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A Silicon Schottky Photodetector Made Directly on a Silicon Fiber

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Abstract

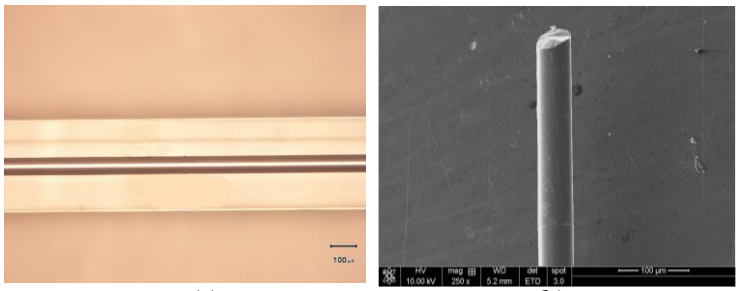
We demonstrate a microscale silicon Schottky photodetector (PD) operating at telecom wavelengths based on internal photoemission process. The PD consists of a metal film on a silicon fiber to form a Schottky contact. The responsivity of the detector is 0.249 mA/W at 1550 nm at the reverse bias voltage 0.5 V.

1. Introduction

A silicon photonics platform offers the best combination between optical communication systems and modern electronic circuitry [1]. However, a hard issue for silicon platform is the fabrication of active devices such as light sources and PDs [2]. The near-infrared transparency window limits the usefulness of silicon as an active absorbing material for photodetection. Because the energy of infrared photons is too low to overcome the potential barrier of silicon bandgap (~1.1 eV), few free carriers could be generated. A way of detecting infrared sub-bandgap optical radiation in silicon is to apply the internal photoemission process [3] using a Schottky barrier PD [4,5]. Schottky PDs are very attractive because of their simple material structures and fabrication process. However, the silicon waveguide based detectors generally require more complicated semiconductor fabrication process to define the waveguide region. In this work we demonstrate a way to fabricating Schottky PDs built directly on a silicon fiber, which can eliminate the need of optical end fiber coupling because of its inherent waveguiding in the silicon fiber.

2. Experiment Section

Though the fabrication of a Si-cored fiber was reported [6], a different method was realized to make long Si-cored fibers of better optical characteristics. And then a silicon fiber was obtained by taking the following process. Polycrystalline n-type silicon powders were packed in a fused silica tube which passed through a heated zone set at some suitable temperature and was drawn out to be in a fiber form. The silicon powders were melted and the fused silica tube became softened before being drawn out of heated region. The silicon core inside the fiber was found continuous without observable defects. To obtain a circular silicon waveguide, the silica cladding of a Si-cored fiber was removed by using buffered hydrofluoric acid solution. Fig. 1(a) and 1(b) show the images of an n-type Si-cored fibers with and without silica cladding, respectively. Fig. 2 shows schematically the diagram of a Schottky PD directly made on a silicon fiber. The silicon fiber waveguide was placed on a glass substrate and coated with NR5-8000 photoresist which served as mask to define detection and contact areas for mental deposition. To make a Schottky PD, a silver pad as ohmic contact was made first on the silicon fiber. Then a 300 nm thick Au layer was deposited on the fiber and followed by a lift-off process to form the Schottky contact.



(a) (b)

Fig. 1(a) An optical microscope image of a Si-cored fiber, (b) SEM image of a Si-cored fiber without silica cladding.

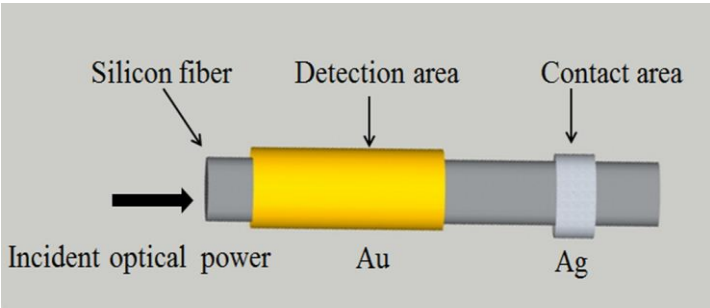


Fig. 2 the diagram of a Schottky PD directly made on a silicon fiber.

For device characterization the current-voltage (I-V) characteristics of the Schottky PD was measured for different optical input power of light operating in 1550 nm wavelength. End fire optical coupling was applied to making light guide to the PD. The optical coupling would be obtained by direct splicing with a conventional single-mode fiber, therefore, The PD is fiber ready without the need of end fiber coupling from a receiving fiber end. Fig. 3 shows the measured photocurrent versus reverse bias at different incident optical power. It is clearly seen that the photo-generated carriers increased with bias voltage and light intensity, proving the function as PD. At 0.5V reverse bias, the dark current was found 0.226 μA, and the photocurrent was 2.9 μA for 10 mW incident power. The value of Schottky barrier was estimated to be 0.74V, similar to the value, 0.78, for n-type silicon-Au Schottky contact [7]. The difference in values may be resulted from on the surface roughness of silicon [8]

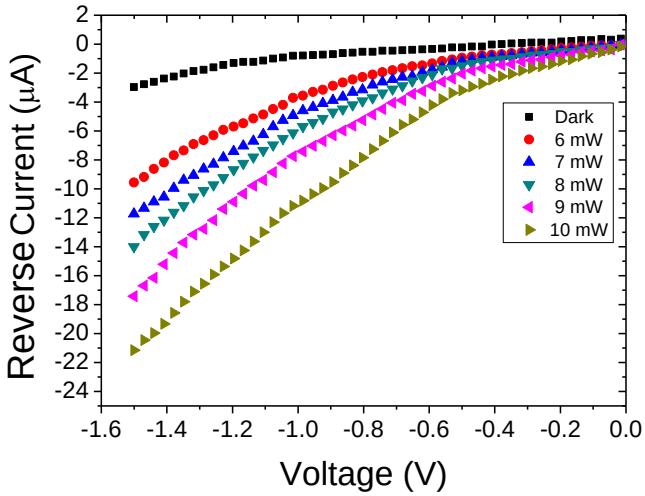


Fig. 3 Measured photocurrent versus reverse bias for optical signals of varied power.

The responsivity of the PD was determined by measuring the current across the Schottky contact under reverse bias as a function of the incident optical power. Fig. 4 shows the measurement result. As expected, the photocurrent increased almost linearly with the input power. The slope of linear fit corresponds to the external responsivity of PD according to $I = I_{dark} + RP_{in}$, where I_{dark} is the leakage current of the detector, P_{in} is the incident optical power and R is the responsivity of the device. Therefore, the responsivity of PD was found 0.249 mA/W at 1550 nm when reverse biased at 0.5 V.

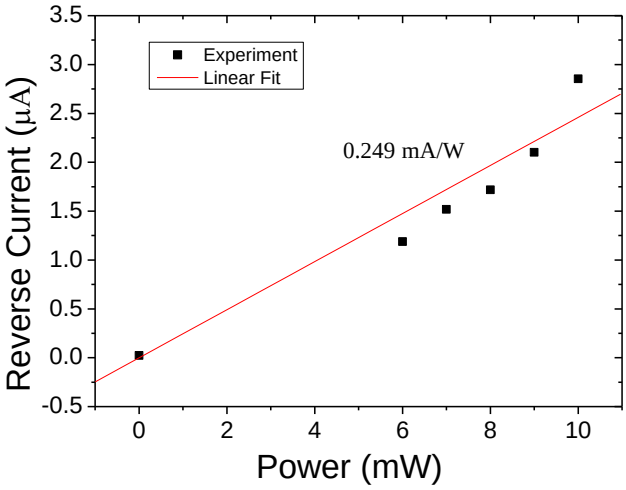


Fig. 4 Measured photocurrent with respect to the incident power of a 1550nm laser at 0.5 reverse bias

3. Conclusion

We have demonstrated a novel method to fabricate a silicon Schottky PDs for working in presumably transparent telecom wavelengths. This method provides a rapid fabrication process for making a silicon waveguide PD without the need of resorting to the conventionally complicated semiconductor process. The device's detection capability was attributed to the internal photoemission. The responsivity of the detector was 0.249 mA/W at 0.5 V reverse bias. Such PDs would be potentially useful for fiber optical ready application in the fields such as power monitoring and optical interconnects.

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