BAPVC Annual Project Report

Project Title: Laser Wafering  
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Summary:
We examine a new process whereby silicon wafers at the optimum thickness of 20-90 µm are directly cut from an ingot of silicon using sub surface laser cutting. A laser with a wavelength of 1.5-2.5 µm ablates a series of etch pits up to several centimeters below the surface of the silicon block. By creating multiple layers of etch pits in the sub surface of a silicon block, the entire block can be divided into individual wafers. Critically, the wafers have the same minority carrier lifetime as the starting ingot.

A parallel project determines the performance of solar cells that can be fabricated from thin wafers. We demonstrate the ability to passivate silicon wafers with a very low surface recombination of 2 cm/s and achieve high open circuit voltages of 753 mV.

Key Accomplishments:
Over the last year we have been using the laser installed at the bio-science building at ASU. The system consists of a 120 fs pumped OPA system. The output wavelength is fixed at 1200 nm with a 2400 nm parasitic. We have been using this system to develop the process while we are waiting for delivery and installation of our laser system.

The focusing of the laser is achieved using a 0.28 numerical aperture objective. A silicon wafer is normally transparent at the 1200 nm wavelength used but at high fluence the laser light is actually absorbed so that a pit should be created below the surface. As shown in Figure 1 below the size of the ablation is around 100 µm. At this stage the focus of the bio-sience laser below the surface has not produced a definitive ablation plane.

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<tr>
<th>5X magnification</th>
<th>10X magnification</th>
<th>20X magnification</th>
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<tr>
<td>6</td>
<td><img src="image1.png" alt="6X Image" /></td>
<td><img src="image2.png" alt="10X Image" /></td>
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<td>7</td>
<td><img src="image4.png" alt="7X Image" /></td>
<td><img src="image5.png" alt="10X Image" /></td>
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Figure 1: Laser ablation achieved using a 1200 nm laser in silicon.

A dedicated laser for the project has been purchased and is presently installed. The new laser allows for ablation at a range of wavelengths 680 – 2900 nm. A series of experiments is
presently underway to characterize the ablation from the new laser as a function of fluence and wavelength.

The second task in the project is to explore the manufacture of solar cells on the substrates once they are created. A key challenge for very thin substrates is that the recombination at the surfaces dominates and passivating the surface defects is critical for the creation of high performance devices. The plot in Figure 2 shows the cells open circuit voltage as a function of cell thickness. The results demonstrate the high level of surface passivation that has been achieved for our devices. Without adequate levels of surface passivation the cell $V_{OC}$ would drop as the wafer gets thinner. In our case the surface recombination is below 2 cm/s and the $V_{OC}$ is a maximum for the thinnest wafers. We have achieved a record $V_{OC}$ of 752 mV on a 44 $\mu$m thick wafer.

![Figure 2: Effective Lifetime and cell open circuit voltage.](image)

**Future Work:**

The work for the next year will cover the use of our laser to better understand the subsurface generation damage mechanism. The work will then proceed to generate a sub-surface damage array of etch pits. Finally the design subsurface damage array system and layer etch process will be conducted.