

審 査 の 結 果 の 要 旨

氏 名 肖 紅 彬

Plasmonic channel structure for sensing and photodetection at telecommunication wavelengths

Photodetection using hot electrons extracted from plasmonic structures has the capability of enabling photodetection at sub-bandgap energies of semiconductor materials, that is, extending the range of useful wavelengths for photodetection (photon energy smaller than the bandgap) of important technological materials such as silicon. Silicon-based photodetectors incorporating hot electrons have emerged as one of the most studied devices used for near infrared photodetection, particularly at telecommunications wavelengths (e.g., the C-band covering the range 1530-1565 nm). A typical design of these photodetectors relies on a grating structure with a metal/semiconductor interface. In these photodetectors, light is absorbed selectively due to the plasmonic resonance, and light absorption is enhanced due to the field localization of the plasmonic resonance at the metal/semiconductor interface. Nanostructures such as nanorods and nanowires have also been employed to realize plasmonic resonances with photoresponses. However, the broad bandwidth, large dark current and small responsivity of these reported photodetectors have limited their practical applications. XIAO proposes a silicon channel-separated interdigitated gold grating structure and demonstrates sensing and photodetection at telecommunication wavelengths. The thesis manuscript consists of five Chapters.

In Chapter One, the basic theory of plasmonic structures used in promoting hot electrons for sensing and photodetection is reviewed, and a description of the hot electron transport at metal/semiconductor interfaces is given. Particularly, three different types of plasmonic structures are reviewed, namely, metal/semiconductor, metal/semiconductor/metal, and Tamm plasmons.

In Chapter Two, the fundamental optical properties of the proposed plasmonic structure consisting of silicon channels separated by gold slabs are investigated by simulation. For photodetection purposes, the structure is designed to absorb light at the gold/silicon interface by exciting a surface plasmon polaritons mode that takes advantage of the structure period and the silicon channels. For sensing purposes, the structure is designed to absorb light at the gold/air interface with a sharp surface plasmon polaritons resonance supporting a strong near field that renders the resonance sensitive to its surroundings. Sensing minute changes in refractive index in the vicinity of the plasmonic structure is demonstrated with a sensitivity as

high as 750 nm/RIU.

In Chapter Three, XIAO applies the structure consisting of silicon channels separated by gold slabs to near-infrared photodetection by using the gold nanoslabs as electrodes. Both parallel (interdigitated) and series electrical connections of the gold nanoslabs are investigated. With a strongly resonant and narrowband photocurrent response, the structures achieve spectrally selective photodetection in the telecommunications C-band. The measured responsivity of the parallel structure reaches 804 nA/mW at the resonant wavelength of 1550 nm and the bias voltage of 0.08 V. The dark current represents less than 1% of the photocurrent. Moreover, a large modulation of 60% of the photocurrent when the light wavelength is varied by only 20 nm (from 1550 to 1530 nm) enables the wavelength monitoring within the C-band. XIAO also uses a theoretical model to quantify the photocurrent response in terms of the optical and electrical properties of the proposed structure. The relatively high photocurrent response with a small full width at half-maximum and readily tunable resonant wavelength not only enable XIAO's proposed structure to achieve spectrally selective photodetection in the near-infrared but also makes it amenable to applications in imaging devices and other optoelectronic devices working in the sub-bandgap regime of semiconductor materials.

In Chapter Four, a structure consisting of a metallic grating on a photonic crystal (distributed Bragg reflector) is proposed and investigated by simulation. This one dimensional structure possesses clear advantages such as ease of fabrication compared to the silicon channel-separated interdigitated gold grating structure and also offers efficient light confinement suggesting a possible design for hot electron based photodetection. The simulated responsivity shows similar performance with the best performing structures reported in the literature.

The conclusion of the work is summarized in Chapter Five.

よって本論文は博士（工学）の学位請求論文として合格と認められる。