（様式４）

# 二国間交流事業 共同研究報告書

令和５年４月７日

独立行政法人日本学術振興会理事長 殿

［日本側代表者所属機関・部局］
北海道大学・電子科学研究所
［職・氏名］
教授・ビジュ ヴァスデヴァンピライ
［課題番号］
JPJSBP 120207702

1. 事 業 名 相手国: インド （振興会対応機関: DST ）との共同研究

2. 研究課題名

（和文） 人工光合成のための半導体ナノ結晶におけるホットエレクトロン移動

（英文） Hot Electron Transfer in Semiconductor Nanocrystals for Artificial Photosynthesis

3. 共同研究実施期間 2020 年 7 月 1 日 ～ 2023 年 3 月 31 日（ 2 年 9 ヶ月）

【延長前】 2020 年 7 月 1 日 ～ 2022 年 6 月 30 日（ 2 年 0 ヶ月）

4. 相手国側代表者（所属機関名・職名・氏名【全て英文】）

Indian Institute of Technology Hyderabad・Professor、Director・
Subrahmanyam Ch.

5. 委託費総額（返還額を除く）

| | | |
|---|---|---|
| 本事業により執行した委託費総額 | | 2,000,000 円 |
| 内訳 | 1年度目執行経費 | 400,000 円 |
| | 2年度目執行経費 | 900,000 円 |
| | 3年度目執行経費 | 700,000 円 |

6. 共同研究実施期間を通じた参加者数（代表者を含む）

| | |
|---|---|
| 日本側参加者等 | 2 名 |
| 相手国側参加者等 | 3 名 |

＊ 参加者リスト（様式 B1(1)）に表示される合計数を転記してください（途中で不参加となった方も含め、全ての期間で参加した通算の参加者数となります）。

7. 派遣・受入実績

| | 派遣 | | 受入 |
|---|---|---|---|
| | 相手国 | 第三国 | |
| 1 年度目 | 0 | 0 | ( ) |
| 2 年度目 | 0 | 0 | ( ) |
| 3 年度目 | 1 | 0 | 1( 1) |

＊ 派遣・受入実績（様式 B1(3)）に表示される合計数を転記してください。

派遣：委託費を使用した日本側参加者等の相手国及び相手国以外への渡航実績（延べ人数）。
受入：相手国側参加者等の来日実績（延べ人数）。カッコ内は委託費で滞在費等を負担した内数。

8. 研究交流の概要・成果等

(1)研究交流概要（全期間を通じた研究交流の目的・実施状況）

(1) The overall purpose of the research was to develop heterojunction (semiconductor–plasmonic gold, Au) nanomaterials and generate hot electrons assisted by the surface plasmon for photocatalytic activities. The research exchange was implemented only in 2022 due to the pandemic, with one visit by the Japanese PI to IIT Hyderabad to study the photocatalytic activities of quantum dot (QD)–based electrodes and one visit by the Indian PI to Hokkaido University to study the plasmonic effects on QDs. Also, a former student from the laboratory of the Indian PI joined as an assistant professor in the Japanese PI's laboratory at Hokkaido University, who supported the project by synthesizing copper–indium–sulfide (CIS) and CIS–ZnS QDs. Furthermore, two doctoral course students from the laboratory of the India PI visited Hokkaido University through institutional support from IIT Hyderabad, which was in March 2023 to investigate the plasmonic effects of Au and bismuth (Bi) nanoparticles on CIS QD–based photoelectrodes. Under this scenario, the research was initially focused independently at Hokkaido University (achieved the synthesis of QDs, preparation of plasmonic Au substrates, and clarification of the optical properties of QDs with and without plasmonic substrates) and IIT Hyderabad (achieved the development of photoanodes with QDs and evaluation of the photocatalytic activities of the photoanodes). Therefore, the main results are the development of various semiconductor QDs, including CdSe, halide perovskite, CIS, and CIS–ZnS, preparation of Au thin film–, Au nanoparticle, and silica–Au–based plasmonic substrates. Further, various QD–based photoanodes with or without plasmonic Au nanoparticles were prepared. Although CO2 reduction was not noticed in the photochemical reactions, the key achievement is the generation of hot electrons by plasmon–assisted QDs, which enhanced photoluminescence (PL), and the light absorption efficiency of QDs was increased by 7–fold. The plasmonic effects on hot electron generation were also investigated in collaboration with Prof. Hiroshi Miyasaka at Osaka University and with Prof. Naoto Tamai at Kwansei Gakuin University through domestic research collaborations on time–resolved PL and transient absorption measurements of QD and QD–Au systems.

(2)学術的価値（本研究交流により得られた新たな知見や概念の展開等、学術的成果）

This research helped us to develop a new–type whispering gallery mode plasmonic Au substrate on silica microparticles. Also, the plasmonic–coupling–induced enhanced emission and light absorption of QDs is another key piece of information. Although the results related to quantum dot preparation and photoanode preparation are published, the plasmon–assisted enhanced emission and light absorption are under publication, which is expected to impact the plasmonic and nanomaterials fields –from fundamental scientific points.

(3)相手国との交流（両国の研究者が協力して学術交流することによって得られた成果）

The following research exchanges were implemented: (i) the joint preparation of photoanodes at IIT Hyderabad, (ii) the joint evaluation of the photocatalytic activities of the electrodes at IIT Hyderabad, (iii) the joint preparation of QDs and plasmon–QD heterojunction samples at Hokkaido University, and (iv) joint–evaluation of the plasmon–assisted PL intensity enhancement and light absorption enhancement for the Au–QD heterojunction samples. These exchanges and joint investigations became possible with the visit of the

Japanese PI to IIT Hyderabad (2022), the Indian PI to Hokkaido University (2022), the joining of an assistant professor from the Indian PI's laboratory to the Japanese PI's laboratory (12/2020 to 11/2022), and the visit of two doctor course students from IIT Hyderabad to Hokkaido University (3/2023).

(4)社会的貢献(社会の基盤となる文化の継承と発展、社会生活の質の改善、現代的諸問題の克服と解決に資する等の社会的貢献はどのようにあったか)

Acknowledgments in published papers and academic conference presentations about this bilateral project helped disseminate the collaboration, the new research aspects, and the DST-JSPS program to many diverse audiences. Also, this research attracted many Indian researchers to join the project. As a result, many other requests emerged for further collaborations with other laboratories at IIT Hyderabad and other institutions in India. Also, the collaboration aspects were networked with researchers at Osaka University and Kwansei Gakuin University. Overall, the plasmon-assisted enhanced light absorption for photocatalytic activities using quantum dot electrodes is expected to contribute to society's increasing carbon-neutral energy needs.

(5)若手研究者養成への貢献(若手研究者養成への取組、成果)

Many young researchers were attracted to and included in the project, including an assistant professor at Hokkaido University, two doctoral course students at Hokkaido University, a postdoctoral fellow at Hokkaido University, two doctoral course students at IIT Hyderabad, a postdoctoral fellow at Kwansei Gakuin University, and as an associate professor at Osaka University. Also, many young Indian researchers were attracted to collaborate with Hokkaido University, which is based on acknowledging the project in academic conferences.

(6)将来発展可能性(本事業を実施したことにより、今後どの様な発展の可能性が認められるか)

This research is expected to develop new plasmon-assisted energy harvesting technology using quantum dot-plasmonic substrates as the light-harvesting medium.

(7)その他(上記(2)～(6)以外に得られた成果があれば記載してください)

例:大学間協定の締結、他事業への展開、受賞など

This bilateral project became a key point of discussion and presentation by the Hokkaido University president during the Japan-India academic forum in Tokyo, where the presidents of all top universities in Japan and the directors of several IITs and Indian universities were present, along with the presence of the MEXT deputy minister, the JST president, and JICA officials. Also, the project was discussed with the director of IIT Hyderabad during the academic forum, which helps advanced Hokkaido University-IIT Hyderabad academic exchanges through JICA. This project helped to obtain a doctoral course student from the Indian PI's laboratory through the JICA Friendship-2 program.