様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

令和　　元 年　　６ 月 ２４ 日現在

機関番号：１３９０１
研究種目：基盤研究(B)（一般）
研究期間：2016～2018
課題番号：１６Ｈ０３８２５

研究課題名（和文）ハイクオリティ原子層ヘテロ構造の作製とバレーフォトニクスデバイスの創製

研究課題名（英文）Fabrication of high-quality atomic-layer heterostructures and novel photonic devices

研究代表者

北浦　良（Kitaura, Ryo）

名古屋大学・理学研究科・准教授

研究者番号：５０３９４９０３

交付決定額（研究期間全体）：（直接経費）　　15,200,000円

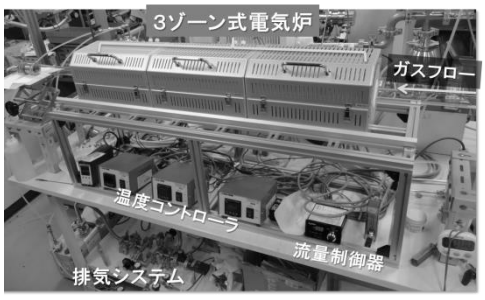
研究成果の概要（和文）：本研究では、原子層を用いた新奇バレーフォトニックデバイスの創製につながる基盤技術として、高品質原子層の結晶成長法およびヘテロ積層構造の作製法の確立を行った。作製した原子層およびヘテロ積層構造の光学応答を調べたところ、非常に半値幅の狭い励起子発光、低励起エネルギーでの励起子分子の生成、バレー自由度に由来する種々の層間励起子の生成を見出した。また、バレー偏極度の測定から、今回作製した原子層およびそのヘテロ構造が、バレー自由度に由来する新奇物性やフォトニックデバイス作製に有望なものであることがわかった。

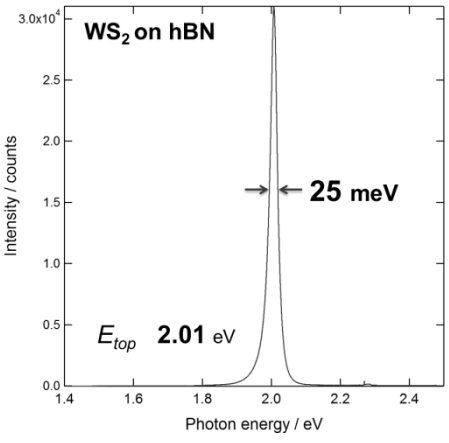
研究成果の学術的意義や社会的意義
原子層ではほぼ全てが表面に露出しているため、その物性は週環境に強く影響を受ける。また、バレー自由度をもつ原子層として注目を集めている遷移金属ダイカルコゲナイド(TMD)原子層は、欠陥生成エネルギーが小さく多くの欠陥を含む低品質の試料しか得られなかった。本研究では、独自設計の化学気相成長法装置と六方晶窒化ホウ素基板を用いることで上記二点を解決し、高品質TMD結晶を得ることに成功した。本研究で確立した手法を用いて生み出される試料は、バレー自由度に由来する新奇物性探索やフォトニックデバイス創製へ向けた基盤となる。

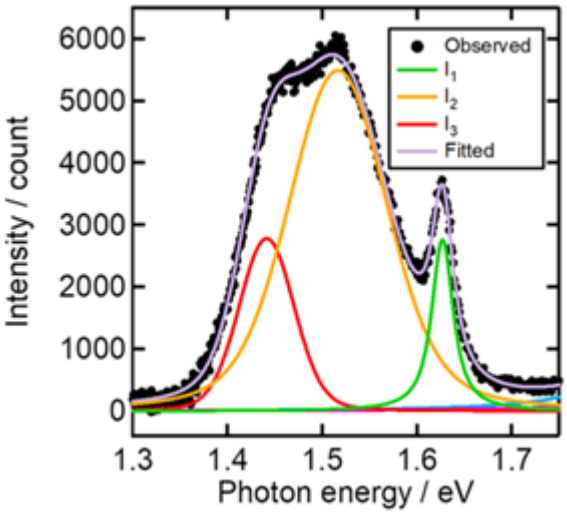
研究成果の概要（英文）：In this work, we have focused on development of a crystal growth method for high-quality atomic layers and atomic-layer heterostructures. We have investigated optical responses of atomic layers and heterostructures and found (1) small-fwhm excitonic emissions, (2) formation of biexcitons with small excitation power density, (3) formation of various interlayer excitons composed of electrons and holes locate at different valleys. In addition, we have observed valley-polarized photoluminescence from both atomic layers and heterostructures, which clearly demonstrates that present samples gives versatile playground for investigation of valley-oriented phenomena and valley-photonic devices.

研究分野：ナノ物質科学

キーワード：原子層　バレー自由度　光学応答


3ゾーン式電気炉
ガスフロー
温度コントローラ
流量制御器
排気システム


WS2 on hBN
25 meV
Etop 2.01 eV
Intensity / counts
Photon energy / eV



1. M. Okada, A. Kutana, Y. Kureishi, Y. Kobayashi, Y. Saito, T. Saito, K. Watanabe, T. Taniguchi, S. Guptra, Y. Miyata, B. I. Yacobson, H. Shinohara, and R. Kitaura, “Direct and Indirect Interlayer Excitons in a van der Waals Heterostructure of hBN/WS_2/MoS_2/hBN”, ACS Nano, 12, 3, 2498-2505 (2018)
2. T. Nakanishi, R. Kitaura, T. Kawai, S. Okada, S. Yoshida, O. Takeuchi, H. Shigekawa, and H. Shinohara, “Modulation of the Local Density of States of Carbon Nanotubes by Encapsulation of Europium Nanowires As Observed by Scanning Tunneling Microscopy and Spectroscopy”, J. Phys. Chem. C, 121, 18195 (2017)
3. Y. Hoshi, T. Kuroda, M. Okada, R. Moriya, S. Masubuchi, K. Watanabe, T. Taniguchi, R. Kitaura, T. Machida, “Suppression of exciton-exciton annihilation in tungsten disulfide monolayers encapsulated by hexagonal boron nitrides” Phys. Rev. B., 95, 24, 241403 (2017)
4. M. Okada, Y. Miyauchi, K. Matsuda, T. Taniguchi, K. Watanabe, H. Shinohara and R. Kitaura, “Observation of biexcitonic emission at extremely low power density in tungsten disulfide atomic layers grown on hexagonal boron nitride” Sci. Rep., 7, 322 (2017)
5. T. Hotta, T. Tokuda, S. H. Zhao, K. Watanabe, T. Taniguch, H. Shinohara, and R. Kitaura,

"Molecular beam epitaxy growth of monolayer niobium diselenide flakes" Appl Phys Lett 13 (2016).

6. Q. Wang, R. Kitaura, S. Suzuki, Y. Miyauchi, K. Matsuda, Y. Yamamoto, S. Arai, and H. Shinohara, "Fabrication and In Situ Transmission Electron Microscope Characterization of Free-Standing Graphene Nanoribbon Devices" ACS Nano 10 (1), 1475-1480 (2016).
7. L. H. G. Tizei, Y. Iizumi, T. Okazaki, R. Nakanishi, R. Kitaura, H. Shinohara, and K. Suenaga, "Single atom spectroscopy: Decreased scattering delocalization at high energy losses, effects of atomic movement and X-ray fluorescence yield" Ultramicroscopy 160, 239-246 (2016).
8. S. Shinha, Y. Takabayashi, H. Shinohara, and R. Kitaura, "Simple fabrication of air-stable black phosphorus heterostructures with large-area hBN sheets grown by chemical vapor deposition method" 2D Mater 3, 035010 (2016).
9. Y. Sasaki, R. Kitaura, J. M. Yuk, A. Zettl, and H. Shinohara, "Efficient preparation of graphene liquid cell utilizing direct transfer with large-area well-stitched graphene" Chem Phys Lett 650, 107-112 (2016).
10. S. H. Zhao, T. Hotta, T. Koretsune, K. Watanabe, T. Taniguchi, K. Sugawara, T. Takahashi, H. Shinohara, and R. Kitaura, "Two-dimensional metallic NbS2: growth, optical identification and transport properties" 2D Mater 3 (2) (2016).

44

1. R. Kitaura, “Properties of van der Waals heterostructures of Transition metal dichalcogenide and hexagonal boron nitrides”, The 9th A3 Symposium on Emerging Materiaks, Kyoto, Japan, Oct. 29-31, 2018
2. R. Kitaura, “Transition metal dichalcogenide based van der Waals heterostructures: fabrication and properties”, The 9th Graphene and 2D Materials Symposium of NT18 conference, Pekig Univ., China, July 15, 2018
3. R. Kitaura, “Transition metal dichalcogenides based van der Waals heterostacks: fabrication and properties”, Japan-India Meeting on Applications of Layered Materials: Advances and Perspectives, Nagoya Univ., Japan, Nov. 9, 2017
4. R. Kitaura, “Transition metal dichalcogenides based van der Waals heterostacks: fabrication and properties”, The 8th A3 Symposium on Emerging Materials, Suzhou, China, Oct. 25-28, 2017
5. R. Kitaura, “Transition metal dichalcogenides based van der Waals heterostacks: fabrication and properties”, ICMass 2017, Nagoya Univ., Sep. 29, 2017
6. R. Kitaura, “Transition metal dichalcogenides based van der Waals heterostacks: fabrication and properties”, 18th International Conference on the Science and Application of Nanotubes and Low-dimensional Materials (NT17), Belo Horizonte Brazil, Jun. 25, 2017
7. R. Kitaura, “Bottom-up fabrication and optical properties of high-quality two-dimensional atomic layers”, 7th A3 symposium on Emerging Materials: Nanomaterials for Electronics, Energy, and Environment, Buyeo, Korea, Oct. 30, 2016
8. R. Kitaura, “Bottom-up fabrication and optical properties of high-quality two-dimensional atomic layers”, 7th UK-Japan Symposium on Fundamental Research Advances in Carbon Nanomaterials, London UK, Jun. 13, 2016

2

1. ” ” CSJ
, 2017
2. ” ”
CMC ''' , 2016

0