract will be 3 years since the date of signature. Both parties can sign the new contract through consultation and mutual consent after the contract is upon expiration with the permission of superior authorities department.

17. The Thousand Talents Agreement was effective for three years “from the date of signature.” Among other things, the agreement obligated LIEBER to conduct scientific research; to “publish high-level articles in the renowned and important international academic journals in the name of Wuhan University of Technology;” to assemble a research team with “strong ability of [sic] research and innovation” in LIEBER’s field of expertise; to “guide 1-2 distinguished young scholars and 3-4 doctoral students … and help them publish systematic articles in the international

renowned journals;" to "organize 1-2 predominant influencing international conferences in his field in the name of Wuhan University of Technology;" and "invite 1-3 international top scientists to work in the lab as visiting scholars." The agreement also required LIEBER to work at or for WUT "not less than nine months a year" by "declaring international cooperation projects, cultivating young teachers and Ph.D. students, organizing international conference[s], applying for patents and publishing articles in the name of" WUT.

18. In exchange for his work for and on behalf of WUT, WUT agreed to pay LIEBER $50,000 USD per month, and living expenses of up to 1,000,000 Chinese Yuan (based on 2012 exchange rates, approximately $158,000 USD) to be paid over the three-year term of the contract. The contract also allocated 11,000,000 Chinese Yuan (or roughly $1.74 million USD based on 2012 exchange rates) for the joint Harvard-WUT Nano Key Lab and related research. The following portion of the contract documented those financial terms. WUT is referred to as "Party A," while LIEBER is referred to as "Party B."

二、甲方义务

1．依法维护乙方应享有的各项权利。

2．为乙方提供良好的工作和生活条件

(1)办公及实验室条件：甲方按乙方的要求为乙方提供办公及实验条件。

(2)科研配套经费：聘期内，甲方为乙方提供 1000 万元科研配套经费（其中包括国家拨款 500 万元），主要用于购置实验仪器设备、科研新方向和基础设施建设；此经费由甲方管理，乙方与甲方的合作教授共同商量支配。

(3)团队建设条件：甲方按乙方的要求为乙方组建学术团队，并每年投入 100 万元团队建设经费，主要用于开支团队成员的工资、安家补贴，团队及乙方本人的差旅等； 此经费由甲方管理，乙方支配。

(4)生活条件：薪酬标准为每月 5 万美元（税前标准），按实际到岗时间支付；另享受 100 万元人民币的生活补贴（免税），分三年用支付。

(5)为乙方指导博士、博士后工作人员和高级访问学者等创造条件，人员由甲方推荐、乙方考察并最终确定。

3．为乙方提供完成本合同规定的工作目标及任务所需要的校内相关政策和支持。

2. Party A's Obligations

(1). Party A shall respect Party B's legal rights

(2). Party A shall provide Party B with necessary working and living conditions

a. working and lab conditions: Party A shall provide Party B with working and lab conditions according to Party B's requirement

b. scientific research funding: Party A shall provide Party B ten million Chinese Yuan (10,000,000 RMB) including five million RMB from national fund during the term of this contract to the construction of new direction and infrastructure construction, equipments and instruments purchasing. This amount of money shall be managed by Party A, and Party B can use it after discussing with the co-professor from Party A.

c. talent team construction condition: Party A shall construct talent team according to Party B's requirement and provide one million Chinese Yuan (1,000,000 RMB) as the funds of talent team construction each year. The funds shall be mainly used as the payment, accommodation, and travel expense of Party B and the team members. This amount of money shall be managed by Party A, and Party B can use it.

d. payment and living conditions: Party A shall provide Party B with fifty thousand U.S. Dollars ($ 50,000) per month (before tax), paid according to his working time in Wuhan University of Technology. Party A shall provide Party B with one million Chinese Yuan (1,000,000RMB) (after tax) as living allowance which will be paid 1/3 a year for three years.

19. In a subsequent email to LIEBER dated July 10, 2012, the WUT Professor told LIEBER that WUT's president had signed the "1000 plan agreement" and that executed copies of the agreement had been mailed to LIEBER in Massachusetts for his signature. In an email dated on or about July 21, 2012, the WUT Professor informed LIEBER that WUT had received copies of the Thousand Talents Agreement signed by LIEBER.

20. After signing the Thousand Talents Agreement, LIEBER returned to WUT in November 2012. LIEBER's travel expenses to and from Wuhan were paid by WUT. Prior to this trip, arrangements were made to pay LIEBER his salary and living expenses as specified in the Thousand Talents Agreement. For example, in an email dated on or about October 26, 2012, a WUT employee (hereafter the "WUT Employee") wrote to LIEBER:

> Before your visit, I would like to talk about one detail in the implementation of the contract of "one thousand talent" high level foreign expert between you and our university. According to the article concerning the payment and living conditions, I want to know the way you prefer to be paid so that everything can be prepared before your coming. I would like to provide two options for you to choose if you do not mind. Option one. I help you open a new bank account in the Chinese Bank named [redacted]. The payment will be put into your account and you can get the payment from the branch of [redacted] in your country. Option Two. I can prepare the payment in cash.

21. Less than three months later, on or about January 10, 2013, the WUT Professor emailed LIEBER an agreement titled "Academic Cooperative Agreement between Harvard University, USA and Wuhan University of Technology, P.R. China." The stated purpose of the agreement, which had a five-year effective term, was to "carry out advanced research and development of nanowire-based lithium ion batteries with high performance for electric vehicles." Apart from its stated objective, the agreement provided for a "cooperative research program" whereby researchers from WUT would "visit Department of Chemistry and Chemical Biology of

Harvard University for two months each year." Without consulting any Harvard officials, LIEBER signed the agreement on Harvard's behalf and returned the executed copies to the WUT Professor on or about January 11, 2013. I understand from conversations with Harvard's representatives that LIEBER did not have the authority to execute this contract on behalf of Harvard.

22. One year later, LIEBER continued to work closely with — and continued to receive compensation from — WUT. For example, on or about January 18, 2014, LIEBER wrote to the WUT Professor and another person affiliated with WUT that he would accept a WUT graduate student (hereinafter the "Graduate Student") as a long-term "WUT-HU joint Ph.D. student" provided that WUT "support all of [the Graduate Student's] salary and research costs while working in my lab." In the same communication, LIEBER discussed an upcoming visit to WUT in February 2014, and he made specific demands regarding the payment of his salary:

> I would like to receive ~1/2 of salary (for the current period) in US dollars, with the remainder deposited into the bank account that was set-up. The ~00 that I promised to pay for the party following Lin Xu's Ph.D. defense in April, can be deduced from either 1/2.

23. In June of 2014, LIEBER continued to discuss his compensation under the Thousand Talents Agreement with WUT. In an email to the WUT Employee dated June 16, 2014, LIEBER asked to maintain his bank account "the way it has been for now" and he reiterated his earlier request that half of his salary be deposited into his Chinese bank account and the other half be paid to him in cash when he next visited WUT. LIEBER further stated, "I think this is close to what [we] have done in [the] past."

24. In late January 2015, LIEBER outlined his ongoing relationship with WUT, confirming that he intended to visit WUT "several" times per year or "perhaps slightly more in the next couple years as we try to build up the nano-bio part of the lab;" that he would be available for "electronic communication on a very regular basis with students (email, telephone, skype) so that

they obtain full input from me as an advisor;" and that "students visiting [from WUT] for periods at Harvard would have [the] same access as normal Harvard graduate students."

25. Around the same time, independent of LIEBER, Harvard administrators learned for the first time of the WUT-Harvard Joint Nano Key Laboratory at WUT, including the fact that LIEBER was the director of the lab. Harvard officials confronted LIEBER about the joint lab, and informed him that the improper use of Harvard's name and logo — orchestrated by LIEBER without Harvard's consent — violated University policy. In response, LIEBER falsely told Harvard officials that he was involved in collaborative research with WUT for "mutual scientific interaction," but that WUT was using Harvard's name and logo without his knowledge or consent.

26. On or about February 3, 2015, LIEBER emailed the WUT Professor and told him that WUT must cease using Harvard's name, stating, "Our agreement for research collaboration is between you/Wuhan University of Technology (WUT) and me, and **does not** constitute an agreement with Harvard University." (Emphasis original.) Subsequent emails suggest that LIEBER took additional steps to try and distance himself — at least publically — from WUT in the wake of Harvard's discovery of the joint Harvard-WUT nano lab. These included cancelling a trip to WUT in June 2015 and advising a postdoctoral fellow at the Lieber Research Group to continue her work in LIEBER's lab *rather* than starting a position at WUT.

27. Nevertheless, LIEBER's Thousand Talents Agreement and the earlier Strategic Scientist Agreement (which, according to their terms, expired in July 2015 and November 2016, respectively) appear to have remained in place well after January 2015. For example, in an email dated February 13, 2015, LIEBER told the WUT Professor that he would continue his review of a manuscript written by WUT researchers. In the same email, LIEBER also said that he "may be in touch with regards to several issues relating to my appointment/salary/funding @ WUT...."

Although it is unclear what precise "issues" LIEBER was referring to, at a minimum, this email shows that LIEBER continued to be paid by WUT after January 2015.

28. In an email dated November 26, 2015, the WUT Professor thanked LIEBER "for all you have done for our university and me!" The WUT Professor also told LIEBER that WUT had "put your salary in your ... [bank] card and we will help you change the cash for you when you come to Wuhan." The fact that WUT continued to pay LIEBER's salary in late 2015 indicates to me that LIEBER, in fact, continued to work for, and with, WUT throughout 2015.

29. The payment of salary to LIEBER by WUT appears to have continued into 2017. In an email dated January 17, 2017, the WUT Professor sent the following message to LIEBER:

> During our last meeting you mentioned the tour of Bejing in the end of Feb. or early March. President [of WUT]..., I and all faculties and students in our Joint Nano Lab would like to invite you to visit WUT and our Joint Nano Lab. If your schedule is available, we would like to take this chance to express our everlasting gratitude to your great support for our university and me! Our university has put your salary in your ... [bank] card and we will help you change the cash for you when you come to Wuhan. Our university will cover your first-class flight ticket and accomadation [sic] like before. We would like to know your idea. With my best regards and thank you very much for your strong support again.

By this point, according to their express terms, LIEBER's Strategic Scientist and Thousand Talents Agreements with WUT had expired. Insofar as it discusses the payment of additional salary to LIEBER in January 2017, this email is evidence that LIEBER may have executed a new agreement with WUT at some point in either late 2016 or early 2017.

Lieber's False Statements to DoD

30. Since 2009, LIEBER has been the principal investigator associated with at least six research grants funded by various DoD entities, including ONR and AFOSR. The total value of

these grants exceeded $8 million. As of April 2018, LIEBER was the principal investigator associated with three active DoD grants.

31. On April 24, 2018, DoD investigators interviewed LIEBER about his active grants and whether LIEBER had appropriately disclosed foreign research collaboration to DoD. During the interview, which took place at LIEBER's lab on the Harvard Campus, LIEBER said that he was familiar with China's Thousand Talent's Plan, but that he had never been asked to participate in the program. Although LIEBER stated that he was never asked to participate in the Thousand Talents Program, he also told DoD investigators that he "wasn't sure" how China categorized him. I believe these statements were false because, as described above, WUT expressly asked LIEBER on numerous occasions in 2012 to participate in the Thousand Talents Program and to sign a Thousand Talents Agreement with WUT. Moreover, based upon the email correspondence described above that I have reviewed, LIEBER *did* sign a three-year Thousand Talents Agreement with WUT on or about July 21, 2012, and was paid by WUT over the course of several years pursuant to that agreement. The agreement that LIEBER signed was titled "Employment Contract of 'One Thousand Talent' High Level Foreign Expert" and it referred to LIEBER as a "One Thousand Talent."

32. On April 26, 2018, two days after his interview with DoD, LIEBER emailed a research associate affiliated with the Lieber Research Group the following message:

> Can you also provide me with the link/info to CAS webpage where I am listed as directing (?) that lab at Wuhan? I lost a lot of sleep worrying about all of these things last night and want to start taking steps to correct sooner than later. I will be careful about what I discuss with Harvard University, and none of this will be shared with government investigators at this time.

I believe that "CAS" refers to the China Academy of Sciences, which I know to be a top Chinese research institute. According to Harvard University's website, LIEBER was elected to the CAS

in December 2015. At a minimum, this email demonstrates that LIEBER withheld information from "government investigators" about his relationship with WUT. Given the timing of this email — two days after his interview with DoD — I believe LIEBER was referring specifically to the DoD investigators.

Lieber's False Statements to NIH

33. I am aware that LIEBER was the principal investigator associated with at least three NIH-funded research grants awarded to Harvard University since 2008. The total value of those grants exceeded $10 million. Two of those grants were being actively funded by NIH as of November 2018.

34. On or about November 15, 2018, NIH inquired of Harvard about whether LIEBER and/or Harvard had failed to disclose LIEBER's then-suspected relationship with WUT and China's Thousand Talents Plan. In order to respond to NIH's inquiry, Harvard interviewed LIEBER about his foreign affiliations generally, and any connection he might have to WUT in particular. Based upon information provided by LIEBER during that interview, Harvard submitted a detailed written response to NIH on or about January 10, 2019. I believe that LIEBER caused Harvard to make materially false and misleading statements about his connection to WUT and the Thousand Talents Plan in that written submission.

35. Specifically, LIEBER caused Harvard to tell NIH that LIEBER "had no formal association with WUT" after 2012, but that "WUT continued to falsely exaggerate" LIEBER's involvement with WUT in subsequent years. This statement was false because, as described above, LIEBER maintained a formal, collaborative relationship with WUT between at least 2012 and 2017 that included the Visiting Scientist Agreement, the Thousand Talents Agreement, an Academic Cooperative Agreement between Harvard and WUT, and possibly other agreements.

36. LIEBER also caused Harvard to tell NIH that LIEBER "is not and has never been a participant in" China's Thousand Talents Plan. This statement was also false because LIEBER did, in fact, sign a three-year Thousand Talents Agreement with WUT on or about July 21, 2012.

CONCLUSION

37. Based on the forgoing facts, and on my experience, training and discussions with other individuals involved in this investigation, I believe that probable cause exists to conclude that on or about April 24, 2018, LIEBER knowingly and willfully made materially false, fictitious and fraudulent statements to DoD in violation of 18 U.S.C. § 1001(a)(2). In addition, I believe that probable cause exists to conclude that on or about January 10, 2019, LIEBER made and caused to be made a series of materially false, fictitious and fraudulent statements to NIH, also in violation in 18 U.S.C. § 1001(a)(2).

_____
Robert Plumb
Special Agent, FBI

Sworn and subscribed before me this _____ day of January 2020.

_____
MARIANNE B. BOWLER
UNITED STATES MAGISTRATE JUDGE

UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

UNITED STATES OF AMERICA	)	Criminal No.
	)	
	)	Violations:
YANQING YE,	)	
	)	Count One: Visa Fraud
	)	(18 U.S.C. § 1546)
Defendant	)	
	)	Count Two: Making False Statements
	)	(18 U.S.C. § 1001(a)(2))
	)	
	)	Count Three: Acting as an Agent of a
	)	Foreign Government
	)	(18 U.S.C. § 951)
	)	
	)	Count Four: Conspiracy
	)	(18 U.S.C. § 371)

INDICTMENT

At all times relevant to this indictment:

General Allegations

A. The People's Republic of China and its Military

1. The People's Republic of China ("PRC") is a "foreign government" as that term is defined under 28 C.F.R. § 73.1(b). The People's Liberation Army ("PLA") is the military arm of the Chinese Communist Party ("CCP") and the armed forces of the PRC. The PLA is composed of six services and support forces: the PLA Army; PLA Navy; PLA Air Force; PLA Rocket Force; PLA Strategic Support Force; and the PLA Joint Logistics Support Force. The Central Military Commission ("CMC") controls the PLA. The PLA uses three schools (the Academy of Military Science, National Defense University, and National University of Defense Technology) to formulate military strategy, research and advance its military capabilities and

weapons systems, and train its armed forces. Professors at these schools also serve as military officers and leaders of the PLA.

2. National University of Defense Technology ("NUDT") is a top military academy directed by China's CMC. It was founded in 1953 by the Harbin's Military Engineering Institute PLA. NUDT is involved in national defense research for the PLA and responsible for modernizing the PRC's armed forces and designing advanced weapons. NUDT is also responsible for training advanced scientific and engineering personnel, commanding personnel, and senior leadership in the PLA.

B. The Defendant and Her Conspirators

3. YANQING YE ("YE") is a Chinese national, a female member of the PLA, and member of the CCP. At all times relevant to the Indictment, YE was a Lieutenant in the PLA and was being directed by senior leaders of the PLA while conducting research at Boston University pursuant to a J-1 non-immigrant visa.

4. Co-conspirator A was, at all relevant times, YE's supervisor as well as a Colonel in the PLA and full professor at NUDT.

5. Co-conspirator B was, at all relevant times, an Assistant Professor in Management Science and Engineering at NUDT and a member of the PLA who according to YE had the rank "of less than Colonel." YE was aware that Co-conspirator B had worked on military research projects regarding rocket launchers.

6. Co-conspirator C was, at all relevant times, an Assistant Professor in NUDT's College of Information Systems and Management.

C. YE Fraudulently Gained Entry into the United States

7. YE applied for, and obtained a, J-1 non-immigrant visa to conduct research in the Department of Physics, Chemistry, and Biomedical Engineering, Center of Polymer Studies, at Boston University. YE's research and studies in the United States at Boston University were funded by the Chinese Scholarship Council ("CSC"). The CSC was established in 1996 as a non-profit institution affiliated with the PRC's Ministry of Education. The CSC is responsible for the enrollment and administration of Chinese Government Scholarship programs and provides funding for both undergraduate and graduate students, as well as post-doctoral visiting scholars, to Chinese citizens wishing to study abroad and to foreign citizens wishing to study in China. CSC is financed mainly by the state's special appropriations or scholarship programs.

8. On or about August 4, 2017, YE electronically signed her visa application and certified that all of her answers on the form were true and correct when, in fact, she misrepresented her foreign military service to gain entry to the United States. In her visa application, YE described her foreign military service as follows:

> Name of Country/Region: CHINA
> Branch of Service: CIVIL SERVICE
> Rank/Position: STUDENT
> Military Specialty: NUDT [National University of Defense Technology]
> Date of Service
> From: 01 September 2009
> Date of Service
> To: 31 July 2017

This description was false as YE's foreign military service did not end on July 31, 2017, as she represented to the U.S. Government. Nor was her rank only that of a "student" in NUDT. To the contrary, YE was in fact a Lieutenant in the PLA and continued to work as a Lieutenant in

the PLA while studying and conducting research in the United States from in or about October 2017 to in or about April 2019. As described below, YE was tasked with numerous assignments from PLA officers while she was in the United States such as conducting research, assessing U.S. military websites, and sending U.S. documents and information to China, which YE completed by masking her affiliation to the PLA. YE also lied on her visa application when she answered "No" to the question: "Do you seek to engage in espionage, sabotage, export control violations, or any other illegal activity while in the United States?" Based upon YE's false representations, on or about September 5, 2017, the U.S. Department of State approved YE's DS-160 application. On or about October 14, 2017, YE gained entry into the United States using her visa that she knew had been procured through fraud and making false statements, in violation of 18 U.S.C. § 1546.

D. YE Makes False Statements to U.S. Law Enforcement

9. On or about April 20, 2019, officers of Customs and Border Protection along with a Special Agent of the FBI conducted an interview of YE at Boston Logan International Airport. During this interview, YE stated, among other things, that Co-conspirator A was her Chinese advisor and a "full professor" at NUDT and he held the military rank of "Colonel." YE falsely claimed that she had minimal contact with Co-conspirator A, and that Co-conspirator A did not provide much oversight of her research projects. She further falsely denied participating in any of Co-conspirator A's military projects. Yet, based upon records found on YE's electronic devices pursuant to a border search, at the instruction of Co-conspirator A, YE had accessed U.S. military websites, researched U.S. military projects, and compiled information for the PLA on two U.S. persons with expertise in robotics and computer science.

10. During the April 20, 2019 interview, YE also denied having any involvement in Co-conspirator B's research. YE described Co-conspirator B as an Assistant Professor of NUDT who held a military rank of "less than colonel." She also claimed that she had no recent communications with him when, in fact, she had numerous WeChat conversations with Co-conspirator B in 2018 and 2019. Indeed, according to a January 2019 WeChat conversation between YE and Co-conspirator B, they were collaborating on a research paper that was focused on a risk assessment model designed to assist the PLA in deciphering data for military applications. On or about April 11, 2019, Co-conspirator B sent YE a message in Chinese that has been translated into English that states: "See if [we can] find projects in risk analysis and policy sponsored by the US military by searching risk + US military directly." YE also provided Co-conspirator B her Boston University VPN login, including her username and password so Co-conspirator B could log into YE's account.

11. Lastly, during this interview, YE stated that she held the rank of Lieutenant in the PLA and admitted she was a member of the CCP. She planned to return to the PRC and complete her PhD at NUDT under the advisement of Co-conspirator A. YE indicated that part of her undergraduate studies at NUDT included classification training and students at NUDT worked on classified projects.

E. YE Acted as an Agent of the PRC without Notification to the Attorney General

12. In direct violation of the terms of her J-1 visa, while in the United States, YE had extensive communications with several senior PLA officers and she continued to work as a PLA Lieutenant. YE was tasked by senior PLA officers, completed those taskings, conducted research on the U.S. military for the PLA, collaborated with Co-conspirator B on research

projects that had potential military applications, and lied about her engagement with PLA officers when directly questioned about them. YE acted as an agent for the Chinese government, yet she never notified the Attorney General as required for agents working for a foreign government.

COUNT ONE
Visa Fraud
(18 U.S.C. § 1546(a))

The Grand Jury charges:

13. The allegations contained in paragraphs 1-12 are hereby re-alleged and incorporated by reference as if fully set forth herein.

14. The conduct alleged in this Count occurred outside the jurisdiction of any particular State or district and within the venue of the United States District Court for the District of Massachusetts, as provided in 18 U.S.C. § 3238.

15. On or about August 4, 2017, in the People's Republic of China, the defendant

YANQING YE,

did knowingly subscribe as true, under penalty of perjury (28 U.S.C. § 1746), a false statement with respect to a material fact in an application, to wit, in response to the question: "Have you ever served in the military?" on the Form DS-160, Application for Immigrant Visa and Alien Registration, YE responded that she only had attained the rank of "student" at NUDT and her period of service to Chinese military ended on July 31, 2017, which statement the defendant then and there knew was false.

All in violation of Title 18, United States Code, Section 1546(a).

COUNT TWO
False Statements
(18 U.S.C. § 1001)

The Grand Jury further charges:

16. The allegations contained in paragraphs 1-12 are hereby re-alleged and incorporated by reference as if fully set forth herein.

17. On or about April 20, 2019, in the District of Massachusetts, the defendant

YANQING YE,

in a matter within the jurisdiction of the executive branch of the Government of the United States, did knowingly and willfully make a materially false, fictitious and fraudulent statement and representation, which YE then knew to be false during an interview conducted by CBP officers and a FBI Special Agent.

All in violation of Title 18, United States Code, Section 1001(a)(2).

COUNT THREE
Acting in the United States as an Illegal Agent of a Foreign Government
(18 U.S.C. § 951)

The Grand Jury further charges:

18. The allegations contained in paragraphs 1-12 are hereby re-alleged and incorporated by reference as if fully set forth herein.

19. Beginning on a date unknown to the Grand Jury, but no later than in or about October 2017, and continuing until in or about April 2019, in the District of Massachusetts and elsewhere,

YANQING YE,

defendant herein, did knowingly act in the United States as an agent of a foreign government, to wit: the People's Republic of China, without prior notification to the Attorney General of the United States as required by law.

All in violation of Title 18, United States Code, Section 951(a).

COUNT FOUR
Conspiracy
(18 U.S.C. § 371)

The Grand Jury further charges:

20. The allegations contained in paragraphs 1-12 are hereby re-alleged and incorporated by reference as if fully set forth herein.

21. Beginning on a date unknown to the Grand Jury, but no later than in or about October 2017, and continuing until in or about April 2019, in the District of Massachusetts and elsewhere, the defendant

YANQING YE,

did knowingly and willfully conspire with others known and unknown to the Grand Jury to commit an offense against the United States, to wit, 18 U.S.C. § 951, that is, to knowingly act in the United States as an agent of a foreign government, the PRC, without prior notification to the Attorney General as required by law, in violation of 18 U.S.C § 371.

OVERT ACTS

21. In furtherance of the conspiracy, and to effect its objects, the defendant and her co-conspirators committed overt acts, including but not limited to, the following:

a. On or about August 4, 2017, YE lied on the Form DS-160, Application for Immigrant Visa and Alien Registration, about her military rank in the PLA, position in the PLA, and the end date of her service. She made these statements to fraudulently obtain a J-1 visa so as to gain entry into the United States and operate within the United States under the direction and control of her senior leaders in the PLA.

b. On or about March 15, 2018, YE sent instructions to Co-conspirator B in Chinese via WeChat on how to access Boston University's document database using her Boston University VPN login information (username and password) thereby giving Co-Conspirator B the ability to log into Boston University posing as YE.

c. Beginning in or about January 2019, Co-conspirator B and YE collaborated on a research paper that was focused on a risk assessment model designed to assist in deciphering data for military applications. As part of this research project, among other things, on or about April 11, 2019, Co-conspirator B advised YE via WeChat: "See if [we can] find projects in risk analysis and policy research sponsored by the US military by searching risk + US military directly." In response, later on April 11, 2019, YE responded via WeChat that she would conduct this research.

d. On or about April 6, 2019, Co-conspirator A instructed YE via WeChat to research a U.S. professor at the Naval Postgraduate School at Monterey, California whose work focused on computer security, digital forensics, and computer and software engineering and prepare a summary of his biography for him. Co-conspirator A advised Ye: "Compile the information into a file, then send it to me please." YE responded: "Sure Teacher [Co-conspirator A]. Please go to bed now. I will start to work on it immediately." Approximately, six hours later, YE sent Co-conspirator A three documents: (1) a Word document that she prepared summarizing the professor's biography; (2) the professor's curriculum vitae from the school's website; and (3) a list of his published articles.

e. On or about April 11, 2019, Co-conspirator C requested YE via WeChat to download a pdf file from a U.S. navy website –

www.public.navy.mil/surfor/Documents/Surface_Forces_Strategy.pdf. YE did as she was instructed and sent Co-Conspirator C this document via WeChat. In response, Co-conspirator C stated: "Now a days, we can't connect to a link with *mil* top level domain from China… This is probably American taking precautions against us." YE agreed with these statements and revealed that when she has been searching for information recently, "sometimes I have to use the IP of the university to enter certain websites."

f. On or about April 15, 2019, Co-conspirator A sent YE requests via WeChat to access the U.S. navy website – **www.onr.navy.mil** and "check if it has a list of projects." Later that same day, Co-conspirator A also requested YE to access the U.S. army website – **www.arl.army.mil** and review the contents of that website for him.

g. On or about April 16, 2019, Co-conspirator A instructed YE via WeChat to conduct research and compile information on a Professor of Electrical and Computer Engineering at University of Texas at San Antonio. This professor's research focused on system of systems technology and intelligent robotics. As instructed, YE compiled the information Co-conspirator A requested and sent it to Co-conspirator A via WeChat on or about April 16, 2019.

All in violation of Title 18, United States Code, Section 371.

UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

UNITED STATES OF AMERICA	)	Criminal No. 20CR10015
	)	
	)	Violations:
v.	)	
	)	Count One: Smuggling Goods From
ZAOSONG ZHENG,	)	the United States
	)	(18 U.S.C. § 554)
Defendant	)	
	)	Count Two: False Statements
		(18 U.S.C. § 1001(a)(2))

INDICTMENT

General Allegations:

A. The Defendant

1. ZAOSONG ZHENG ("ZHENG") is a Chinese national who entered the United States through the J-1 non-immigrant visa program ("J-1") on or about August 8, 2018. ZHENG's J-1 visa application was sponsored by Harvard University and granted by the State Department on or about July 17, 2018. While in the United States, ZHENG received a stipend of approximately $2,000 per month from the Chinese Scholarship Council. The Chinese Scholarship Council ("CSC") was established in 1996 as a non-profit institution affiliated with the PRC's Ministry of Education. The CSC is responsible for the enrollment and administration of Chinese Government Scholarship programs and provides funding for both undergraduate and graduate students, as well as post-doctoral visiting scholars, to Chinese citizens wishing to study abroad and to foreign citizens wishing to study in China. CSC is financed mainly by the state's special appropriations or scholarship programs.

2. ZHENG obtained medical degrees while living in the People's Republic of China

("PRC"). From in or about August 2018, and continuing until in or about December 2019, ZHENG conducted research in the area of biomedical sciences, specifically in cancer pathology, at the Beth Israel Deaconess Medical Center ("BIDMC").

B. Beth Israel Deaconess Medical Center and Wenyi Wei Laboratory

4. BIDMC is a teaching hospital and medical research facility of Harvard Medical School located in Boston, Massachusetts. BIDMC has numerous laboratories, including the Wenyi Wei laboratory. The focus of the Wei Laboratory is the study of cancer cells.

D. ZHENG Smuggles Vials Containing Biological Research and Specimens

5. Between on or about September 4, 2018, and on or about December 9, 2019, ZHENG worked at Wei's laboratory at BIDMC on cancer-cell research.

6. On or about Monday, December 9, 2019, ZHENG went to Boston Logan International Airport and attempted to leave the United States bound for Beijing, China on Hainan Airlines (HU) flight 482 with vials of biological materials and research he had stolen from Wei's laboratory.

7. Before ZHENG boarded HU flight 482, Customs and Border Protection ("CBP") officers located two checked bags in ZHENG's name and examined them. They discovered 21 vials wrapped in plastic and hidden in a sock. The vials were visually inspected and appeared to contain liquid. The officers suspected that the contents were biological in nature. As indicated below, the vials have been tested and analyzed and the results of this testing confirmed that the vials contained Deoxyribonucleic Acid ("DNA"), and therefore constitute biological specimens. Accordingly, ZHENG was required to package the vials in a heat sealed bag and label them with the words "[s]cientific research specimens, 49 CFR 173.4b applies." The vials were not

properly packaged or declared in accordance with U.S. transportation regulations.

8. CBP officers identified ZHENG and approached him before he boarded HU flight 482. CBP officers asked ZHENG multiple times if he was traveling with any biological items or research material in either his carry-on or checked luggage. ZHENG replied "no." ZHENG was then removed from the jetway and escorted to the baggage secondary area, where he acknowledged his ownership of the checked baggage containing the 21 vials.

E. ZHENG Admits He Stole Biological Research from BIDMC

9. On or about December 10, 2019, ZHENG returned to Logan Airport to board a flight destined for the PRC. When ZHENG arrived at the airport, he was met by Special Agents of the Federal Bureau of Investigation. With the aid of a Mandarin linguist, ZHENG was advised of his *Miranda* rights, which he waived, and was then interviewed. ZHENG explained that he worked at a laboratory at BIDMC, conducting research related to cancer. ZHENG admitted that he had stolen biological specimens from BIDMC and that he was planning to take the specimens to China so that he could conduct further research on the specimens in his own laboratory and publish the results under his own name.

10. On or about December 10, 2019, the vials found in ZHENG's luggage were sent to a government laboratory for testing. On or about January 17, 2020, the government received confirmation from the laboratory that the material in the vials contained DNA, and therefore constituted biological specimens for the purpose of Title 49, United State Code, Section 173.4b.

11. 49 C.F.R. § 173 sets forth the regulations for travel with hazardous materials. 49 C.F.R. § 173.4b regulates air travel with non-infectious biological specimens. In relevant part, it provides that:

> Non-infectious specimens, such as specimens of mammals, birds, amphibians, reptiles, fish, insects and other invertebrates . . . are not subject to the requirements of this subchapter[1] provided the following packaging, marking and documentation provisions, as applicable, are met:
> (1) The specimens are . . .
> (ii) Placed in vials or other rigid containers with no more than 30 mL of alcohol or alcohol solution. The containers are placed in a plastic bag that is heat-sealed;
> (2) The bagged specimens are placed in another plastic bag with sufficient absorbent material to absorb the entire liquid contents inside the primary receptacle. The outer plastic bag is then heat-sealed . . . and
> (5) The outer package must be legibly marked "Scientific research specimens, 49 CFR 173.4b applies."

COUNT ONE
Smuggling Goods From the United States
(18 U.S.C. § 554)

The Grand Jury charges:

12. The allegations contained in paragraphs 1-11 are hereby re-alleged and incorporated by reference as if fully set forth herein.

13. On or about December 9, 2019, in the District of Massachusetts, the defendant,

ZAOSONG ZHENG,

did fraudulently and knowingly export and send, and attempt to export and send, from the United States, merchandise, articles, and objects, to wit: biological specimens, contrary to the laws and regulations of the United States, specifically, 49 C.F.R. § 173.4b.

All in violation of Title 18, United States Code, Section 554.

[1] Those requirements set forth further regulations that govern the transportation of hazardous materials including infectious biological specimens.

COUNT TWO
False Statements
(18 U.S.C. § 1001(a)(2))

The Grand Jury further charges:

14. The allegations contained in paragraphs 1-11 are hereby re-alleged and incorporated by reference as if fully set forth herein.

15. On or about December 9, 2019, in the District of Massachusetts, the defendant,

ZAOSONG ZHENG,

knowingly and willfully made a materially false, fictitious and fraudulent statement and representation in a matter within the jurisdiction of the executive branch of the Government of the United States, that is, when asked by Customs and Border Protection officers whether he was traveling with any biological items or research material, he answered "no," when in fact he had hidden 21 vials containing biological specimens in his luggage.

All in violation of Title 18, United States Code, Section 1001(a)(2).

A TRUE BILL

[redacted]

FOREPERSON

BENJAMIN TOKOFF
ASSISTANT UNITED STATES ATTORNEY
DISTRICT OF MASSACHUSETTS

District of Massachusetts: January 21, 2020
Returned into the District Court by the Grand Jurors and filed.

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HAROLD G. PUTNAM
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Synthetic Nanoelectronic Probes for Biological Cells and Tissue

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Abstract

Research at the interface between nanoscience and biology has the potential to produce breakthroughs in fundamental science and lead to revolutionary technologies. In this review, we focus on nanoelectronic/biological interfaces. First, we discuss nanoscale field effect transistors (nanoFETs) as probes to study cellular systems, including the realization of nanoFET comparable in size to biological nanostructures involved in communication using synthesized nanowires. Second, we overview current progress in multiplexed extracellular sensing using planar nanoFET arrays. Third, we describe the design and implementation of three distinct nanoFETs used to realize the first intracellular electrical recording from single cells. Fourth, we present recent progress in merging electronic and biological systems at the 3D tissue level by using macroporous nanoelectronic scaffolds. Finally, we discuss future development in this research area, the unique challenges and opportunities, and the tremendous impact these nanoFET based technologies might have in advancing biology and medical sciences.

Keywords

Nanowire; field effect transistor; intracellular; extracellular; synthetic tissue

1. INTRODUCTION

Semiconductor science and technology is a driving force of the modern society due to the ever-increasing miniaturization of semiconductor processing and transistor devices(1–6). To continue the remarkable success of semiconductor technology and possibly produce new paradigms for logic, memory and sensor devices, many researchers have been investigating devices based on synthesized nanostructures(2,5,7–12) in which geometries, organizations and physical properties can be designed and controlled at the nanometer scale.

A wide spectrum of nanostructured materials have been designed and synthesized over the past several decades, including colloidal nanoparticles(13,14), semiconductor nanowires (NW)(3,4,15,16), and graphene(10,17–20), where properties distinct from their bulk counterparts have been discovered and exploited. For any class of nanostructured materials to become a platform for discovery and development, it is critical that new structures and

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DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

EXHIBIT 18

assemblies with tunable composition, morphology, and properties at different length scales be obtainable(3,10,18). In this regard, semiconductor nanowires have been recognized as one of the most successful platforms available today in nanoscience. First, it is now possible to design nanowire structures *de novo* and synthetically realize these structures with complex, yet controlled, modulations in composition(8,16,21–26), doping(16,23), defect(27–29) and even topography(30–32). Second, this high-level of synthetic control enables nanowire building blocks to be created that have predictable physical properties for testing fundamental limits of performance(5,16). Third, it is now possible to assemble hybrid or multicomponent functional materials in novel layout and configuration using these diverse nanowire building blocks(31,33–45), allowing for rational exploration of the possible applications of multi-component materials. With these characteristics and capabilities, nanowires are ideal building blocks for exploring what is possible in nanoscience and also creating new technologies. This has been the focus in nanoscience community over the past decade and continues to be so as it crosses over other disciplines, such as synthetic biology(46–51).

Research at the interface between nanoscience and biology has the potential to produce breakthroughs in fundamental sciences and lead to revolutionary technologies(52,53). In particular, the exploration and application of semiconductor nanowire materials and devices in cellular systems could produce unprecedented interactions down to the molecular level. Such interactions have been utilized to gain insights especially those relevant to human health by stimulating, recording from and delivering objects to single cells and tissues in controlled ways to induce desired physiological responses, while minimizing undesirable effects(52,53).

There are two types of nanowire-based platforms in biomedical sciences: *basic platforms* that can be readily adapted to address biomedical questions; and *advanced platforms* that are specifically designed to push the frontiers of what is possible by, for example, enabling a new measurement tool. The *basic platforms* use conventional nanowire material and device systems with well-exploited physical or chemical properties, and they also have wide-ranging applications in many other fields, such as energy scavenging systems(54–61) or components for integrated circuit(34,35). These *basic platforms*, such as planar nanowire field effect transistors(34,35,37,40,43) or vertical nanowire arrays(55–58,60,61), have been used in biomolecular sensing(52,53), extracellular recording(52,53), drug delivery(62–64) and localized cellular imaging(65). On the other side, the *advanced platforms* have been designed to address some intrinsic complexity in biology and medical sciences in way simply not possible previously. They allow new types or new scales of interact and measurements with their target systems(31,66–68), and in so doing, open up completely new opportunities in science and technology. Examples of *advanced platforms* include recent intracellular field effect transistor probes(31,67–69) and nanoelectronics-innervated synthetic tissues(66).

This review discusses the basic concepts of nanoscale field effect transistors (nanoFETs) and their applications in cellular electrophysiology. The first section highlights the motivation behind nanoFET probes to study cellular systems versus existing recording technologies, followed by the introduction of chemical synthesis to realize nanoFETs *de novo*. The second section gives an overview of the current progress in multiplexed extracellular sensing using planar nanoFET arrays. Electrical recordings at single cell, tissue and organ levels will be discussed, and their limits and promises will be delineated. The third section will detail the main designs and implementations of nanoFETs in intracellular electrical recording from single cells, the first paradigm change in intracellular electrophysiology since the 1950s. NanoFET based techniques will be compared with conventional micropipette and microelectrode probes, and the limits and future opportunities

of these new probes will be discussed. The fourth section will introduce very recent progress in merging electronic and biological systems at the 3D tissue level by introducing the new concept of macroporous nanoelectronic scaffolds. The first-ever nanoelectronics 'innervated' synthetic tissues will be reviewed and their applications will be discussed. The final section will present our perspectives on future development in this research area, the unique challenges and opportunities, and the tremendous impact these nanoFET based technologies might have in advancing biology and medical sciences.

2. FUNDAMENTALS OF NANOFET

2.1. Why and how are nanoFETs applied in biology and medicine?

The ability to make electrical measurements inside single cells or throughout the entire 3D space of the tissue can have many important impacts in electrophysiology and biomedical sciences. The patch clamp technique, in which a pulled glass micropipette filled with electrolyte is inserted into a cell, offers intracellular electrical measurements with high signal-to-noise ratio (S/N) and single ion channel recording capability(70). Ideally, the micropipette should be as small as possible to increase the spatial resolution and reduce the invasiveness of the measurement, and ideally, allow for recording from subcellular structures. However, the overall performance of the technique also depends on the impedance of the interface between the micropipette and the cell interior (*i.e.*, the smaller the probe tip size, the larger the junction impedance), which sets limits on the temporal resolution and S/N of the micropipette-based electrical probes(31,41). Advanced techniques that involve inserting metal or carbon microelectrodes or nanoelectrodes into cells or tissues could be subject to similar dilemma, because all these tools are single terminal devices and electrochemical thermodynamics and kinetics must be considered for device operation(71–78). We will discuss them in details in the subsequent sections.

In integrated circuits, the basic device element is a multi-terminal FET that uses either electrons or holes as the charge carriers(79) (Figure 1a). Although the charge carriers are ions in biological systems, there are many biophysical links that connect ions to electrons and holes in a FET. For example, the dynamic flow of ions in biological system can generate spatially defined field potential(80). The Poisson equation(81) links such potentials directly to the ionic current sources and sinks that produce them. The Goldman-Hodgkin-Katz voltage equation(81) has also been used in cell membrane physiology to determine the equilibrium potential across a cell's membrane, where it takes into account all of the ions that permeate through that membrane. The potentials, generated by ion flows and gradients, can function as the gate signals to modulate the electrical output in FET devices (Figure 1b and 1c). The sensitivity of a FET or how well the transistor can receive and amplify the gate signal is usually defined as transconductance (G_m)(6,52,53,79), which is inversely proportional to the dimension (L) of the active device(6). This fact implies that the use of nanoelectronics would have improved sensitivity compared to its bulk and planar counterparts. As shown in the following sections, nanoFETs have shown to be able to record electric potentials inside cells(31,67–69) and from the internal regions of synthetic tissues(66), and because their performance does not depend on impedance, they can be made much smaller than micropipettes and microelectrodes. Moreover, nanoFET arrays are better suited for multiplexed measurements(67,68).

2.2. Chemical synthesis of nanoFETs

Three distinct classes of *de novo* design and synthesis have been used to yield nanoFETs building blocks , covering structural motifs in one-dimension (1D), 2D and 3D (Figure 2). The basic semiconductor nanowire structure (Figure 2a, I) consists of a uniform composition, 1D structure with a diameter typically in the range of 3–500 nm. In the growth

process, which builds upon earlier work showing vapor-liquid-solid (VLS) growth of micrometer to millimeter diameter wires(82,83), the nanocluster catalyst (typically gold nanoparticles) forms a liquid solution with nanowire reactant component(s), and when supersaturated, acts as the nucleation site for crystallization and preferential 1D growth(84,85). Other growth mechanisms, such as vapor-solid-solid (VSS) and vapor-solid (VS)(15), can also be explored to yield high quality semiconductor nanowires. Within this framework, it is straightforward to synthesize nanowires with different compositions, such as groups III-V, IV and II-VI semiconductors(8,15,86,87), using the appropriate nanocluster catalysts and growth temperatures/pressures. Additionally, nanowire structures in which the composition, dopant and even growth mechanisms (*e.g.*, VLS, VSS) are modulated along axial(21,22,88–90) (Figure 2b) or radial directions(25,29,91)have also been widely exploited. These axial and radial nanowire heterostructures provide a number of advantages compared to homogeneous semiconductor nanowires, and they have proven exceptionally powerful for a broad range of electronic, photonic and optoelectronic device applications(16). For example, germanium/silicon core/shell nanowires have been chemically synthesized for high mobility nanowire FETs due to quantum confinement of carriers within the germanium core by the larger band-gap silicon shell(5,92–95).

The second structural motif was recently demonstrated by an approach in which topological centers are synthetically introduced in a controlled manner in linear 1D structures (Figure 2a, II)(31,32). In this area, we demonstrated that iterative control over nucleation and growth leads to kinked nanowires, in which the straight sections are separated by triangular joints and where doping can be varied at these topologically defined points (Figure 2c). Moreover, new work has shown that it is possible to control the stereochemistry of adjacent kinks in a manner that allows the synthesis of increasingly complex two- and three-dimensional structures akin to organic chemistry, thus opening up a great opportunity for the future in terms of designed synthesis(31).

A third basic motif involves the synthesis of branched or tree-like nanowire structures (Figure 2a, III)(24,26,96). To this end, we reported a rational, multistep approach toward the general synthesis of 3D branched nanowire heterostructures(24). Single-crystalline semiconductor, including groups IV, III–V, and II–VI, and metal branches have been selectively grown on core or core/shell nanowire backbones, with the composition, morphology, and doping of core (core/shell) nanowires and branch nanowireswell controlled during synthesis.

Although the first structural motif has been used most extensively as building blocks of *basic platforms*, the second and third motifs have much higher level of structural and functional complexity, and show great potential of bottom-up synthesis to yield increasingly powerful functional building blocks for *advanced platforms*.

3. MULTIPLEXED EXTRACELLULAR ELECTRICAL RECORDING

3.1. Why nanoFETs for multiplexed extracellular recording

Natural and synthetic cellular assemblies are usually organized into 2D or 3D hierarchical networks operating on spatial and temporal scales that span multiple orders of magnitude. Advances in microfabrication of high-density passive multielectrode arrays (MEAs) and active transistor arrays on silicon substrates enable direct electrical recording down to ca. 10 micrometer length scales, although it is important to recognize that signals recorded within ~100 μm are often correlated[4–6], and moreover, it has been difficult to to resolve the cellular signals at the single cell level. As mentioned above, simply reducing the size of individual metal electrodes to achieve more localized detection is not viable due to corresponding

increases in their impedance[7,8], which intrinsically limits the resolution of such passive recording devices.

Silicon nanowire nanoFET arrays have several features that make them unique for high-resolution multiplexed extracellular recording from cellular systems. First, previous studies have shown that nanowire nanoFETs can exhibit ultra-high sensitivity detection of charged biomolecules, including detection of single particles(53). Second, bottom-up fabrication of nanoFETs yields devices that have nanoscale protrusions from the substrate surface(53,97). This can reduce device to cell/tissue separation and promote enhanced cell-nanostructure interaction and has resulted in high S/N extracellular recording of field potentials from cultured cells and cardiac tissue with signals improved compared to planar FETs. Third, the bottom-up approach also enables high-performance nanoFET fabrication on transparent, flexible and stretchable substrates(34,38–40). The freedom to design device structures and arrays on substrates adapted to specific biological applications also opens up new possibilities for interfacing with living tissues, for example, bio-resorbable and implantable devices(98–101). This freedom also allows other measurements or manipulations to be performed in conjunction with nanoFET recordings, such as high-resolution optical imaging. Fourth, the active junction area of typical nanoFETs, 0.01~ 0.1μm^2, is much smaller and can provide better spatial resolution of signals compared to MEA and planar FETs that are 10^2 to 10^5 times larger in active area(41). Last, nanoFET detectors provide fast intrinsic response time which is critical for high temporal resolution recordings(95,102).

3.2. Electrical interfacing with cultured neurons

An early example of multiplexed nanoFET recording layout consists of a neonatal rat cortical neuron and four peripheral silicon nanoFETs that are arranged at the corners of a rectangle, where polylysine patterning was used to promote axon and dendrites growth across single nanoFETs(103) (Figure 3a). This multiplexed nanoFET/neurite hybrid was used to study spike propagation with NW1 as a local input to elicit action potential spikes. After stimulation with a biphasic pulse sequence, back propagation of the elicited action potential was detected in the two dendrites crossing elements NW2 and NW3. The lack of observed signal from NW4 demonstrates the absence of crosstalk in the hybrid device array, and thus the capability for multiplexed subcellular resolution detection.

3.3. Recording from cardiomyocyte monolayers

We also carried out multiplexed measurements using the nanoFET arrays interfaced with cultured embryonic chicken cardiomyocytes (Figure 3b)(33). The nanoFETs were patterned in a linear array with an average spacing of 300 μm so that signal propagation within cardiomyocyte monolayers could be characterized. Recording from multiple nanoFETs in contact with spontaneously beating monolayer yielded very stable and high S/N (>10) field potential spikes. In this experiment, the relative large signal magnitude confirmed that a good junction is formed between each of the nanoFETs and PDMS/cell substrate. Additionally, a cross-correlation method was used to determine robustly the time differences between the signals recorded by the devices. The time shifts between devices and device separations yielded propagation speeds of 0.07–0.21 m/s that are consistent with other measurement on cardiomyocyte monolayers. The variation in propagation speeds in these initial studies is not surprising given the monolayer inhomogeneity and suggests an important future direction. We suggest that high-resolution multiplexed nanoFET recording together with optical imaging will enable details of intercellular propagation to be characterized for well-defined cellular structures.

3.4. Recording from tissues and organs

Finally, nanoFETs have been used to probe electrical activities from tissues and organs(41,42). To this end, we have studied the activity patterns of layer II/III cells in the piriform cortex of acute rat brain slices by stimulating different sets of axon fibers in the lateral olfactory tract (LOT). In a representative experiment, eight devices within a four-by-four 2D array oriented under the pyramidal cell layer of an acute slice were simultaneously monitored following stimulation at eight different spots (*a–h*) in the LOT(41) (Figure 3c). Strong stimulation of all axons fibers in the LOT yielded similar response by nanoFETs *1–8* with clear population spike signals (postsynaptic activities) regardless of stimulation positions. Reduced stimulation intensity was also used so that at each spot only a subgroup of fibers was activated. Notably, visual inspection of 2D activity maps for each of the eight stimulation positions demonstrates clearly how heterogeneous activity can be resolved (Figure 3d), and thus define a complex functional connectivity in the piriform cortex.

3.5. Challenges and promises

Although great progress has been made in the extracellular electrical recordings using nanowire nanoFETs, many challenges remain. For example, there is still a pressing need to further enhance the nanoFET S/N so that very weak endogenous biological signals, with the amplitude of ~ 100 μV, can be readily resolved. We can potentially achieve this goal by (1) new chemical design and synthesis of high mobility nanowire building blocks for nanoFET, (2) nanoscale engineering of nanowire materials to reduce nanoFET noise by, for example, thermal annealing and/or surface passivation.

It is also important to note that the high input impedance of the nanoFETs circumvents the common challenges confronted by implanted microelectrodes, where gradual increases of single terminal device impedance due to, for example, absorption of proteins, leads to degraded S/N over time(41,104,105). This feature makes nanoFETs very promising for multiplexed, in vivo chronic recordings. This is particularly true considering the facts that (i) nanoscale device feature size allows integration of multiple nanoFETs on minimally invasive and movable electrophysiological probes(68), (ii) bottom-up fabrication makes it possible to choose biocompatible or even biodegradable materials as substrates to reduce mechanical mismatch and to minimize inflammatory tissue response(31,66,68,98–101), and (iii) the nanoscale topology could be arbitrarily designed *de novo* to promote better attachment of single cells or even intracellular contacts. Therefore, nanoFETs should bring many exciting opportunities to interfacing living tissue and organs with electronics for biomedical applications (*e.g.*, diagnostic devices for brain trauma and surgical tools for cardiac therapy), and even new cybernetic biosystems for hybrid information processing.

4. INTRACELLULAR ELECTRICAL RECORDING

4.1. Why intracellular?

As the key cellular component, lipid membranes represent important structural and protective elements of the cell that form a stable, self-healing, and virtually impenetrable barrier to the ions and small molecules(106). Since these membranes have resistance (R) and capacitance (C), the membrane RC circuit also behaves as an electrical barrier and would attenuate and even distort the intracellular signals as they are detected by extracellular sensors. More importantly, although cellular signal transduction often starts with an extracellular signaling molecules activating a cell surface receptor, it is the subsequent intracellular processing that eventually creates a cellular response. Deciphering of such intracellular signal transmission and amplification processes is critical to the understanding of cellular information flow and cell physiology. Therefore, it is highly desirable to deliver

nanoFETs into the cell and directly record intracellular electrical activities, which can provide much more detailed understanding of the inner workings of cells..

4.2. Why nanoFETs for intracellular recording?

Although nanoFETs have been exploited for ultrasensitive detection of biological markers and high-resolution extracellular recording from cells(53), localized and tunable intracellular sensing and recording had not been demonstrated prior to our work because all FET and nanoFET devices were created on planar substrates --- using the *basic nanoFET platform*. Ideally, rather than force the cell to conform to the substrate, a movable and 3D nanoFET with the necessary source (S) and drain (D) electrical connections could move into contact with the cell and probe within the cell membrane. However, minimally invasive insertion of a nanoFET into the confined 3D space of single cells, or even 3D cellular networks, was still a major challenge before year 2010 because the S and D typically dominated the overall device size and defined a planar and rigid structure, regardless of whether the nanoFET was on or suspended above a substrate. An *advanced nanoFET platform* that is designed specifically for intracellular measurement is needed to meet this requirement(32,67–69). Three distinct examples that we have recently introduced to address this central challenge are shown schematically in Figure 4a, and include (1) kinked nanowire nanoFET, (2) branched-intracellular nanotube nanoFET, and (3) active nanotube nanoFET devices.

Existing probes capable of intracellular sensing and recording include voltage-sensitive optical dyes or proteins(107–110), and single-terminal glass or carbon microelectrodes as mentioned briefly in prior section(70,72) (Figure 5). Voltage-sensitive dyes can readily be used to interrogate action potentials with high spatial resolution, but they still have limitations in terms of signal-to-noise (S/N) ratio, pharmacological side effects, phototoxicity, and difficulty in differentiating single spikes(108). For electrical probes (Figure 5), the single electrical connection facilitates design and mechanical insertion into cells, but the requirement of direct ionic and/or electrical junctions between probe tips and cytosol also introduce several limitations. First, the tip size of these probes (~0.2 to 5 μm) is a compromise between being small enough (<5 μm) to penetrate or rupture the cell membrane with minimum damage and large enough (>0.2 μm) to yield a junction impedance that is sufficiently low so that small cellular signals can be discerned from thermal noise. Second, direct exposure of intracellular species to extraneous probe surfaces or electrolytes in probe lumen, especially for larger glass micropipettes, might induce irreversible changes to cells and, thus, prevent long-term and noninvasive cellular recordings. Finally, these probe techniques are intrinsically passive and are not capable of built-in signal processing and facile integration with other circuitries, especially given the emerging need to enable a cell-machine communication(111–114).

NanoFETs can function in a sub–10-nm-size regime(2). In principle, their exceptionally small size enables them to function as mechanically noninvasive probes capable of entering cells through endocytic pathways, as can occur with nanoparticles(115–118). Moreover, when interfacing with cells, nanoFETs process input/output information without the need for direct exchange with cellular ions; thus, the issues of interfacial impedance and biochemical invasiveness to cells can be ignored or minimized (Figure 5). In addition, because signals are transduced by change in field/potential at well-isolated surfaces, nanoFETs can detect cellular potential, as well as biological macromolecules, and could be integrated for potential multiplexed intracellular measurements. Until recently, these advantages could not be exploited, although our recent work(31,67–69) (Figure 4a) has now shown three solutions that open up these exciting opportunities.

4.3. Designs and implementation of intracellular nanoFET probes

In 2010, the first nanoFET intracellular probes were designed and chemically synthesized without lithography to encode a ~ 100 nm FET device at the apex of a kinked nanowire(31) (Figure 4a,b). This was achieved through control over cis-/trans- conformations and modulation doping during the silicon nanowire synthesis(31,32). Subsequently, the free arms of such kinked nanowires were electrically contacted to free-standing and flexible electrodes. Electrical characterization of the 3D nanowire probes showed they were robust to mechanical deformation, recorded solution pH changes with high-resolution, and, when modified with phospholipid bilayers, recorded the intracellular potential of single cells. Significantly, electrical recordings of spontaneously beating cardiomyocytes demonstrated that the 3D nanoFET probes continuously monitored extra- to intracellular signals during cellular uptake for the first time. The nanometer size, biomimetic surface coating, and flexible 3D device geometry render these active semiconductor nanoprobes a new and powerful tool for intracellular electrophysiology.

The kinked nanoFET based intracellular recording represents the first example of interfacing semiconductor devices with cells intracellularly, but the kink configuration and device design also place certain limits on the probe size and the potential for multiplexing. To address these issues, we reported a new device platform in which a branched SiO_2 nanotube was synthetically integrated on top of a nanoFET (BIT-FET)(67)(Figure 4a,c). This branched nanotube penetrated the cell membrane, bringing the cell cytosol into contact with the extracellular FET, thus allowing intracellular recording of transmembrane potential. Studies of cardiomyocyte cells demonstrated that when phospholipid-modified BIT-FETs are brought close to cells, the nanotubes spontaneously penetrate the cell membrane and yield full-amplitude intracellular action potentials, thus showing that a stable and tight seal forms between the nanotube and cell membrane. Significantly, we also showed that multiple BIT-FETs can be used for multiplexed intracellular electrical recordings from both single cells and networks of cells.

Recently, we also demonstrated a conceptually new and practically simple nanoFET probe that consists of a single semiconductor nanotube(68)(Figure 4a,d). The fabrication of the active nanotube transistor (ANTT) intracellular probe involves the fabrication of S/D contacts to one end of a silicon or other semiconductor nanotube, and electrical isolation of these S/D contacts from surrounding medium. Then the solution filling the interior of the nanotube can gate the transistor and the variation of interior electrochemical potential is recorded as a change in device conductance. In experiments, the free end of ANTT probes were inserted into cardiomyocyte cells, and the time-dependent changes associated with action potential spikes were recorded by this nanoFET probe. As expected, if a similarly configured solid nanowire nanoFET was inserted into the cell, no signal was observed since it would not be possible to “gate” the nanoFET. Finally, the straightforward fabrication of ANTT devices was exploited to prepare multiple ANTTs at the end of single probes, which enabled multiplexed recording of full-amplitude intracellular action potentials from single cells, and multiplexed arrays of single ANTT device probes (Figure 4d).

4.4. Challenges and promises

Despite these advances, additional work remains to advance further the nanoFET-based intracellular measurement techniques (Figure 5). For example, the S/N is, at current stage, not better than that from glass micropipette recordings although spatial resolution is much higher. The current designs of nanoFETs only enable potential recordings, but measurement of ionic currents is also possible if other signal transduction mechanisms are combined with nanoFET. Moreover, the capability for cell stimulation in addition to recording is still lacking. Nevertheless, we believe that the advantages of the nanoFET intracellular probes

already demonstrated in our work, including the capability to realize sub-10 nm probes, ease of operations (*e.g.*, there is no need to compensate/calibrate the probe junction potential and capacitance, etc.), the biomimetic cellular entrance, minimal mechanical and biochemical invasiveness, and the potential for large-scale, high-density, multiplexed recording, make them very attractive new measurement tools that will extend substantially the scope of fundamental and applied electrophysiology studies to regimes hard to access by current methods. For example, an exciting future application of these nanoFET probes will be measuring membrane potentials directly from cellular organelles, a Holy Grail in intracellular electrophysiology.

5. NANOELECTRONICS INNERVATED SYNTHETIC TISSUES

The development of synthetic 3D macroporous biomaterials as extracellular matrices (ECMs) represents a key area because (i) functionalized 3D biomaterials allow for studies of cell/tissue development in the presence of spatiotemporal biochemical stimulants(119,120), and (ii) the understanding of pharmacological response of cells within synthetic tissues(121–123) is expected to provide a more robust link to *in vivo* disease treatment than that from 2D cell cultures. Advancing further such biomaterials requires capabilities for monitoring cells throughout the 3D microenvironment. While electrical sensors are attractive tools, it has not been possible to integrate such elements with porous 3D scaffolds for localized real-time monitoring of cellular activities and physicochemical changes.

Recent efforts in coupling electronics and tissues have focused on flexible, stretchable planar arrays that conform to tissue surfaces(10,42,53,98–101), or implantable microfabricated probes(124). These approaches have been used to probe electrical activities near surfaces of the heart, brain and skin, and they have shown translational potential. However, these new electronic tools are currently limited in merging electronics with tissues throughout 3D space while minimizing tissue disruption, because of the 2D support structures and the electronic sensors are generally much larger scale than the extracellular matrix (ECM) and cells. Our studies using nanoFETs have shown that electronic devices with nanoscopic features were able detect extra- and intracellular potentials from single cells but had also been limited to surface or near surface recording from tissue and organs(42,53). Merging electronics seamlessly throughout tissues (Figure 6a) had remained a major challenge. To address this challenge we recently set-forth the key constraints(66) include: (1) The electronic structures must be macroporous, not planar, to enable 3D interpenetration with biomaterials; (2) the electronic network should have nanometer to micrometer scale features comparable to biomaterial scaffolds; and (3) the electronic network must have 3D interconnectivity and mechanical properties similar to biomaterials (Figure 6b).

5.1. A new concept of merging electronics with cellular systems

Our fundamentally new approach integrates nanoelectronics into tissues in 3D, and the integrative synthetic approach involved stepwise incorporation of biomimetic and biological elements into nanoelectronic networks across nanometer to centimeter size scales(66) (Figure 6a). First, chemically synthesized kinked or uniform silicon nanowires were registered and electrically connected to yield FETs (step A, Figure 6a), forming the nanoelectronic sensor elements for hybrid biomaterials. Second, individual nanoFET devices were arranged and integrated into free-standing macroporous scaffolds (step B, Figure 6a), termed ‘nanoelectronic scaffolds’ (nanoES). The nanoES were tailored to be 3D, to have nanometer to micrometer features with high (>99 %) porosity, and to be highly flexible and biocompatible. NanoES could also be hybridized with biodegradable synthetic ECMs to enable suitable cellular microenvironments prior to tissue culture. Finally, cells were cultured inside nanoES or hybrid nanoES (step C, Figure 6a), with subsequent generation of biological species and the merging of cells with nanoelectronics in 3D. The entire

biomimetic process make a natural transition from electronic to biological systems by integrating the third component, nanoES, into the synthetic tissues (Figure 6c). Metal-electrode or carbon nanotube/nanofiber based passive detectors are not considered in our work because impedance limitations (*i.e.*, signal/noise and temporal resolution degrade as the area of the metal or carbon electrodes is decreased) make it difficult to reduce the size of individual electrodes to the subcellular level, a size regime necessary to achieve noninvasive 3D interface of electronics with cells in tissue.

5.2. Designs and preparation of synthetic tissues

In our experiments, we have designed two types of 3D macroporous nanoES (reticular- and mesh- nanoES) to mimic the structure of natural tissue scaffolds (Figure 7)(66). These nanoES were formed by self-organization of coplanar reticular networks with built-in strain (Figure 7a) and by manual manipulation of 2D mesh matrices (Figure 7b). We showed that nanoES exhibited robust electronic properties and could be used alone or seamlessly merged with other biomaterials as biocompatible extracellular scaffolds for efficient 3D culture of neurons, cardiomyocytes and smooth muscle cells (Figure 7c,d). Significantly, we have demonstrated multiplexed electrical recordings of extracellular field potentials from 3D nanoelectronic innervated cardiac patches, including the effects of drugs (Figure 7e,f). The results suggested the feasibility of continuous electrical monitoring of engineered tissue in 3D for *in vitro* therapeutic assays. Finally, we have used 3D distributed nanoelectronic devices for simultaneous monitoring of pH inside and outside an engineered tubular vascular construct that was developed from the nanoelectronic scaffold, suggesting the potential of a multifunctional prosthetics.

5.3. Challenges and promises

These results open up a new field whereby nanoelectronics are merged with biological systems in 3D, and as in any nascent area opportunities and challenges abound. For example, the sensing capabilities could be broadened to address various disease states, *in vitro* (organ-on-a-chip) or *in vivo*(125) by exploiting the diverse nanowire building blocks available from designed synthesis. Cell or tissue interactions with nanoES could be fine-tuned by modification with cell growth determinants(121). NanoES could be enhanced to provide electrical and mechanical stimulation to enhance cell culture; *in vivo* these properties could provide functionalities such as pacing, and moduli that match those of host tissues. Long-term *in vivo* biocompatibility of nanoES should be studied. One can envision nanoES-based tissues that are hard-wired to provide closed-loop systems that sense and treat, that enable telemetric monitoring of physiological processes, or that provide connections between engineered constructs with the host nervous system.

6. WHAT'S NEXT?

The challenges associated with nanotechnology applications in biomedical sciences are numerous, but the impact on understanding how the cardiac or nervous systems work, how they fails in disease and how we can intervene at a nanoscopic or even a molecular level is significant. For example, neural developmental factors, such as the cadherins, laminins and bone morphometric protein families, as well as their receptors, could be manipulated in new ways(126). The bottom-up nanowire nanotechnology offers the capacity to explore the functional specificity of these molecules by incorporating them into pre-defined locations in nanowire devices to have highly targeted effects towards single cells.

The merging of nanoelectronics or nanoscience in general with the entire fields of synthetic biology and/or system biology(46,47) is also tempting and could be highly rewarding. This would be one of the next big leaps in materials sciences and biological sciences. It is

especially true given that there's a whole toolbox of nanoelectronic and nanophotonic devices that one can think about building into cellular circuitry and merging them with biological information processing systems, and the fact that we have already achieved the intracellular interrogation(31) and the 3D electrical innervation of tissues(66) with semiconductor nanoelectronics!

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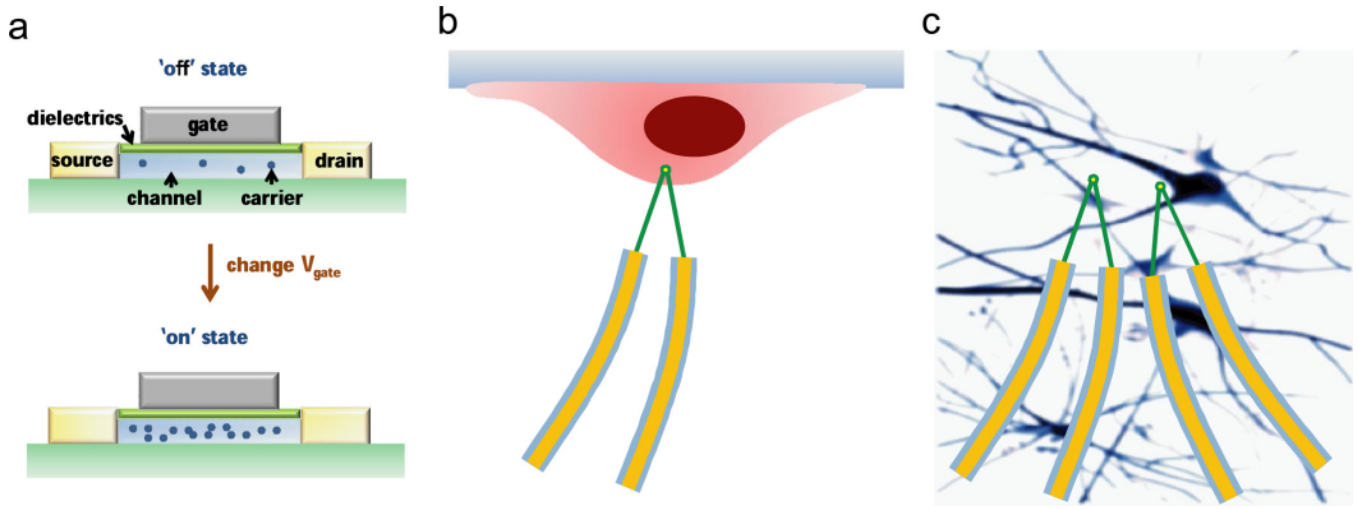


Figure 1. FET basics and electrical interfaces between nanoFET and biological systems

(*a*) Schematic of a planar FET device. In FET, current flows along a semiconductor path called the channel. At one end of the channel, there is an electrode called the source. At the other end of the channel, there is an electrode called the drain. The third electrode that applies a voltage to the channel is called gate, which modulates the electron/hole carrier density and the output of the FET devices. A small voltage change in gate signal can cause a large variation in the current from the source to the drain. This is how FET works and in particular, amplifies signals. (*b-c*) Schematics of electrically based cellular sensing using a kinked nanoFET, where intracellular potentials (*b*) or extracellular field potentials (*c*) can be used to change the nanoFET conductace, analogous to applying a voltage using a gate electrode.

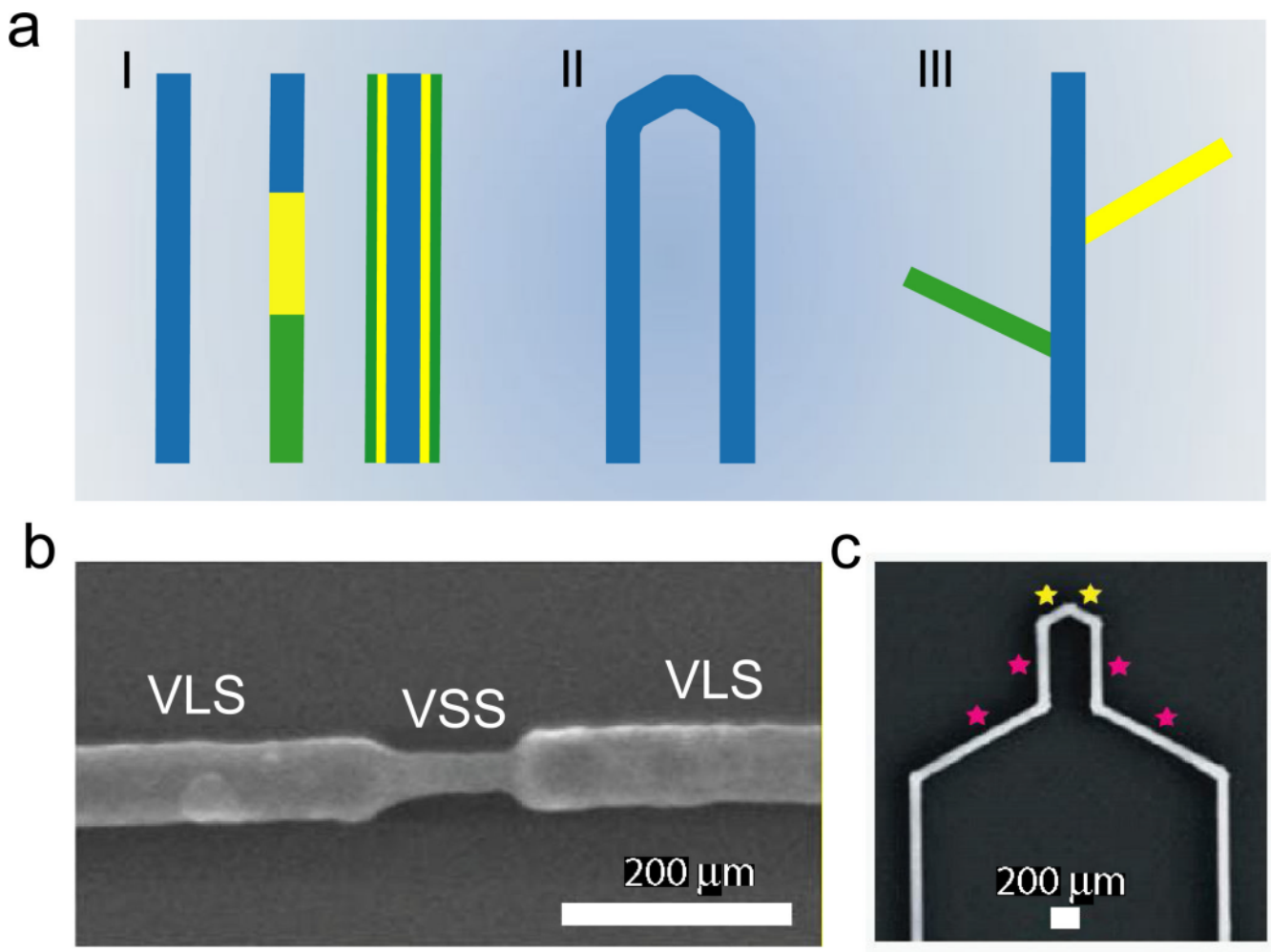


Figure 2. Semiconductor nanowire structural motifs for nanoFETs

(*a*) Schematics of 1D (I), 2D (II) and 3D (III) motifs. 1D motif (I) can have uniform composition and doping (I, left) or axially (I, middle) or radially (I, right) modulated. A kinked nanowire with structurally coherent "kinks" introduced in a controlled manner during axial elongation represents an example of 2D motif (II). Heterobranched nanowires yield 3D structure (III) and the branch junction (*e.g.*, blue/yellow segment junction) can be exploited for localized sensing. (*b*) An axial nanowire heterostructure made by modulation in VLS/VSS growth mechanisms. (*c*) A multiply kinked nanowire showing a probe structure. Yellow and magenta stars denote *cis*- and *trans*- conformations, respectively.

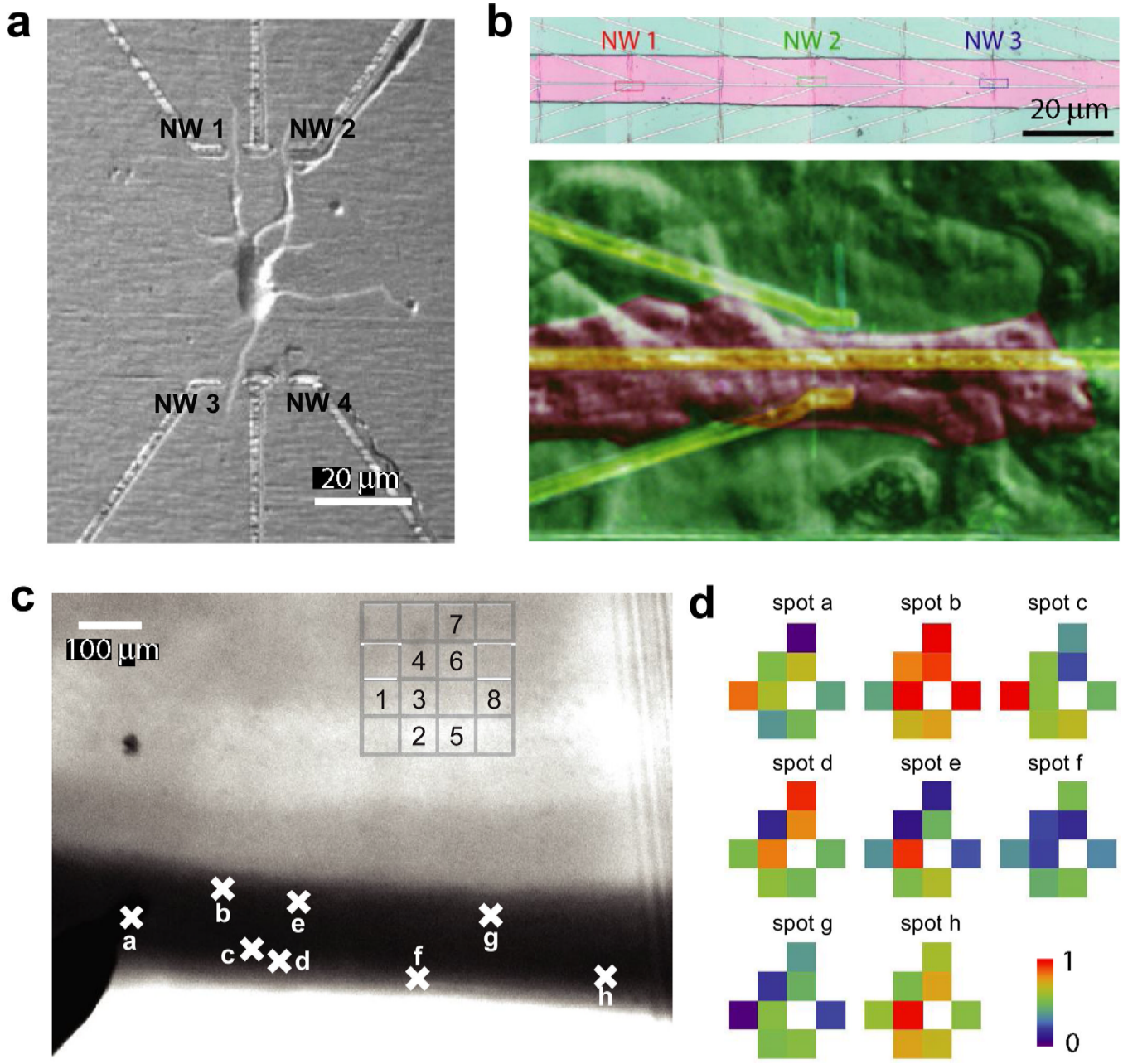


Figure 3. Multiplexed extracellular electrical recordings using nanoFETs

(*a*) Optical image of a cortical neuron interfaced to three of the four functional nanoFETs in an array. (*b*) upper panel, optical micrograph showing three nanoFET devices (NW1, NW2, and NW3) in a linear array, where pink indicates the area with exposed NW devices. Lower panel, a differential interference contrast bright field image showing individual cardiomyocytes (purple) and single nanoFETs (yellow). (*c*) Optical image of an acute slice over a 4 × 4 NWFET array. Signals were recorded simultaneously from the eight devices indicated on the image. Crosses along the LOT fiber region of the slice mark the stimulation spots *a–h*. The stimulator insertion depth was not controlled precisely in these experiments. (d) Maps of the relative signal intensity or activity for devices 1–8.

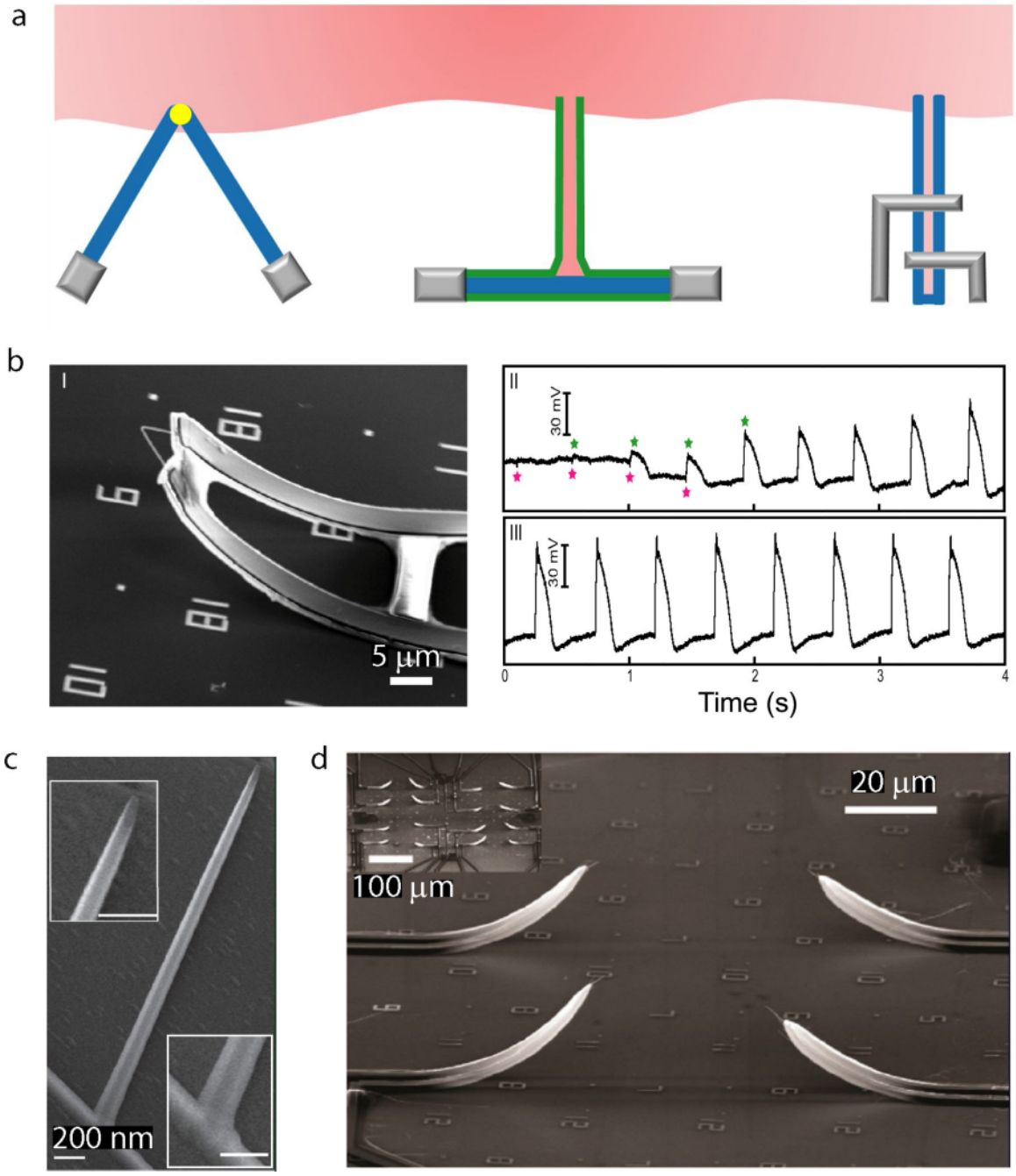
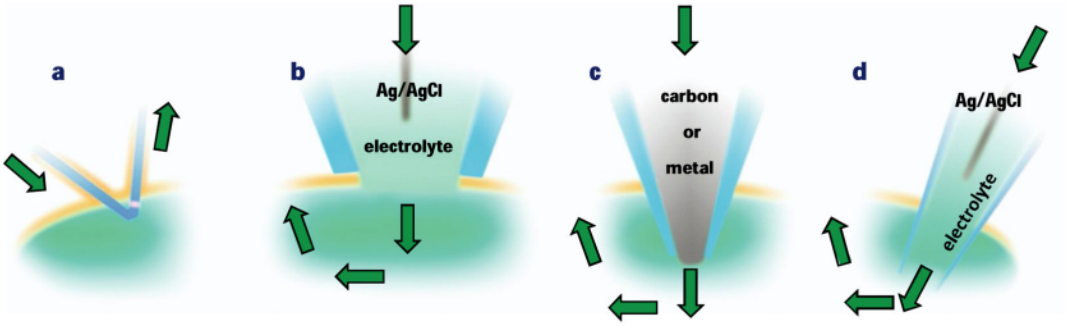


Figure 4. Intracellular electrical recordings using nanoFETs

(*a*) Schematics of kinked nanoFET (left), BIT-FET (middle) and ANTT (right) probes. (*b*) SEM image of a kinked nanoFET probe (I) and its intracellular electrical recordings (II, III) from spontaneously beating cardiomyocytes. (*c*) SEM of a BIT-FET probe, insets highlight the tip and root parts of the hollow branch. (*d*) SEM image of ANTT probe array.



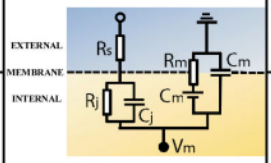
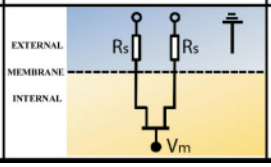
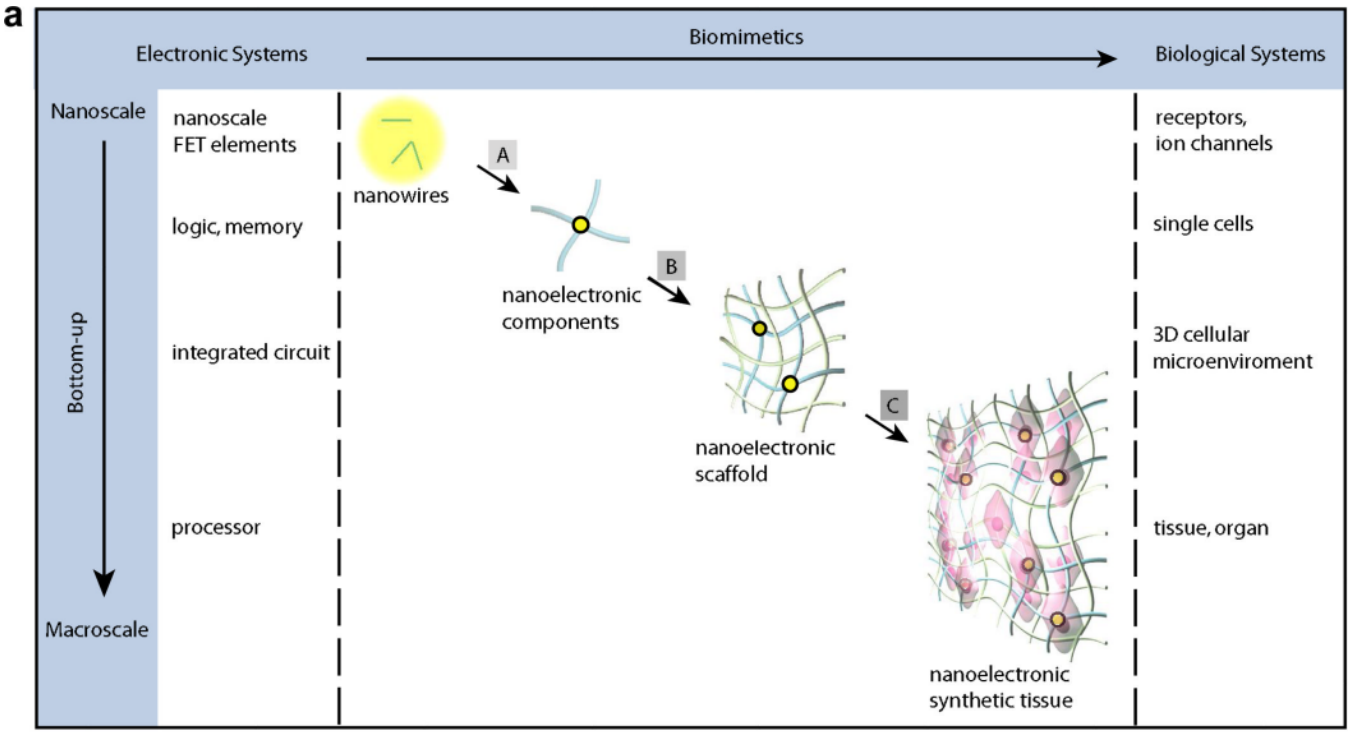
IC technique	Equivalent circuit	Size (nm)	Calibrations	Capabilities	Invasiveness	Cellular entrance
Glass micropipette (b and d)		~ 50-5000 Impedance limited	Both amplitude and shape	Can record both current and voltage, Single ion channel to whole cell recording	Electrochemical and mechanical	Mechanical or electrical
Carbon or metal micro-/nano-electrode (c)		~500-1000 Impedance limited	Both amplitude and shape	Can record both current and voltage, Whole cell recording	Electrochemical and mechanical	Mechanical or electrical
nanoFET (a)		~10-100	Amplitude	Can only record voltage, Whole cell recording, Multiplexing is scalable, High spatiotemporal resolutions	Minimal	Biological

Figure 5. A comparison between kinked nanoFET probe (a) and conventional intracellular tools (b–d)

The green arrows in (a–d) indicate the current flows. R_s, series resistance; R_j, junction resistance; R_m, membrane resistance; V_m, intracellular potential; C_j, junction capacitance; C_m, membrane capacitance.



b

	Targets	Approaches	Implementation Examples	Steps		
Biomimetics	Composition	+ Synthetic polymer	Deposit PLGA, alginate	A	B	
		+ Natural polymer	Add or secrete collagen, polysaccharides		B	C
		+ Cellular species	Biosynthesize proteins and lipids			C
		- Electronic materials	Reduce silicon, metals, dielectrics	A	B	
	Structure	+ Porosity	Increase to > 90%	A	B	
		- Feature size	Decrease to sub-micrometer	A	B	
	Mechanics	+ Flexibility	Decrease bending stiffness to < 10 nN·m	A	B	C
		+ Stretchability	Use serpentine device designs	A	B	C
	Bio-functions	+ Morphogenesis	Enable cell growth and proliferation			C
		+ Other Signalings	Activate ECM cues		B	C
		- Cytotoxicities	Use biocompatible materials	A	B	

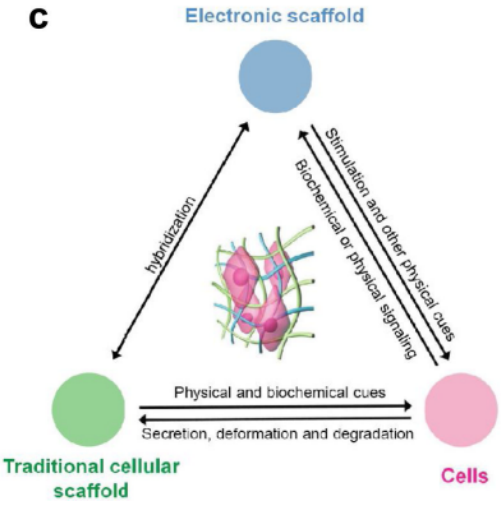


Figure 6. Integrating nanoelectronics with cells and tissue

Conventional bulk electronics are distinct from biological systems in composition, structural hierarchy, mechanics and function. Their electrical coupling at the tissue/organ level is usually limited to the tissue surface, where only boundary or global information can be gleaned unless invasive approaches are used. (*a*) A new concept was introduced where an integrated system can be created from discrete electronic and biological building blocks (for example, semiconductor nanowires, molecular precursors of polymers and single cells). Three biomimetic and bottom-up steps have been designed: step A, patterning, metallization and epoxy passivation for single-nanowire FETs; step B, forming 3D nanowire FET matrices (nanoelectric scaffolds) by self or manual organization and hybridization with traditional ECMs; step C, incorporation of cells and growth of synthetic tissue through biological processes. Yellow dots: nanowire components; blue ribbons: metal and epoxy

interconnects; green ribbons: traditional ECMs; pink: cells. (*b*) Rationale and approaches for biomimetic implementation of nanoelectronics innervated synthetic tissues. A, B and C are the same steps used in (*a*). (*c*) The new electronic scaffold component in synthetic tissues enables additional interactions with traditional cellular scaffold and cells.

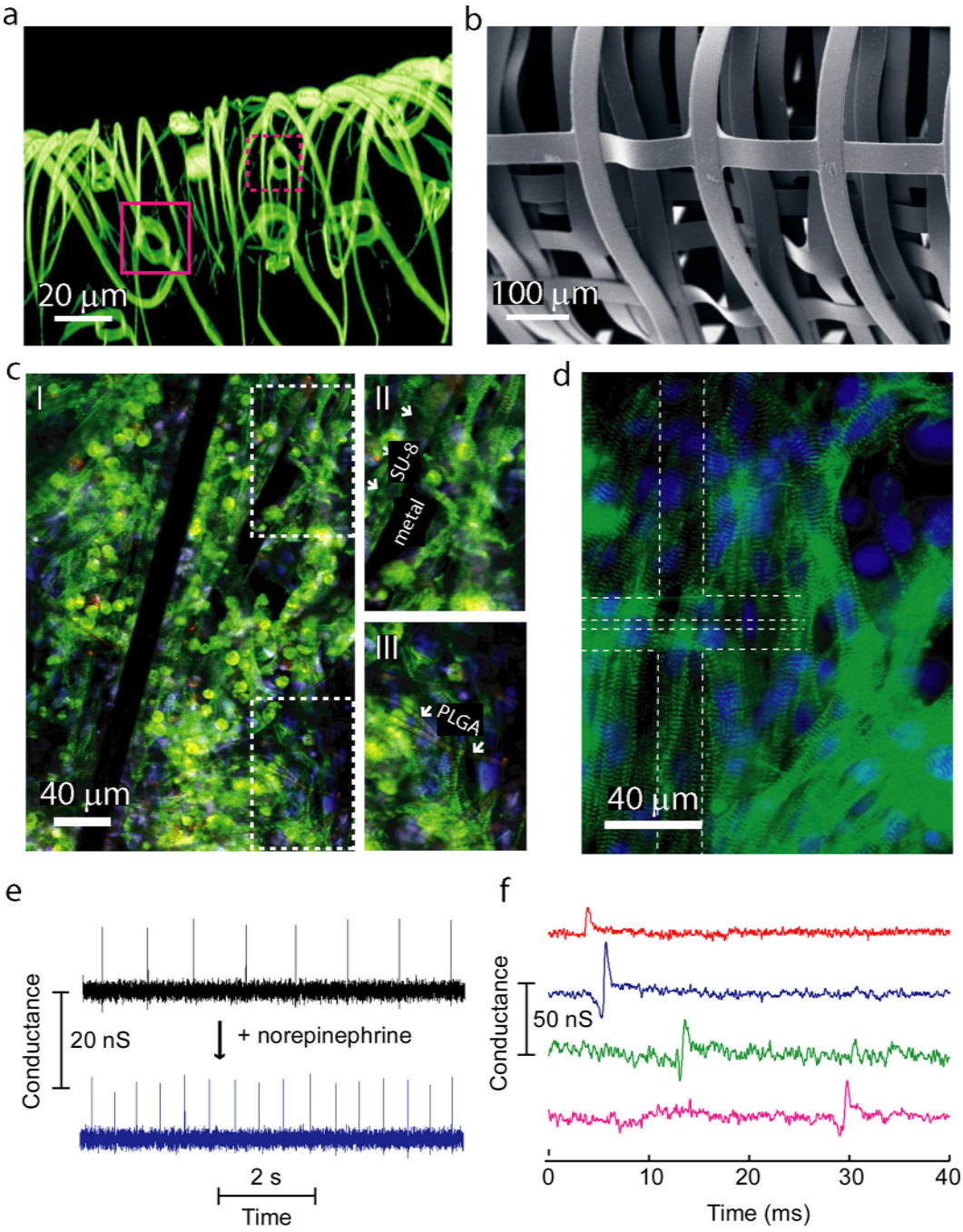


Figure 7. NanoES and synthetic tissues

(*a*) 3D reconstructed confocal fluorescence micrographs of reticular nanoES. The scaffold was labelled with rhodamine 6G. Solid and dashed open magenta squares indicate two nanowire FET devices located on different planes. (*b*) SEM image of a loosely packed mesh nanoES, showing the macroporous structure. (*c*) Confocal fluorescence micrographs of a synthetic cardiac patch. (II and III), Zoomed-in view of the upper and lower dashed regions in I, showing metal interconnects, the SU-8 scaffold (arrows in II) and electrospun PLGA fibres (arrows in III). (*d*) Epi-fluorescence micrograph of the surface of the cardiac patch. Green (Alexa Fluor 488): α-actin; blue (Hoechst 34580): cell nuclei. The position of the source–drain electrodes is outlined with dashed lines. (*e*) Conductance versus time traces

recorded from a single-nanowire FET before (black) and after (blue) applying noradrenaline. (*f*) Multiplex electrical recording of extracellular field potentials from four nanowire FETs in a mesh nanoES. Data are conductance versus time traces of a single spike recorded at each nanowire FET.

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February 19, 2020 · 4:00 AM ET

GEOFF BRUMFIEL

Harvard University professor Charles Lieber leaves the Moakley Federal Courthouse in Boston late last month.

Charles Krupa/AP

Until late last month, Charles Lieber lived the quiet life of an elite American scientist. His lab at Harvard University researched things like how to meld tiny electronics with the brain. In his spare time, he grew award-winning pumpkins in front of his house.

EXHIBIT 19

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SHORT WAVE

Harvard Professor's Arrest Raises Questions About Scientific Openness

February 19, 2020 · 4:00 AM ET

GEOFF BRUMFIEL

"This is a big, big case," says Frank Wu, a professor at the University of California Hastings College of the Law who tracks Chinese espionage cases. "This is a case that's all about U.S.-China relations. It's about competition. It's about how science should be done."

MILITARY TECHNOLOGY SOCIAL MEDIA

DARPA to 'exploit social media, messaging & blog data' to track geopolitical influence campaigns

If abused, the data exploitation could end up serving geopolitical influences in its own right: perspective

Tim Hinchliffe 4 months ago no comment darpa , geopolitics , military technology , pentagon , perspective , social media monitoring

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From bad to good: Chang the lives of the forme incarc

The power to monitor, track, and potentially quash online campaigns before they become popular is getting a whole lot easier.

With the goal of detecting geopolitical influence campaigns while they are still evolving, DARPA is looking to exploit data from social media, messaging, online blogs, and digital news sources with a new research program.

And today, the Defense Advanced Research Projects Agency (DARPA) held an invite-only proposers day on Zoom to go over its new INfluence Campaign Awareness and Sensemaking (INCAS) program.

> *"INCAS will exploit primarily publicly-available data sources including multilingual, multi-platform*

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TECH AND SOCIETY

> *social media (e.g. blogs, tweets, messaging), online news sources, and online reference data sources" — DARPA*

The INCAS research program is aimed at detecting, categorizing, and tracking online geopolitical influence campaigns, including those that fly under the radar of most analysts, while simultaneously looking to reduce the influence of cognitive biases, such as confirmation bias, in the process.

To achieve its goals, "INCAS will exploit primarily publicly-available data sources including multilingual, multi-platform social media (e.g. blogs, tweets, messaging), online news sources, and online reference data sources," according to the INCAS special notice.

If ever politicized, this type of DARPA-funded research could end up becoming its own antithesis — a geopolitical influence campaign in its own right.

DARPA has been funding research into monitoring social media and online news sources for a long time now, and big tech companies like Google, Twitter, and Facebook openly embrace this tactic with every type of coordinated inauthentic behavior removal update they give.

Back in 2011, DARPA launched the Social Media in Strategic Communication (SMISC) program "to help identify misinformation or deception campaigns and counter them with truthful information" on social media.

Sound familiar with what's happening on social media news feeds today?

> *"The INfluence Campaign Awareness and Sensemaking program will develop techniques and tools that enable analysts to detect, characterize, and track geopolitical influence campaigns with quantified confidence" — DARPA*

While DARPA serves to advance the capabilities of the US military, the technology developed often has a way of breaking-in to the private sector somewhere down the road.

For example, "DARPA-funded research [...] has led to the development of both military and commercial technologies, such as precision guided missiles, stealth, the internet, and personal electronics," according to a March 17, 2020 Congressional Research Service Overview report.

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Changing The 'Chatter' Of Our Inner Voice From Destructive To

Curtis Hougland

Recently, it was reported that DARPA-incubated tech — which was originally developed for combating ISIS propaganda — was overtly politicized by a Political Action Committee (PAC) founded by an ex-DARPA contractor to target and monitor the president of the United States, although DARPA said the claim was misleading.

Back in May, the *Washington Post* reported that the Defeat Disinfo PAC, founded by Curtis Hougland, was "using open-source technology initially incubated with funding from DARPA," and that it was "in service of a domestic political goal — to combat online efforts to promote President Trump's handling of the coronavirus pandemic."

Following publication of *Washington Post* story that was later picked up by *FOX News*, DARPA issued a statement on Twitter saying that "Hougland's claim DARPA funded the tech at the heart of his political work is grossly misleading," and that the agency was "apolitical."

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Additionally, a DARPA spokesperson told *FOX News*, "Unequivocally, DARPA funding did not help advance the technology with which Hougland now works any more than does his use of other agency technologies like the internet or mobile phone."

The narrative remains; however, that "Hougland had received funding from DARPA [...] to assist in the

propaganda fight against ISIS, which had developed a small but sophisticated content machine that exploited social networks to amplify its vision," according to *Vanity Fair*.

Hougland would later found an AI startup called Main Street One, along with a Political Action Committee that leveraged his own startup's technology in a way that appears to be very similar to what he allegedly saw at DARPA.

His startup, Main Street One, aims "to win narratives online for campaigns, causes, and companies," according to a section of its mission statement.

> *"INCAS is not specifically focused on detecting misinformation or bot activity" — DARPA*

Now, DARPA is set to launch the INCAS program, which "will develop techniques and tools that enable analysts to detect, characterize, and track geopolitical influence campaigns with quantified confidence"
using automated influence detection across social media, digital media, and other online data sources.

If DARPA's INCAS program is successful in achieving its goals, the technology it develops would have the power to detect influence campaigns that are often overlooked by analysts because they get so little traffic.

DARPA says that these "'low and slow' campaigns are hard to detect early as their message volume may be beneath platform trending thresholds."

The research program "is *not* specifically focused on detecting misinformation or bot activity, as influence

campaigns may exploit a variety of tactics and true information, but should be able to exploit such signals from extant capabilities to aid in detecting influence messaging," according to the special notice.

Theoretically, DARPA's INCAS program could create technology that would allow analysts to detect and take action against online movements before they get a chance to grow.

Whether online campaigns be nefarious or benign, the power to monitor, track, and quash them before they gain popularity is getting a whole lot easier.

Facebook's Portal born out of Pentagon-inspired Building 8

Facebook has a new hardware product called Portal, a video sharing device which has Amazon's voice assistant Alexa built-in, and it is the first physical product released from Building 8. The breach of 50 million Facebook user accounts and a loss of $11 billion didn't stop Facebook CEO Mark Zuckerberg from today launching the presale ... Continue reading

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IARPA awards a research contract for extracting data from text to Raytheon BBN, which harvests the text of social media postings and other data. “An opportunity to develop better methods to extract complex semantic information from documents” The Intelligence Advanced Research Projects Activity (IARPA) has awarded contracts for its Better Extraction from Text Towards Enhanced Retrieval … Continue reading

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Tim Hinchliffe

Tim Hinchliffe is the editor of The Sociable. His passions include writing about how technology impacts society and the parallels between Artificial Intelligence and Mythology. Previously, he was a reporter for the Ghanaian Chronicle in West Africa and an editor at Colombia Reports in South America.
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Henry Schein Named to Fortune® Magazine's 'Change the World' List

Company Recognized for Its Role as Co-Founder and Private Sector Lead of the Pandemic Supply Chain Network

EXHIBIT 21

https://fortune.com/change-the-world/2020/search/ (Graphic: Business Wire)

September 21, 2020 08:05 AM Eastern Daylight Time

MELVILLE, N.Y.--(BUSINESS WIRE)--Henry Schein, Inc. (Nasdaq: HSIC) announced today that it has been named to FORTUNE® magazine's "Change the World" list, an annual ranking of companies that have had a positive social impact through activities that are part of their core business strategy. Henry Schein was recognized for its role in helping to create the Pandemic Supply Chain Network (PSCN), a public-private partnership aimed at saving lives by strengthening the resilience of the global health supply chain in response to pandemics. Henry Schein serves as the PSCN's private sector lead.

The PSCN, co-founded by Henry Schein, is a public-private initiative that brings together the private sector and global organizations – including the World Health Organization, World Economic Forum, the United Nations World Food Programme, the World Bank, the U.S. Centers for Disease Control, UNICEF, and approximately 60 health care manufacturers and suppliers – to embrace a common commitment to a cause. Since the PSCN's inception, Henry Schein, as private sector lead, has worked intensively to develop a platform for data sharing, market visibility, and operational coordination for health care products to more effectively match global demand with global supply.

The trust-based relationships built between sectors through the PSCN has been crucial in enabling the sharing of information and facilitating the ability of key stakeholders to navigate together the supply chain challenges caused by global pandemics.

"Henry Schein is driven by a sense of purpose and mission, and we are honored to be named to FORTUNE® magazine's 'Change the World' list for our enduring commitment to these values," said Stanley M. Bergman, Chairman of the Board and Chief Executive Officer of Henry Schein. "Since our founding in 1932, Henry Schein has been guided by the belief that we can align our strengths as a business with the needs of society to make a positive difference. Through the Pandemic Supply Chain Network, we have had the opportunity to work with leaders from all sectors of society to help create a safer world through more effective pandemic preparedness and response."

Since the onset of the COVID-19 pandemic in late 2019, the PSCN has taken an active role in developing critical tools to strengthen the supply chain, including advocacy, procurement, and product recommendations. Henry Schein's long-term leadership in the PSCN enabled the Company to deploy insights in response to the COVID-19 pandemic, specifically advocating for and disseminating guidelines for proper usage of personal protective equipment (PPE) to promoting the judicious use of PPE. The Company's collaboration with its PSCN partners reinforces Henry Schein's commitment to public-private partnerships as a means of addressing complex societal issues.

FORTUNE® magazine's "Change the World" list celebrates companies and leaders that embrace corporate purpose and recognize how it can add value to business and society. FORTUNE® evaluates the companies by measurable social impact, business results, degree of innovation, and corporate integration. To view the entire list, please visit: https://fortune.com/change-the-world/.

About Henry Schein, Inc.

Henry Schein, Inc. (Nasdaq: HSIC) is a solutions company for health care professionals powered by a network of people and technology. With approximately 19,000 Team Schein Members worldwide, the Company's network of trusted advisors provides more than 1 million customers globally with more than 300 valued solutions that improve operational success and clinical outcomes. Our Business, Clinical, Technology, and Supply Chain solutions help office-based dental and medical practitioners work more efficiently so they can provide quality care more effectively. These solutions also support dental laboratories, government and institutional health care clinics, as well as other alternate care sites.

Henry Schein operates through a centralized and automated distribution network, with a selection of more than 120,000 branded products and Henry Schein private-brand products in stock, as well as more than 180,000 additional products available as special-order items.

A FORTUNE 500 Company and a member of the S&P 500® index, Henry Schein is headquartered in Melville, N.Y., and has operations or affiliates in 31 countries. The Company's sales from continuing operations reached $10.0 billion in 2019, and have grown at a compound annual rate of approximately 13 percent since Henry Schein became a public company in 1995.

For more information, visit Henry Schein at www.henryschein.com, Facebook.com/HenrySchein, and @HenrySchein on Twitter.

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