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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士（理学）　氏名　チャタジー　スバスリ

学 位 論 文 題 名

Synthesis and Surface Engineering of InSb Colloidal Quantum Dot for Short Wave Infrared Photodiodes
（アンチモン化インジウムコロイダル量子ドットの合成と表面工学及び短波赤外光フォトダイオードへの応用）

Indium antimonide (InSb), a typical III − V direct bandgap semiconductor, exhibits excellent electronic properties including a narrow bandgap (0.17 eV at 300 K), high electron mobility at room temperature, small effective masses for holes and electrons, low thermal conductivity, small exciton binding energy (0.5 meV), and large exciton Bohr radius of 60 nm. These excellent physical properties are advantageous for use as an optical absorption layer in short-wavelength infrared (SWIR) photodiodes (PDs), which are gaining attention in a variety of applications, including remote sensing, light detection and ranging, optical communications, bioimaging, thermal imaging, and medical monitoring for healthcare research. In this context, the synthesis of InSb colloidal quantum dots (CQDs) in which charged carriers would be strongly confined are attracting a great deal of attention in recent years, but there are still a limited number of published papers on their synthesis. Three possible reasons are raised. First, due to the highly covalent nature of InSb, their synthesis requires reactive organometallic precursors compared to II-VI compound semiconductors. Nevertheless, choices of precursors of indium and antimony are limited at present. Second, due to its strong covalent nature, nucleation, and growth of InSb nanocrystals require a high energy field provided at high temperature for the synthetic reaction. Third, post-synthetic purification is still a challenging theme. Therefore, the thesis focuses on the synthesis of high crystalline impurity less InSb CQDs with readily available halide precursors at first. Second, to improve the carrier mobility for fast charge transfer, long chain oleylamine (OLA) ligand was exchanged with atomic ligand such as bromide and sulfide for self-powered SWIR photodiode application.

Chapter 1 provides general background of SWIR-light emitting materials, overview about the synthesis of CQDs and figure of merits for photodetection. In details the process, the purpose of this research which led to the urgency of studying InSb CQD for SWIR-light sensing.

Chapter 2 focuses on the facile synthesis of InSb CQDs with halide precursor. Unlike to previous all the InSb CQDs synthesis reports, the motivation of this study is to synthesis pure phase impurity-less InSb CQDs with less reactive and easily available and stable precursors. I have used chloride and bromide precursors by following hot-injection synthesis procedure. Additionally, we have compared the product prepared by the two precursors.

Chapter 3 focuses on the surface modification by ligand exchange procedure. As OLA is a long chain ligand which helps to CQDs dispersed in solution, while it acts as an insulator for charge transfer for device application. Therefore, ligand exchange from long to short chain is an important step in solution processed optoelectronic field. Here, ligand exchange was performed by bromide and sulfide ligands to increase carrier mobility and charge transfer between the CQDs.

Chapter 4 focuses on the fabrication of InSb CQD based photodiode for SWIR sensing. Here, I have demonstrated first-ever InSb CQD based photodiode for SWIR sensing where bromide capped InSb was used as active layer. The resulting PDs achieve a photoresponse of ∼550 ms at 0 V, with combining the best values of responsivity and external quantum efficiency of 0.098 A/W and 10.1% under a bias voltage of -1 V at room temperature even in ambient air. Secondly, to improve the carrier mobility sulfide capped InSb CQD was further used as active layer, QPD responded as self-powered photodiode and achieves 1.3% EQE and responded 200 ms at 0 V, with 18.5% EQE at -1 V under 1100 nm.

Chapter 5 summarizes the achievements in these works, proposes future work on p-n junction InSb with further improvement and conclude the thesis.