Optimizing efficiency of photon emission from electrically driven silicon color centers

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The need for efficient monolithically integrated light sources in silicon drives this research to electrically pump photons from silicon color centers (CCs). In prior work, photoluminescence (PL) was used to excite color centers and verify CC synthesis. In this work, CC-embedded p-i-n junction devices are used to stimulate CCs and generate electroluminescence (EL). Two types of CCs are used in these devices: W and G centers, which emit in the telecommunications band at 1218 nm and 1279 nm, respectively[1-3]. Thus, these silicon CCs are promising prospects for advancing the needs of quantum communications.

The CC-embedded p-i-n devices were fabricated on two silicon-on-insulator (SOI) wafers, one of which contains W-centers, and G-centers for the other. Phosphorous and boron ions were implanted for the n-type and p-type ohmic regions. The intrinsic region of the devices was implanted with silicon or carbon ions to form W and G centers, respectively. A post-implant anneal was done to enable CC formation followed by the deposition of TiAu contact pads to enable electrical contact to each device. The device design varies across the wafer with respect to the 1) implant window width, 2) ohmic wire width, and 3) separation between the ohmics, as shown in Figure 1. These splits are intended to elucidate the effects of the design on the electro-optical behavior of the devices.

Emission of W and G centers is only seen at cryogenic temperatures below 40 K, thus the electro-optic measurements of the devices must be conducted at such temperatures[4]. Using a cryostat reaching 4 K, a die containing 12 devices is mounted on a printed circuit board to enable electrical accessing of each device. A photodiode is positioned over the die to collect the photocurrent upon applying a voltage to each device. Figure 2 shows the efficiency of light at a common device consumption power of 100 μW for W-center devices with respect to varying ohmic separations. The efficiency is calculated as the ratio between the power collected by the photodiode to the power consumed by the device. The devices are then placed in an optical cryostat to determine whether the light is emitted from the CCs by collecting the EL spectrum. We have successfully observed EL from the W-center embedded p-i-n devices with results for the G-center devices underway. In this talk, the effects of design on the electro-optical efficiency of our devices will be analyzed along with progress on EL measurements to date.

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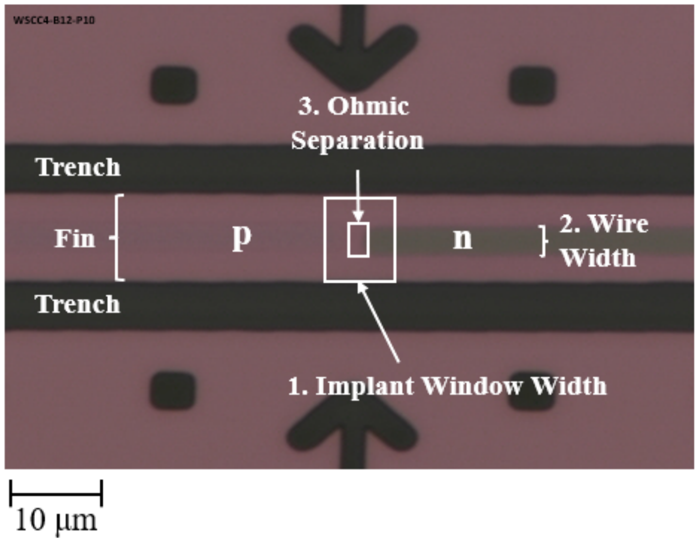

Figure 1. A micrograph of a CC-embedded p-i-n device with the design parameters (implant window width, wire width, and ohmic separation) labeled. The trenches are used for charge isolation and the width of the fin for all devices is 9 µm.

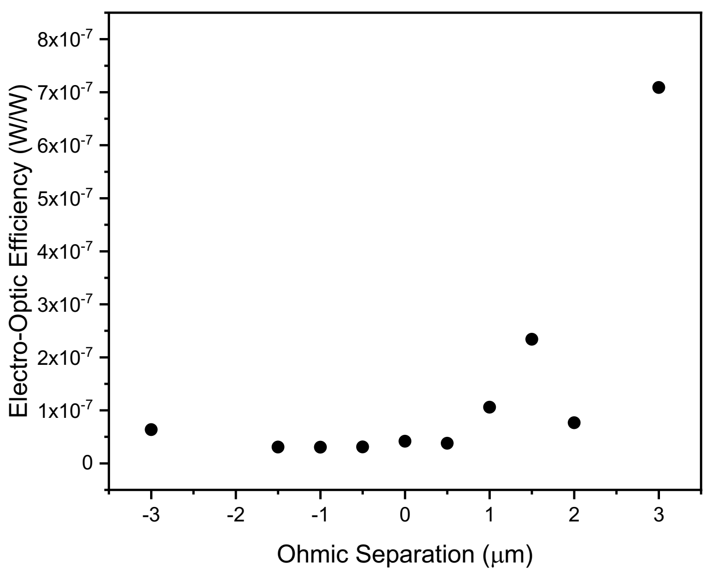

Figure 2. The efficiency of light collected using a photodiode from W-center embedded p-i-n devices with the same implant window width and wire width but with varying ohmic separations. The efficiency is calculated as the ratio of the power of light emitted from the device (collected by the photodiode) to the power consumed by the device. The efficiency is taken from data at a common device power of 100 µW.