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論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Optical interaction enhancement of MoS2 using nanostructures investigated by cathodoluminescence
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学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	Material science and engineering	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Engineering)
学生氏名： Student's Name	Vu Thi Dung		指導教員（主）： Academic Supervisor(main)	Takumi Sannomiya
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要旨（英文800語程度）
Thesis Summary (approx.800 English Words)

The thesis presents information about the optical interaction enhancement of MoS_2 semiconductor using nanostructures investigated by the cathodoluminescence technique. The thesis is separated into five chapters including Chapter 1- Introduction, Chapter 2 - Methods, Chapter 3 - Short-range order plasmonic nanoholes, Chapter 4 - Luminescence enhancement of MoS_2 flake through plasmonic-exciton coupling, Chapter 5 - Exciton-dielectric mode coupling of single MoS_2 nanoflakes, and Chapter 6 - Conclusion and outlook.

Chapter 1- Introduction: Firstly, we introduce general introduction of the thesis relating about luminescence enhancement of MoS_2 semiconductor using nanostructures. The luminescence of MoS_2 semiconductors is weak for applications which requires efficient methods to solve this problem. Therefore, we present potential methods using optical nanostructures used in this thesis. this. The current research status of MoS_2 luminescence enhancement and fabrication of nanostructures, purpose and structures of this thesis are presented.

Chapter 2 - Methods: We present the methods used in this thesis. We introduce the method of magnetic sputtering deposition, scanning transmission electron microscope and atomic force microscope instruments. In addition, in this chapter we classify cathodoluminescence emission into coherent and incoherent emission, characterize and clarify the difference between these two types of emission.

Chapter 3 - Short-range order plasmonic (SRO) nanoholes: Plasmonic nanohole arrays can efficiently enhance and concentrate the electromagnetic field via surface plasmon polaritons. The optical resonances in nanohole arrays are usually determined by the inter-hole spacing or periodicity with respect to the surface plasmon wavelength. However, because the inter-hole spacing varies locally in SRO arrays, the plasmon resonance changes. In this chapter, we fabricate SRO plasmonic nanoholes by using colloidal lithography and self-assembly technique. Using the CL method, we investigate the local resonance of SRO nanoholes and compare it with hexagonally ordered nanoholes. The CL photon maps and resonance peak analysis demonstrated that electric fields are localized at the edges of the holes and that their resonances are influenced by inter-hole distances as well as their distributions. This illustrates Anderson localization of electromagnetic waves with regionally improved electromagnetic local density of states in SRO nanoholes.

Chapter 4 - Luminescence enhancement of MoS_2 flake through plasmonic-exciton coupling: In this chapter, we present the first method to enhance the internal luminescence using a hybrid structure consisting of MoS_2 flake placed on top of Au nanopyramid arrays. To achieve the luminescence enhancement in MoS_2, it requires a suitable design and optical controls for Au plasmonic nanopyramid structure, to maximize the coupling efficiency with the excitons of MoS_2. The Au nanopyramid array is fabricated using a combination of colloidal lithography and self-assembly techniques of the mask colloid particles. The local plasmonic field confined within the nanopyramids interacting with the excitons enhances the luminescence intensity of the MoS_2 flake. We experimentally visualized local luminescence enhancement in MoS_2 flakes in hybrid structures through CL map photons. By comparing the intensity of the MoS_2 emission with and without the underlying nanopyramids, we have successfully demonstrated a significant luminescence enhancement resulting from the plasmon-exciton coupling of Au nanopyramids and MoS_2 flakes.

Chapter 5 - Exciton-dielectric mode coupling of single MoS_2 nanoflakes: MoS_2 are high refractive index materials thatcan ,when shaped into nanostructures, effectively confine the electromagnetic field at nanoscale dimensions, resulting in complex light emission with exciton and dielectric resonances. In this chapter, we investigate the luminescence enhancement of MoS_2 caused by dielectric resonances in nanoscale dimensions by experimentally visualizing the emission modes of single MoS_2 nanoflakes through CL maps. The photon emission distribution on individual nanoflakes is visualized, followed by a comparison of emission wavelengths for various flake shapes. The acquired CL mapping data is spectrally deconvoluted to split the overlapping emission modes in nanoflake, and the dielectric mode is determined further based on the field distribution. We explore how the resonant modes contribute to luminescence enhancement based on the identified deconvoluted peaks. We also observed dielectric modes with resonant wavelengths that is dependent on the shape and size of the nanoflake, while the exciton emission peaks with energies are unaffected by the flake geometry. We further experimentally and theoretically visualized the emission polarization and angular emission patterns using a fourth dimensional CL technique and boundary element method simulations. The acquired CL mapping indicates the interaction of the exciton and dielectric resonant modes, leading to the field enhancement.

Chapter 6 – Conclusion and outlook: In this chapter, we summarize the results reported from chapters 3, 4 and 5 regarding the enhanced emission of MoS_2 using optical nanostructures, and suggest future research directions. For the future work, based on the coherence of the emitted light regarding the electron beam excitation, the CL signal is categorized into either coherent or incoherent. The high beam current creates proportionally more coherent photon emission, whereas incoherent photon intensity may not be linearly dependent on the beam current due to saturation.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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