Silicon Microspheres for Optoelectronics

***Huzeyfe Yılmaz*[1], *Mohammed S. Murib*[1,2], *Ali Serpengüzel*[1], *Kenichi Taira*[3], *and Josuke Nakata*[3]**

[1]Huzeyfe Yilmaz and Ali Serpengüzel are with the Koç University, Microphotonics Research Laboratory, Physics Department, Rumelifeneri Yolu, Sarıyer, Istanbul 34450 Turkey.
huzyilmaz@ku.edu.tr, aserpenguzel@ku.edu.tr

[2]Mohammed S. Murib is currently with the Hasselt University, Institute for Materials Research, Wetenschapspark 1, B-3590 Diepenbeek, Belgium
mohammed.murib@uhasselt.be

[3]Kenichi Taira and Josuke Nakata are with the Kyosemi Corporation, Department of Technical Development, 2nd Research and Development Headquarters, Toiso 385-31 Eniwa, 061-1405 Japan.
taira@kyosemi.co.jp, nakata@kyosemi.co.jp

Abstract

Optoelectronic properties of silicon microspheres are explored. The IV characteristics show an electrical response similar to two back-to-back Schottky diodes. Optical resonances with Q-factors of 10^5 are observable in the elastic scattering spectra.

1. Introduction

Silicon is an excellent candidate for the optoelectronic material of choice of the 21st century. Spheres on the other hand have interesting optical properties. Sphere is the most symmetric geometric shape, and therefore is ideal for light collection with maximum possible solid angle of 4π. Spherical silicon crystals were grown under microgravity in a drop shaft [1]. Spherical silicon spheres have been developed for solar cell applications [2].

In addition to its geometric optic properties, such as acting as a thick lens, the sphere possesses quantum electrodynamic (QED) properties, such as acting as an optical cavity, with high quality factor optical resonances, i.e., whispering gallery modes (WGM's) or morphology dependent resonances (MDR's). Optical channel dropping has been performed using the optical resonances of silicon microspheres [3]. Optoelectronic properties of silicon microspheres with approximate diameters of 1.0 mm have also been studied [4].

Fig. 1. A silicon microsphere with an average diameter of 1.165 mm.

Recently, optical modulation in silicon microspheres has been observed [5]. In this work, we report on the optoelectronic properties of slightly larger silicon microspheres with approximate diameters of 1.2 mm.

Figure 1 shows the image of a silicon microsphere with an average diameter of 1.165 mm. The image is acquired by a visible camera and a standard optical microscope. A 10X lens, a 5X eyepiece and 2X digital zoom of the camera were used for a total of 100X magnification. The diameter of the sphere is measured in different directions and orientations with a digital micrometer with a resolution of 1 μm.

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2. Experimental Setup

Figure 2 shows the experimental setup used for current-voltage (IV) response measurements and optical elastic scattering experiments. The silicon microsphere is placed in between two gold/copper alloy probes and on top of an optical fiber half coupler (OFHC). The elastic scattering data at 90° is collected with the help of an optical microscope. The sphere in this picture has an approximate diameter of 1.00 mm.

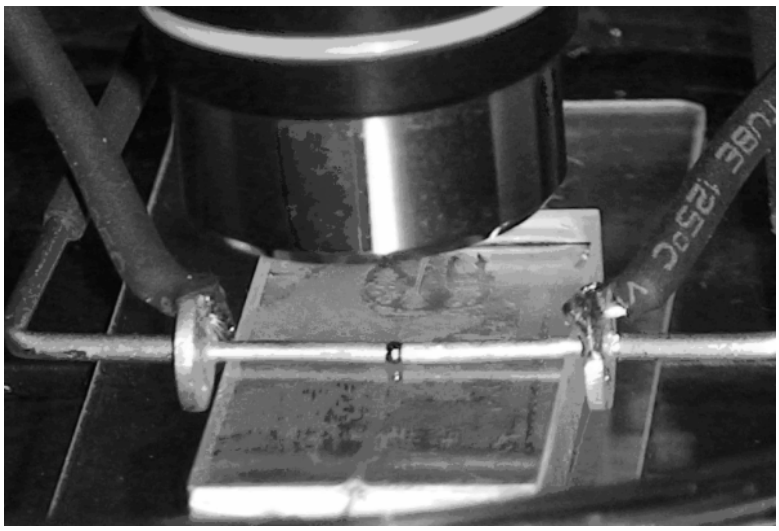

Fig. 2. The experimental setup used for IV response measurements and optical elastic scattering experiments.

3.1 Electrical Measurements

The IV response of the silicon sphere is measured using a computer controlled voltage supply and a current meter. The semiconductor (silicon) microsphere and the two gold/copper alloy probes/holders have a metal-semiconductor-metal (MSM) structure, and electrically respond like two back-to-back Schottky diodes. Figure 3 shows the measured IV curve for the MSM structure.

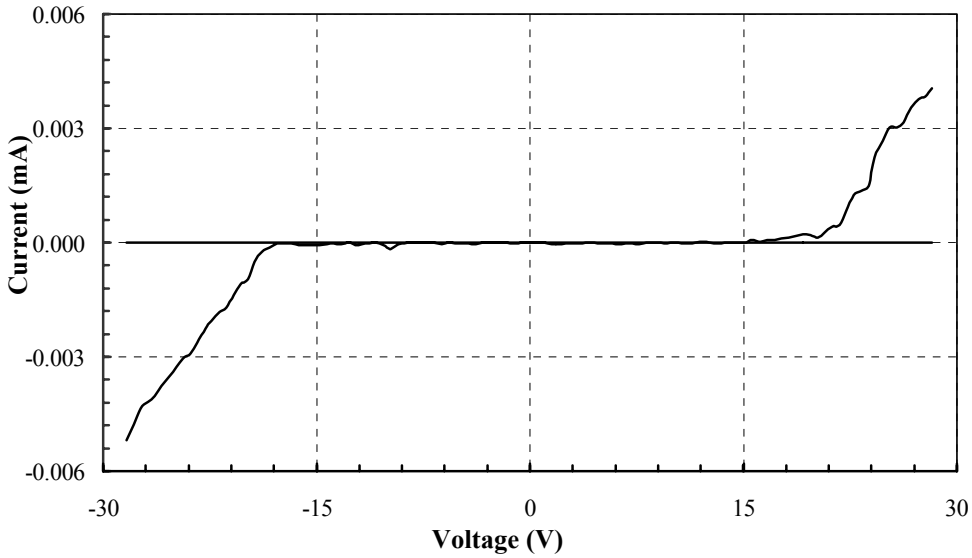

Fig. 3. Measured IV curve for the MSM structure.

3.2 Optical Measurements

Elastic light scattering at 90° from the silicon sphere is measured using a tunable near infrared semiconductor diode laser (SDL) operating at 1475 nm. The SDL light is coupled in and out using an optical fiber half coupler (OFHC). When incident light from the tunable SDL is subject to total internal reflection (TIR) inside the sphere, optical resonances occur at certain wavelengths. Figure 4 shows high spectral resolution elastic scattering intensity at 90° around an optical resonance, with a quality factor on the order of 10^5 for the silicon sphere of radius 582.5 μm.

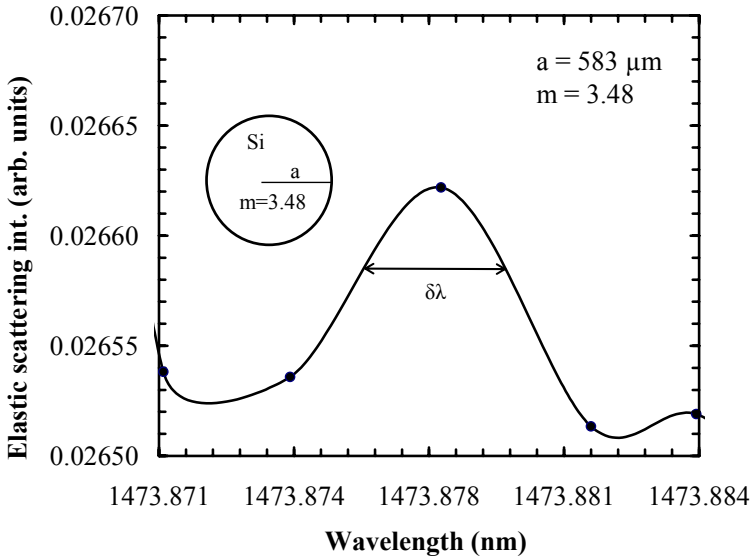

Fig. 4. High spectral resolution elastic scattering intensity around an optical resonance, with a quality factor on the order of 10^5 for the silicon sphere of radius 582.5 μm.

Figure 5 shows the high spectral coverage elastic scattering spectrum at 90° from a silicon microsphere. The morphology dependent resonance peaks are visible in elastic scattering spectrum. The quality factor of these optical resonances is on the order of 10^5.

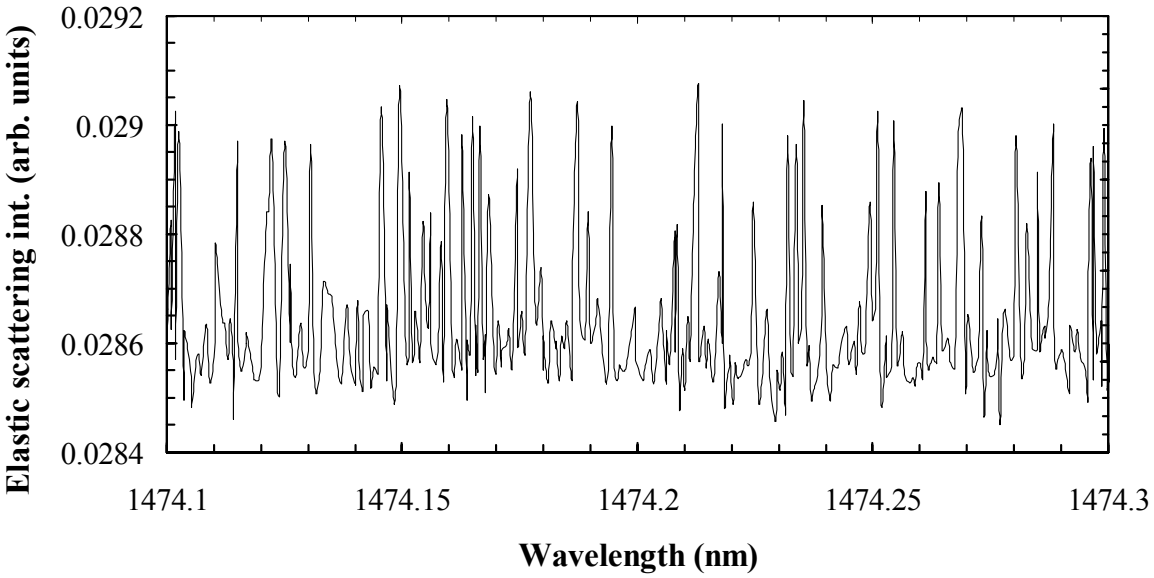

Fig. 5. High spectral coverage elastic scattering intensity from a silicon microsphere. The morphology dependent resonance peaks in the elastic scattering spectrum can be observed.

4. Conclusions

In conclusion, we have characterized the optoelectronic properties of silicon microspheres in the near infrared telecommunication bands using a tunable semiconductor diode laser (SDL). The silicon microsphere and the two gold/copper alloy probes/holders form a metal-semiconductor-metal (MSM) structure. The IV characteristics of the MSM exhibit an electrical response similar to that of a two back-to-back Schottky diodes. Optical resonances with quality factors on the order of 10^5 are observable in the 90° elastic scattering spectra. Silicon microspheres are ideally poised for a novel generation of discrete and integrated optoelectronic devices of silicon photonics.

5. Acknowledgments

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7. References

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