18.10.10

ID No.: P16065

必ず ID 番号を記入すること

Be sure to enter the Fellow's ID number

Form 7／様式 7

外国人特別研究員作成／By Fellow

2018 / 9 / 19

(YYYY) (MM) (DD)

JSPS Fellow's

Signature (Handwritten only) : Qianchun Weng

Research Report (by Fellow)
(Cover Page)

I hereby submit the research report of my fellowship.

1. Name (Print) : Qianchun Weng
2. Nationality : China
3. Host Institution : The University of Tokyo
4. Host Researcher : Yusuke Kajihara
5. Title of Research in Japan : Terahertz Nanoscopy of Non-equilibrium Dynamics
6. Fellowship Tenure : From 2016 / 09 / 01 (YYYY) (MM) (DD) To 2018 / 08 / 31 (YYYY) (MM) (DD)

***Notes for writing the Research Report**
***Type this form except the date and the signature.**
Please prepare your Research Report in English or Japanese within three to ten pages including this page. The contents should include:

7. Background of Research

All material surfaces are covered by electronic evanescent waves (with characteristic extension lengths from the surface up to 0.01~ 0.1 nm): The scanning tunneling microscope (STM) is to probe such surface electron waves (or the electronic local density of state (LDOS)) through tunnel currents. Similarly, all material surfaces are covered by electromagnetic (EM) evanescent waves (with characteristic extension lengths up to 1.0 ~ 100 nm). This is because any moving charges (conduction electrons and/or ion cores of lattice) inside the material generate EM evanescent waves bound closely to the surface. Theoretically, the existence of EM evanescent waves at given temperatures (with no external excitation) is established and investigated in terms of electromagnetic (EM) LDOS. The dominant spectral range is expected to be in the infrared/THz region (λ= 8~ 20 μm). It is theoretically expected further that the waves provide a unique nano-scale tool to probe dynamic phenomena in materials. But it has not been experimentally studied up to now due to experimental difficulties.

8. Research methodology

Before I join the host group at the University of Tokyo, I have constructed a sensitive terahertz (THz) near-field microscope, similar to the one in the host group. It is a new microscope which is capable of **imaging EM evanescent waves** with nanometer resolution, and applied it to study non-equilibrium electron dynamics in nanoscale. I continued this challenging study in the JSPS research project. Samples are GaAs quantum well devices and NiCr narrow metal leads.

9. Results/impacts

In this JSPS project, I challenged to image nanoscale non-equilibrium phenomenon with THz near-field microscope, which has never been achieved in the past. Two **particularly outstanding research results** are achieved and listed below:

(1) Imaging of hot electron energy dissipation in semiconductor devices

[paper published in: **Science 360, 775-778 (2018)]**

Hot electrons in GaAs/AlGaAs nano devices have been visualized with nanoscale resolution for the first time. Nonlocal energy dissipation has been disclosed, due to the fact that the electron-phonon energy relaxation length exceeds the spatial resolution of the microscope.

(2) Imaging of nanoscale Joule-heating in current flow metal leads

[paper published in: **Nano Lett. 18, 4220-4225 (2018)]**

Probing temperature variation at the nanoscale is of great interest and fundamental importance in diverse areas of modern science and technology. Despite recent progress in the development of contact-type nano-thermometers, one inherent disadvantage is that the measured temperature is disturbed by the direct thermal contact. Infrared radiation thermometer is free from such contact-induced disturbance, but suffers from insufficient spatial resolution diffraction-limited in the micrometer range. I use the THz-SNoiM to map the local temperature distribution on a current-heated, subwavelength NiCr wire, providing the first "near-field" version of infrared radiation thermometer.

Note: As much as possible, describe the contents and results of your research in a manner that is easily understandable to a non-specialist in your field. Provide a concrete description if (1) papers related to your work have been published in major academic journals, (2) particularly outstanding research results were achieved, or (3) patent applications have been made or other tangible outcomes achieved through the research.

10. Research Presentations during the period of the fellowship (Name of the conference, title, place, date)

(1) (**Keynote talk**) 43rd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz), "Nanothermometry of electrons and phonons", Nagoya, Japan, Sept. 9th-Sept. 14th, 2018.
(2) (Oral) 78th Japan Society of Applied Physics (JSAP) Autumn Meeting, "Nanoscale temperature mapping of current-heated narrow metal wires", Fukuoka, Japan, Sept. 5th-Sept. 8th, 2017.
(3) (**Keynote talk**) 42nd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz), "Real-space nano-imaging of hot electron dynamics", Cancun, Mexico, Aug. 27th-Sept. 1st, 2017.
(4) (Poster) 22nd International Conference on Electronics Properties of Two Dimensional Systems (EP2DS), "Visualize hot electrons in two dimensional devices at steady-state", Penn State, USA, July. 31st-Aug. 4th, 2017.
(5) (Oral) 64th Japan Society of Applied Physics (JSAP) Spring Meeting, "Nano-imaging of hot electrons in an operating device at room-temperature", Yokohama, Japan, Mar. 15th, 2017.
(6) (Oral) 5th Russia-Japan-USA-Europe Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies (RJUSE TeraTech), "Terahertz nano-imaging of non-equilibrium local dynamics", Sendai, Japan, Oct. 31st-Nov. 4th, 2016.

11. A list of paper published during or after the period of the fellowship, and the names of the journals in which they appeared (Please fill in the format below). Attach a copy of each article if available.

Author(s)	Title	Name of Journal	Volume	Page	Date	Note
Qianchun Weng et al	Imaging of nonlocal hot-electron energy dissipation via shot noise	**Science**	360	775-778	May 18, 2018	
Qianchun Weng et al	Near-field Radiative Nanothermal Imaging of Nonuniform Joule Heating in Narrow Metal Wires	**Nano Letters**	18	4220-4225	June 7, 2018	

12. Awards during the period of the fellowship (Name of the award, Institution, date etc.)