AFRL-AFOSR-VA-TR-2021-0047

Direct-write Nano Josephson Superconducting Tunnel Junctions

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06/15/2021
Final Technical Report

Air Force Research Laboratory
Air Force Office of Scientific Research
Arlington, Virginia 22203
Air Force Materiel Command

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
15-06-2021	Final	15 May 2015 - 15 Feb 2021

4. TITLE AND SUBTITLE
Direct-write Nano Josephson Superconducting Tunnel Junctions

5a. CONTRACT NUMBER

5b. GRANT NUMBER
FA9550-15-1-0218

5c. PROGRAM ELEMENT NUMBER
61102F

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
UNIVERSITY OF CALIFORNIA, SAN DIEGO
9500 GILMAN DR
LA JOLLA, CA 92093
USA

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AF Office of Scientific Research
875 N. Randolph St. Room 3112
Arlington, VA 22203

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/AFOSR RTA1

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-AFOSR-VA-TR-2021-0047

12. DISTRIBUTION/AVAILABILITY STATEMENT
A Distribution Unlimited: PB Public Release

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This report is for the period May 15, 2015 to February 15, 2021, and contains a summary of our key results, and accomplishments. The specific aim of this grant was to study the basic device physics of helium ion fabricated Josephson junctions and how their transport properties are affected by anisotropy in high-temperature superconductor materials. Our work involved materials synthesis, nanoscale device fabrication and advanced electrical measurements. Educationally this grant finically supported, a project scientist, an Assistant Professor, 2 post-doctoral researchers, 7 graduate students, and 2 undergraduate research assistants. Research activities of several other students were indirectly supported through the use of AFOSR supported equipment, and materials produced using processes developed under this award.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			KENNETH GORETTA
U	U	U	UU	12	**19b. TELEPHONE NUMBER** *(Include area code)* 426-7349

AFOSR Final Technical Report

FA9550-15-1-0218 *Direct-write Nano Josephson Superconducting Tunnel junctions*
Professor Shane Cybart, UC Riverside
Professor Robert Dynes, UC San Diego

Abstract:
This report is for the period May 15, 2015 to February 15, 2021, and contains a summary of our key results, and accomplishments. The specific aim of this grant was to study the basic device physics of helium ion fabricated Josephson junctions and how their transport properties are affected by anisotropy in high-temperature superconductor materials. Our work involved materials synthesis, nanoscale device fabrication and advanced electrical measurements. Educationally this grant finically supported, a project scientist, an Assistant Professor, 2 post-doctoral researchers, 7 graduate students, and 2 undergraduate research assistants. Research activities of several other students were indirectly supported through the use of AFOSR supported equipment, and materials produced using processes developed under this award.

Introduction:
Since the discovery of the unconventional copper-oxide high-transition-temperature superconductors (HTS), researchers have explored many methods to fabricate superconducting tunnel junctions from these materials for fundamental measurements essential for testing and guiding theories for the still-unsolved explanation of these remarkable superconductors. The difficulty is that the superconducting coherence length is very short and anisotropic in these materials; typically, ~2 nm in the *a*-*b* plane and ~0.2 nm along the *c*-axis. The coherence volume encloses only a few superconducting pairs, so even the presence of small scale inhomogeneities can locally disrupt superconductivity. Therefore, the electrical properties of Josephson junctions are sensitive to chemical variations and structural defects on atomic length scales. Thus, to make multiple, uniform HTS junctions, control at the atomic scale is required. In 2014 we demonstrated very high-quality all-HTS Josephson superconducting tunnel junctions (both Josephson and quasiparticle tunneling) created by using a 500 picometer (pm) diameter focused beam of helium ions to direct-write tunnel barriers into $YBa_2Cu_3O_{7-\delta}$ (YBCO) thin films. This technique provided a reliable, and reproducible pathway for the scaling up of quantum mechanical circuits as well as an avenue to conduct superconducting tunneling studies in HTS for basic science. Under this award we further developed fabrication techniques and transport studies of different superconductors in the *a*-*b* plane of various HTS materials and how material and geometric properties affect these types of Josephson devices.

UCSD 2015-2017
The first two years of our research program started at UCSD where Cybart served as PI and Project Scientist. Our initial efforts were split between the study of nano-scale Josephson junctions and development of an off-axis sputtering process for deposition of thin films. The former effort contributed to two key publications in Applied Physics Letters. The first paper [2] describes how helium ion implantation can be utilized to create Josephson junctions with nanoscale dimensions two orders of magnitude smaller than state-of-the-art processes at that time. This significant reduction in scale enables Josephson devices with much higher resistance than prior-art devices

which lead to higher figures of merit and lower noise properties. The second paper [3] combines this nano-junction technique, with another to create high-sensitivity low noise nano-slit SQUIDS for sensitive magnetometry, illustrated in Figure 1. Here ion irradiation from a focused helium ion beam is utilized to directly convert material on the nanoscale to form nano-Josephson junctions and a very narrow slit for the interferometer. These SQUIDS have a high 12 Ohm resistance, arising from the small size of the junctions with a very large 0.4mV amplitude modulation voltage.

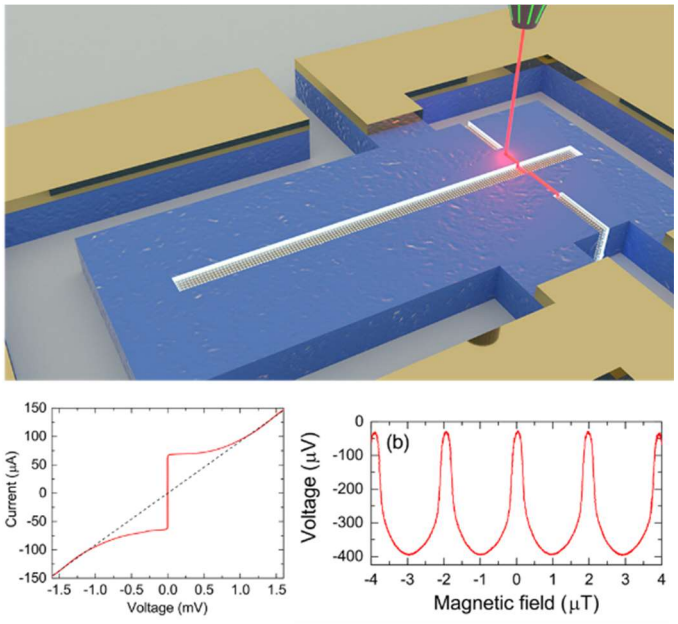

Figure 1. Nanoslit SQUID. (top) Ion irradiation from a focused helium ion beam is utilized to directly convert material on the nanoscale to form nano-Josephson junctions and a very narrow slit for the interferometer. **(Bottom left)** Current-voltage characteristic showing a high 12 Ohm resistance, arising from the small size of the junctions**. (Bottom Right)** Nano slit SQUID transfer function with large 0.4mV amplitude.

The second effort undertaken was to construct a reactive sputtering system for in-house growth of thin film rare earth cuprate superconductors. Working with two undergraduate research assistants (Nielson-Konzen and Qu), Cybart designed and constructed a unique system (Figue 2), featuring off-axis magnetrons and an on-axis hollow cathode oxygen ion source. This configuration allows for the superconducting phase of the material to be stabilized at lower pressure, improving material characteristics and shortening deposition time. Students participated in the construction of the system, and materials growth after it was completed. After several test runs, we were able to determine growth parameters to create very high-quality Y-Ba Cu O thin films.

Development of the new growth capabilities substantially improved our process starting material. At the same time, it also provided hands-on research experience for two students who later earned their master degrees at UCR and MIT.

The success of this early work generated a lot of interest from the scientific community and was a key factor in Cybart joining the faculty of Engineering at UC Riverside in late 2016 as an Assistant Professor.

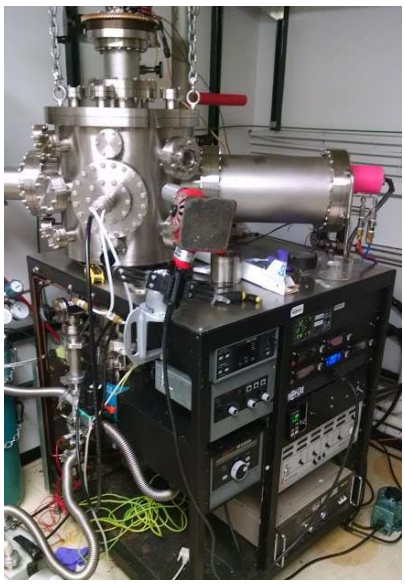

Figure 2. Reactive Sputter System. Custom built UHV system for deposition of cuprate thin films.

UCR 2017-2020

In July 2016, Cybart began building a laboratory at UC Riverside with the goal of establishing a complete process line for high-TC devices. This required moving some systems from UCSD as well as acquiring new ones. A significant addition was made in 2018 with the purchase of a Zeiss helium ion microscope, shown in Figure 3. Partially supported by this grant. With our own in-house system, we no longer had to travel to recharge facilities or work against time limits to complete our junctions. This helped the group develop much deeper process knowledge and to increase experimental throughput. Several publications invited talks and student presentations resulted from these experiments [1-14].

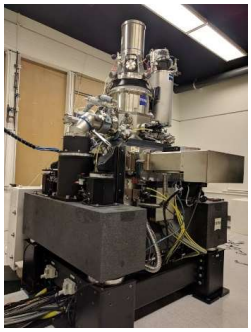

Figure 3 Zeiss Orion Plus system at UCR.

Publication [10] in particular was highlighted on the cover of Applied Physics Letters. Here we describe a configuration, enabled by nanometer scaling, where we create a high-performance three terminal device from a nano-SQUID inductively coupled to nano-positioned control line shown Figure 4. The helium ion beam is used to create Josephson junctions and nanoscale insulating barriers place a control line less than 10nm away from the SQUID body. Because magnetic field falls off quickly as increasing distance, nano-positioning of the line provides very strong inductive coupling as shown in Figure5.

This high-impact work is very significant to the field of superconducting electronics because it provides a means to connect low impedance (~1ohm) superconducting electronics driven by mA currents to higher impedance (~50 Ohm) voltage pulses compatible with semiconductor amplifiers. Furthermore, configurations like this may be compatible with fan out strategies for neuromorphic computing.

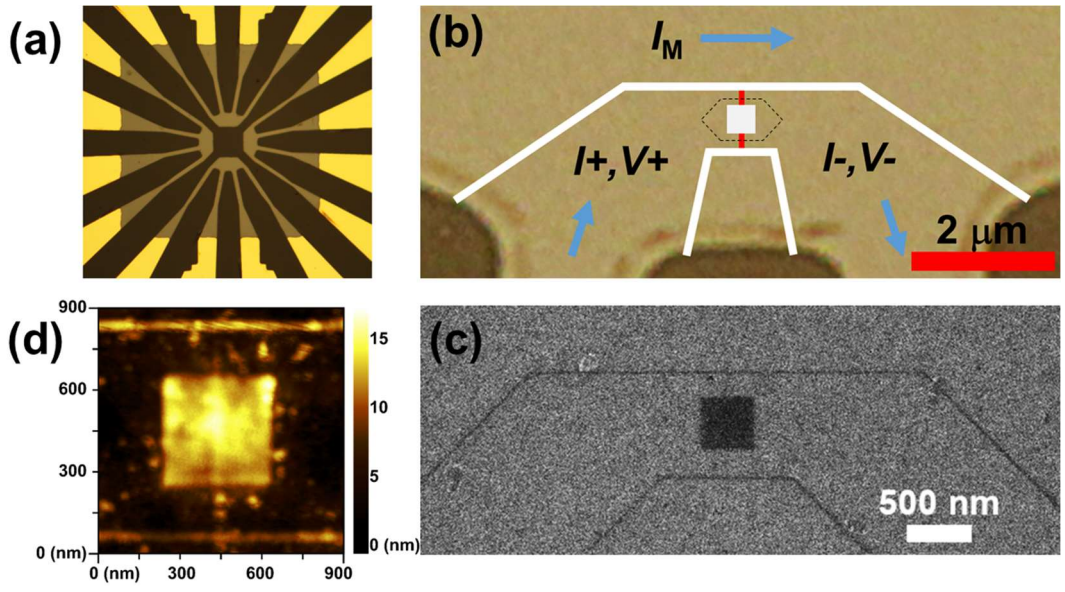

Figure 4 NanoSQUID amplifier. (a) Images of a nanoSQUID highlighting (b) where focused irradiation is used to pattern nanoscale features. A helium ion image (c) and AFM (d) scan are shown for an actual device.

UCSD 2018-2021

While most of the experimental efforts transitioned to UC Riverside, the remaining group of researchers at UCSD supported some device fabrication efforts, xray diffraction, and low temperature scanning tunneling microscopy. This work was predominately carried out by Sarkar using a custom-built low-T STM that was transferred from UC Berkeley to UC San Diego. Sarkar has been responsible for modifying and rebuilding it to improve the resolution and sensitivity of this microscope to study structures and defects in two dimensional systems. This work has successfully looked at the 2-dimensional superconductor BSCCO, the superconductor and charge density wave material NbSe2 and various configurations of graphene and graphite. Studies of the step-edge of cleaved NbSe2 and Graphite have been and are being investigated in much more detail than previous studies. For example, a Moire pattern of Graphite illustrated (below) has suggested the twist angle between planes can be quantitatively analyzed. Going forward there are whole classes of structured 2D materials can be investigated and perhaps manipulated.

Researchers supported and Broader Impacts

Besides research this grant supported several educational aspects with Broader Impacts in diversity. Overall, this award supported 4 women engineers, 3 Hispanic first generation college students and 10 US Citizens. this grant supported thesis work for 9 PHDs. Five of these have been successfully defended while 4 are currently scheduled for

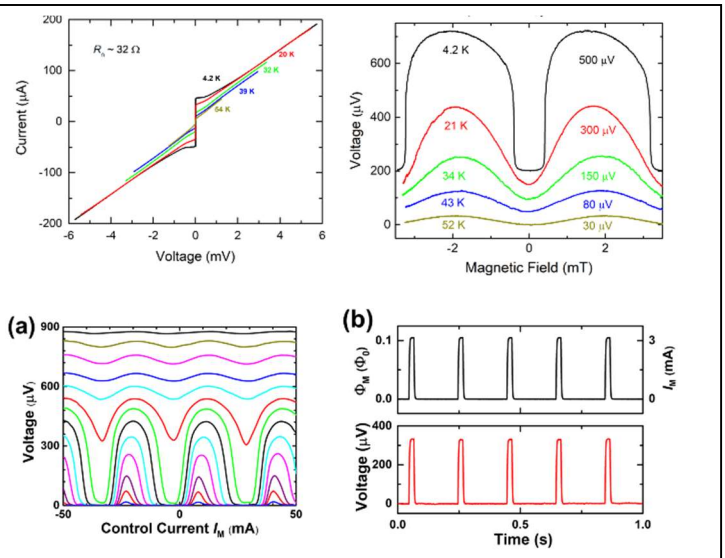

Figure 5 NanoSQUID amplifier. (Top) I-V characteristic and voltage modulation for a 400nm nanoSQUID. **(Bottom)** Utilization of the device as a three terminal transimpedance amplifier. (a) shows the strong coupling of the nanoSQUID to the third terminal and (b) highlights the conversion of superconducting current pulses to high impedance voltage.

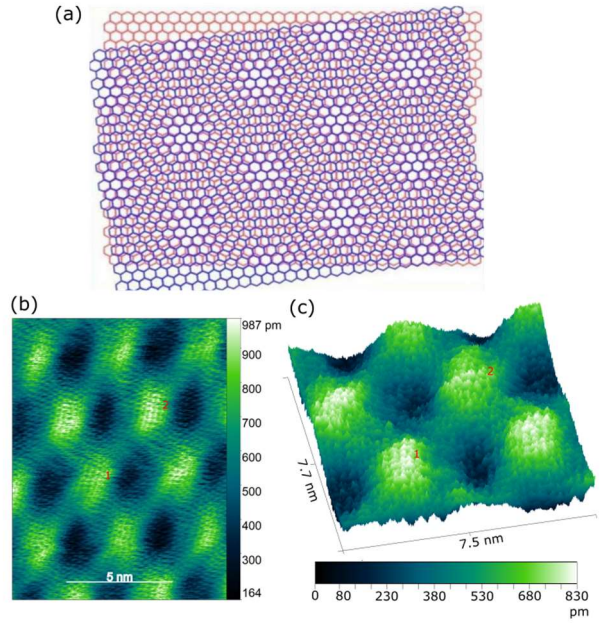

Figure 6 Low-T STM. (a) Schematic model of Moiré pattern created by twisting two graphene sheets by 7.3 degrees. **(b,c)** 2D STM topographic plot observed on graphene with twist angle of 4.3 degrees. superconducting current pulses to high impedance voltage.

summer 2021. Lastly, this award was instrumental in founding Cybart's lab at UCR and subsequently his promotion in 2019 to Associate Professor with Tenure in the Department of Electrical Engineering.

Researchers supported by this grant:

UCSD			
name	**title**	**period**	**hours**
Shane Cybart	*Project Scientist*	06/2015 to 12/2015	783
Ethan Cho	*Graduate Student Researcher*	06/2015 to 08/2016	391
Lance Nielson-Konzen	*Undergraduate Researcher*	01/2016 to 06/2017	155
Ashley Qu	*Undergraduate Researcher*	07/2016 to 06/2017	424
Darren Helstowski	*Graduate Student Researcher*	06/2017 to 07/2017	174
Nirjhar Sarkar	*Graduate Student Researcher*	10/2017 to 12/2019	1305
UCR			
name	**title**	**period**	**hours**
Shane Cybart	*Assistant Professor*	09/2017 to 09/2020	614
Ethan Cho	*Post Doc*	08/2017 to 09/2020	2434
Hao Li	*Post Doc*	09/2018 to 07/2020	1159
Anthony Cortez	*Graduate Student Researcher*	05/2018 to 08/2018	160
Yuchao Zhou	*Graduate Student Researcher*	09/2018 to 10/2018	90
Stephen McCoy	*Graduate Student Researcher*	09/2019 to 03/2020	772
Jay LeFebvre	*Graduate Student Researcher*	01/2020 to 06/2020	423

Collaborations:

Dr. Genda Gu, Brookhaven National Laboratory and Professor Kazuo Kadowaki, Tsukuba University

A component of our work investigated bismuth based high-temperature superconductors (Bi2212) to compare and contrast irradiation properties of this class of superconductor with the cuprate family. Both Dr Gu and Professor Kadowaki provided high-quality single crystals that were used to cleave 2D sheets for helium ion irradiation of Josephson junctions. Unlike YBCO, this class of superconductor cannot be grown reliably in thin-film form, therefore, by cleaving off layers we were able to create materials thin enough for ion beam patterning to fashion circuits from the material for electrical transport anisotropy studies. Initial results shown in Figure 7 are promising and will be published in future articles and in [32].

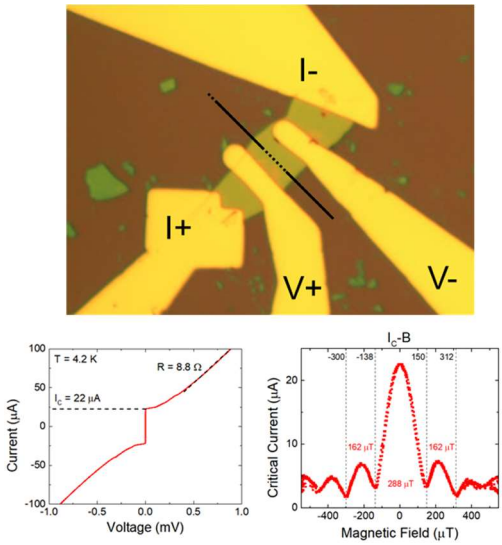

Figure 7 Bi2212 Josephson junctions (top) Bi2212 flake and gold electrodes utilized to create in -plane Josephson devices. (bottom left) I-V characteristic for helium ion Bi2212 junction and (bottom right) Fraunhoffer diffraction pattern confirming the in-plane Josephson effect.

Riccardo Comin, MIT
Professor Comin in the Department of Physics at MIT is a leading expert on xray resonant scattering in cuprate materials. He is supported by an AFOSR Young Investigator award to study charge density waves (CDW) in cuprates. The Cybart group at UC Riverside grew and patterned cuprate thin films of HoBaCuO, [23] and EuBaCuO [29] for the MIT work. In their beam time measurements, they found stronger CDW signatures than those typically found in YBaCuO. The next steps in this work will be to study CDW dynamics in the presence of large currents or magnetic fields. A manuscript is in preparation for Nature Materials.

Professor Nobuyuki Yoshikawa, Yokohama National University
Professor Yoshikawa is a leading expert in a type of superconducting digital circuitry called Adiabatic Quantum Flux Paramatron (AQFP). This newly emerging architecture is attractive for ion damage junction technology because the physical circuit parameters such as critical current and normal state resistance are a good match. This is in contrast to single flux quantum (SFQ) logic which requires higher critical currents. We worked with the Yoshikawa group to design planar AQFP designs compatible with our process. A few test devices were created and preliminary testing was performed in Yokohma National University in January 2020. This activity was disrupted due to the pandemic.

Professor Horst Rogalla (Colorado) and Dr. Sam Benz (NIST)
The group at UC Riverside collaborated with Rogalla and Benz on their project to create a high temperature superconductor quantum temperature standard. Electrodes and macroscopic circuit features were fabricated at NIST and sent to UC Riverside for helium ion irradiation of Josephson junctions.

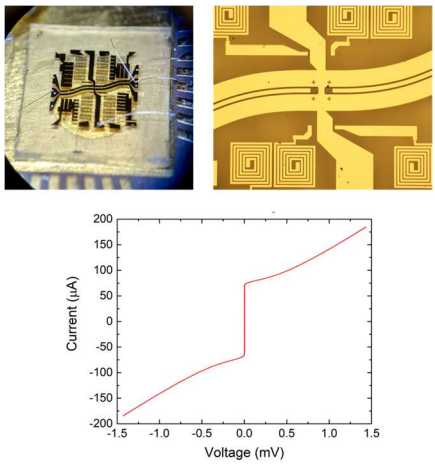

Figure 8 Quantum Temperature Sensor (top)Quantum temperature sensor fabricated at UCR for testing at NIST

Dr. Shinichi Ogawa and Dr. Chiharu Urano, AIST
The National Institute of Advanced Industrial Science and Technology (AIST) in Japan was amongst the first users of the Zeiss helium ion system and the first group to use it for circuit fabrication. The leader of that group (now retired), Shinichi Ogawa has over a decade of experience in focused helium ion beams. Members from the Cybart group visited the AIST site to work with Ogawa and Urano to learn how to better optimize the beam for fabrication of Josephson junctions. During these interactions we learned several techniques to better prepare the ion source including increasing beam voltage, obtaining better focus, as well as error mitigation in patterning. As a result of these interactions, we improved our process which enabled large gains in circuit figure of merit ($I_C R_N$) at high operation temperature.

Daniel Cunnane, NASA Jet Propulsion Lab
Working with the Jet propulsion lab, UCR fabricated collaborated in the testing of a high-TC, THZ mixer. Working with JPL we developed a process to embed a Josephson junction into a log spiral

antenna for mixing. A UCR graduate student, (Anthony Cortez) and post docs fabricated these devices and performed preliminary testing in the UCR lab. After optimizing the process, Cortez spent a summer internship at JPL performing more advanced electrical testing [8, 24, 31]. In this work, the key result is that our YBCO devices can operate at frequencies as high as 2.5 THz with noise properties similar to other high-Tc approaches. Cortez successfully defended his Thesis and will be joining the faculty of Point Loma University as an Assistant Professor in fall 21.

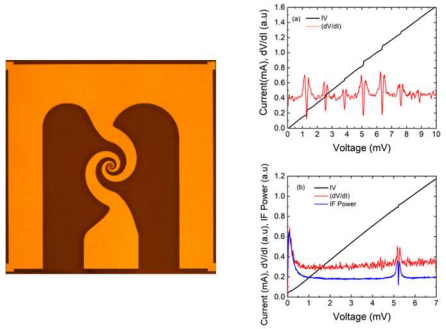

Figure 9 THZ HTS Mixer THZ Josephson mixer fabricated for JPL

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- [2] E.Y Cho, Y.W Zhou,., J.Y Cho, and S.A.Cybart, *Superconducting nano Josephson junctions patterned with a focused helium ion beam*. **Appl. Phys. Lett**., 5p 113(2), 022604 2018.
- [3] E.Y. Cho, H. Li, J.C. LeFebvre, Y.W. Zhou, R.C. Dynes, and S.A. Cybart, *Direct-coupled micro-magnetometer with Y-Ba-Cu-O nano-slit SQUID fabricated with a focused helium ion beam.* **Appl. Phys. Lett**., 113(16), 162602 2018. (**Editors Suggestion**)
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PHD Theses

[27] *Focused Helium Beam Irradiated Josephson Junctions*, Ethan Cho PHD thesis UCSD 2016

[28] *Arrays of Superconducting Quantum Interference Devices (SQUIDs) In Y-Ba-Cu-O Utilizing Ion Irradiation Patterning*, Travis Wong PHD thesis UCSD 2016

[29] *Rare Earth Cuprate Analysis for High Tc Superconducting Devices,* Stephen McCoy, PHD UCR 2020

[30] *Superconducting Magnetometers and Electronics Control System*, Yuchao Zhou, PHD UCR 2020

[31] *THz Mixing Using Y-Ba-Cu-O Josephson Junctions Fabricated with Focused Helium Ion Beam Irradiation*, Anthony Cortez, PHD UCR 2021

In progress

[32] Yanting Wang UCR 9-21

[33] Han Cai UCR 9-21

[34] J. Lefebvre UCR 9-21

[35] N. Sarkar UCSD 9-21

Shane Cybart Invited Presentations

- *$YBa_2Cu_3O_7$ NanoSQUIDs Fabricated with Focused Helium Ion Beam Direct Writing,* **Japanese Society of Applied Physics Fall Meeting**, Sapporro, Japan, (September 2019).
- *$YBa_2Cu_3O_7$ NanoSQUIDs Fabricated with a Focused Helium Ion Beam,* **Japanese Society of Applied Physics Spring Meeting**, Tokyo, Japan, (March 2019).
- *An Introduction to the Helium Ion Microscope,* **Japanese Society of Applied Physics Spring Meeting**, Tokyo, Japan, (March 2019).
- *High Transition Temperature Josephson junctions,* **University of Southern California ECE Seminar**, Los Angeles, CA, (February 2019).
- *High Transition Temperature Josephson junctions and reprogrammable electronics,* **Quantum Design Seminar**, San Diego, CA, (February 2019).
- *Helium Ion High-Transition-Temperature Josephson Junctions for Digital Applications*, **Hypres Superconducting Electronics Seminar,** Elmsford, NY. (February 2019)
- *High Transition Josephson Junctions and Nano SQUIDs* **University of Central Florida Plasma Workshop**, Orlando FL. (January 2019)

- *High-Transition-Temperature Josephson Junctions and Nano-SQUIDs*, **International Symposium on Superconductivity**, Tsukuba, Japan. (December 2018)
- *Helium Ion High-Transition-Temperature Josephson Junctions for Digital Applications*, **Yokohama National Unversity, Department of Electrical and Computer Engineering Seminar,** Yokohama, Japan. (December 2018)
- *Scaling of YBCO electronics to the nano-scale using direct-write helium ion lithography*, **14th International Symposium on High Temperature Superconductors in High Frequency Fields**, Yamagata Japan (June 2018)
- *High Tc Josephson junctions and nanowires fabricated with direct write helium ion beam lithography,* **Yokohama National Unversity, Department of Electrical and Computer Engineering Seminar,** Yokohama, Japan. (June 2018)
- *High Transition Temperature Josephson Junctions*, **UCSD Mechanics and Materials Seminar**, La Jolla CA. (May 2018)
- *High Transition Temperature Josephson Junctions*, **Quantum Electronic Solids for the USAF 2030,** The Univ. of Houston Texas Center for Superconductivity, Houston TX (April 2018) Distinguished Speaker.
- *Direct-write helium ion lithography of high-Tc electronics*, **NASA Jet Propulsion Lab Micro Devices Seminar**, Pasadena, CA. (December 2017)
- *Modification of High-Tc Superconductors with Focused Helium Ion Irradiation,* **Materials Research Society Fall Meeting**, Boston, MA. (November 2017)
- *Direct-write Helium Ion Lithography of High-Transition Temperature Superconducting Electronics,* **The 20th Workshop on Superconductor Electronics: Devices Circuits & Systems,** Santa Cruz, CA, (November 2017)
- *Direct-write Helium Ion Lithography of High-Transition Temperature Superconducting Electronics,* **University of Rochester ECE Seminar Series**, Rochester NY (October 2017)
- *Focused helium ion beam fabrication of superconducting nanoelectronics,* **Lawrence Berkeley National Laboratory, Quantum Architectures Symposium,** , Berkeley , CA, (August 2017)
- *Nanofabrication of superconducting devices using focused helium ion irradiation*, **Toyohashi University of Technology, Dept. of Environmental and Life Sciences Seminar,** Toyohashi, Japan. (July 2017)
- *Direct writing of High-TC Josephson Junctions with Focused Helium Ion Beams,* **Cryogenic Engineering Conference and the International Cryogenic Materials Conference**, Madison WI. (July 2017)
- *Direct-write Helium Ion Lithography of High-Transition Temperature Superconducting Electronics***, Carl Zeiss Second North American User Meeting**, Orlando FL. (June 2017)
- *Focused Helium Ion Direct-write Patterning of Superconducting Electronics,* **Advances in Ion Microscopy for Nanofabrication & Materials Science,** Cal Tech. Pasadena, CA. (June 2017)
- *Direct-write Helium Ion Lithography of High-Transition Temperature Superconducting Electronics,* **UC Irvine MAE Seminar,** Irvine, CA. (May 2017)
- *Helium ion lithography for oxide electronics,* **Japanese Society of Applied Physics Meeting,** Yokohama, Japan. (March 2017)

- *Nanopatterning of Oxide Superconducting Electronics,* **Sociedad Mexicana de Materiales (SMM) and Materials Research Society (MRS) Materials Research Congress,** Cancun Mexico. (August 17, 2016)
- *Focused Helium Ion Beam Josephson Junctions and Nanowires,* **Electron, Ion and Photon Beam Technology and Nanofabrication**, Pittsburg PA. (June 1, 2016)
- *Focused Helium Ion Beam Modification of high-T_C Superconductors and Magnetic Materials*
- **Carl Zeiss Helium Ion Microscopy User Group Meeting**, Peabody MA. (March 24, 2016)
  Direct-write Helium Ion Lithography of $YBa_2Cu_3O_7$ Nano Josephson junctions and SQUIDs
- **Quantum Design Seminar**, San Diego, CA, 2016.
- *Application of Focused Helium Ion Beams for Direct-write Lithography of Superconducting Electronics,* **American Vacuum Society Symposium**, San Jose, CA 2015.
- *Direct-write Helium Ion Lithography of $YBa_2Cu_3O_7$ Nano Josephson junctions and SQUIDs* **University of Maryland Condensed Matter Physics Colloquium**, College Park, MD, 2015.

Student and Postdoc Conference Presentations

- Ethan Cho, *Direct-write ion beam irradiated Josephson junction devices*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Hao Li, *YBa2Cu3O7-δ Nano-SQUIDs Fabricated by Focused Helium Ion Beam Direct Writing*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Adam Weiss, *Pulse-Driven High-Tc Josephson Junctions for Quantum Voltage Devices*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Han Cai, *Inductance investigation of single layer and multilayer YBa2Cu3O7 thin films grown by reactive coevaporation*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Yanting Wang, *Estimation of the Width of Focused Helium Ion Beam Josephson Junctions*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Yuchao Zhou, *Electronic Feedback System for Superconducting Quantum Interference Devices*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Anthony Cortez, *High-Frequency Properties of Y-Ba-Cu-O Josephson Junctions*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Jay LeFebvre, *Series Arrays of Long Josephson Junctions Fabricated with a Focused Helium Ion Beam in YBa2Cu3O7−δ*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Ji Wang, *Portable Solid Nitrogen Cooling System for High Transition Temperature Superconductive Electronics*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Stephen McCoy, *HoBaCuO Thin Films for Superconductive Electronics*, IEEE International Superconductive Electronics Conference, Riverside, CA, 2019.
- Stephen McCoy, *Reactive Ion Beam Assisted Deposition of Rare Earth Cuprates,* MRS Spring Symposium Phoenix, AZ,2019.
- Holly Grezdo, *Focused Helium Ion Beam Induced Superconductor Insulator Transition in YBCO,* MRS Spring Symposium Phoenix, AZ, 2019.
- Ethan Cho, *Metal-Insulator Transition in High-Transition Temperature Superconductor Josephson Junction Barriers,* MRS Spring Symposium Phoenix, AZ, 2019.
- Han Cai, *YBa2Cu3O7 Nano-SQUIDs Based on Tunnel Nano-Junctions Fabricated by*

Focused Helium Ion Beam Direct Writing, MRS Spring Symposium Phoenix, AZ, 2019.

- Jay LeFebvre, *Focused Helium Ion Beam Irradiation Long YBCO Josephson Junction Arrays*, IEEE Applied Superconductivity Conference, Seattle, WA, 2018.
- Hao Li, *Inductance Investigation of YBa2Cu3O7−δ Nano-Slit SQUIDs Fabricated with A Focused Helium Ion Beam*, IEEE Applied Superconductivity Conference, Seattle, WA, 2018.
- Ethan Cho, *Investigation of Arrays of Two-dimensional High-TC SQUIDs for Optimization of Electrical Properties*, IEEE Applied Superconductivity Conference, Seattle, WA, 2018.
- Yanting Wang, *YBa2Cu3O7 – CeO2 – YBa2Cu3O7 Multilayers Grown by Reactive Co-evaporation on Sapphire Wafers*, IEEE Applied Superconductivity Conference, Seattle, WA, 2018.
- Ji Wang, *Detection of magnetic nanoparticles using high transition temperature superconducting quantum interference devices*, IEEE Applied Superconductivity Conference, Seattle, WA, 2018.
- Anthony Cortez, *Tuning Y-Ba-Cu-O Focused Helium Ion Beam Josephson Junctions for use as THz Mixers*, IEEE Applied Superconductivity Conference, Seattle, WA, 2018.
- Anthony Cortez, *Tuning Y-Ba-Cu-O Focused Helium Ion Beam Josephson Junctions for use as THz Mixers*, IEEE Applied Superconductivity Conference, Seattle, WA, 2018.
- Anthony Cortez, *Tuning Y-Ba-Cu-O Focused Helium Ion Beam Josephson Junctions for use as THz Mixers*, IEEE Applied Superconductivity Conference, Seattle, WA, 2018
- Ethan Cho, *Helium Ion Direct Write Patterning of Superconducting Electronics*, AVS 65 Long Beach, CA, 2018.
- Jay LeFebvre, *High Transition Temperature Nano Superconducting Quantum Interference Devices*, APS March Meeting, Los Angeles, CA, 2018.
- Ethan Cho, *Nano Josephson junctions patterned with a focused helium ion beam*, APS March Meeting, Los Angeles, CA, 2018.
- Lance Konzen, *Reactive Sputtering of YBCO Films for Superconductive Electronics*, 20th Biennial U.S. Workshop on Superconductor Electronics, Devices, Circuits, and Systems United States Committee for Superconductor Electronics, Inc., Santa Cruz, CA, 2017.
- Robert Quach, *Characterization of YBCO on LSAT and STO substrates using AFM and Resistance vs Temperature Measurements*, Southern California Conferences for Undergraduate Research, Pomona, CA, 2017.
- Yuchao Zhou, *Josephson Junctions and Arrays made with Focused Helium Ion Beam*, IEEE CEC/ICMC, Madison, WI, 2017.
- Ethan Cho, *Focused Helium Beam Fabricated Superconducting Devices*, EIPBN Conference, Orlando FL, 2017.
- Yuchao Zhou, *Focused Helium Ion beam Josephson Junctions and Arrays*, EIPBN Conference, Orlando FL, 2017.
- Ethan Cho, *Superconducting quantum interference devices made with normal metal and insulator barrier Josephson junctions in Y-Ba-Cu-O directly written with a focused helium beam*, IEEE Applied Superconductivity Conference, Denver, CO, 2016.