Silicon Nanowire Solar Cells by Metal-Assisted Chemical Etching

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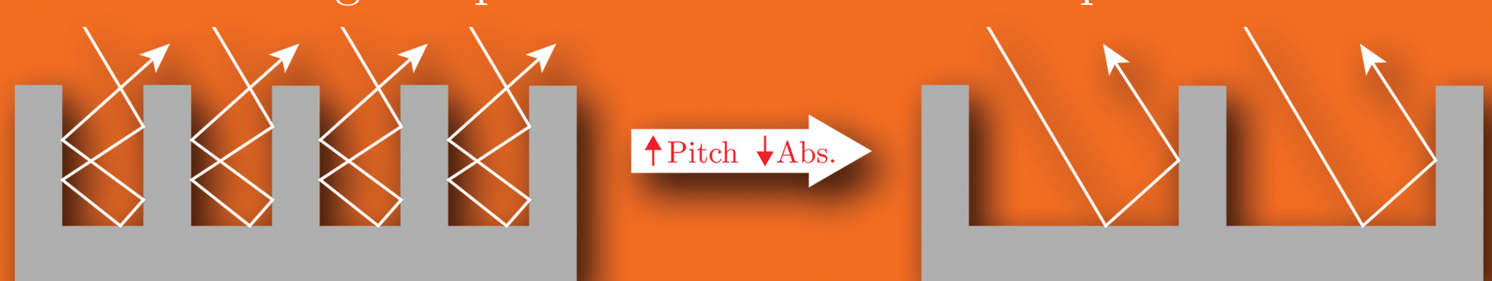
Abstract

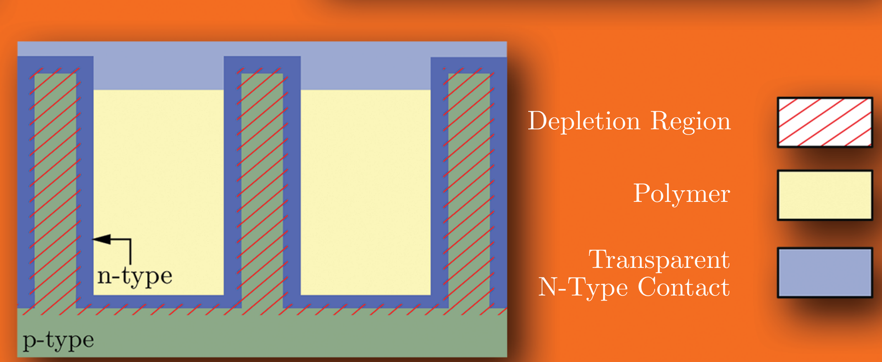
Silicon nanowire (SiNW) arrays were generated from a nanosphere lithography patterned gold mask by metal-assisted chemical etching. The optical reflectance of these SiNW arrays was studied as a function of nanowire diameter, pitch, and height. Less than 1% reflectance was achieved over the 300 to 1000 nm wavelength range for both 200 and 300 nm diameter wires at different pitches and at as low as 3 µm wire heights. Monolayer doping was used to generate a radial p-n junction with an estimated junction depth of 50nm inside the nanowires to enable the fabrication of silicon nanowire solar cells. Slight rectification and light-generated current was measured in short (1.6 µm) nanowire devices, however, lack of surface passivation led to poor device performance.

Introduction

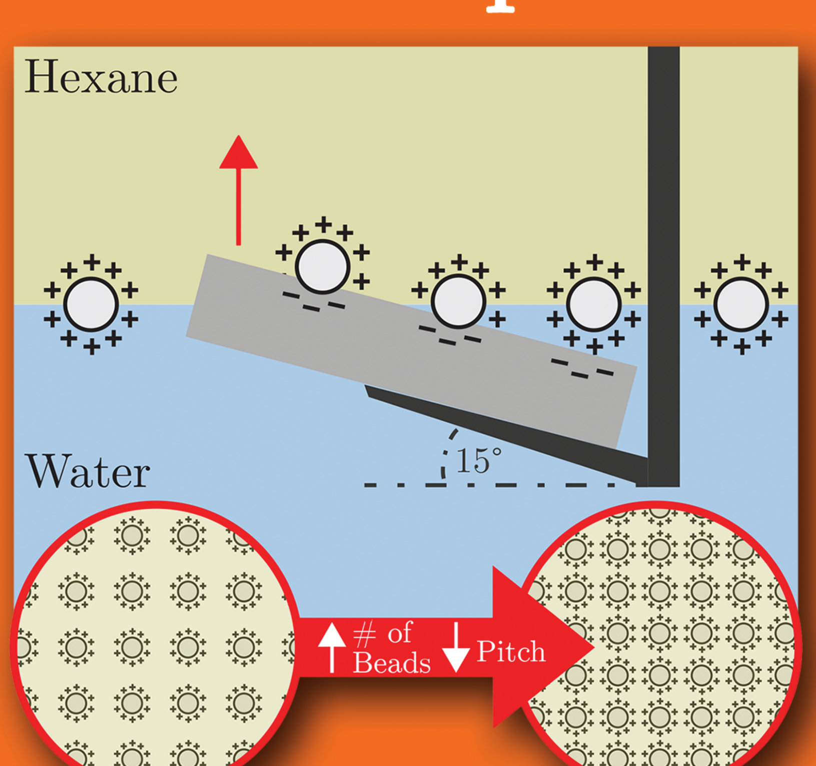
Arrays of silicon nanowires (SiNWs) have been shown to have advantageous optical properties which are directly dependent on the diameter, pitch, and height of the wires - showing the importance of having independent control over each parameter.



The improved optical absorption and increased carrier collection efficiency makes them of interest to be used as the active region of a solar cell.



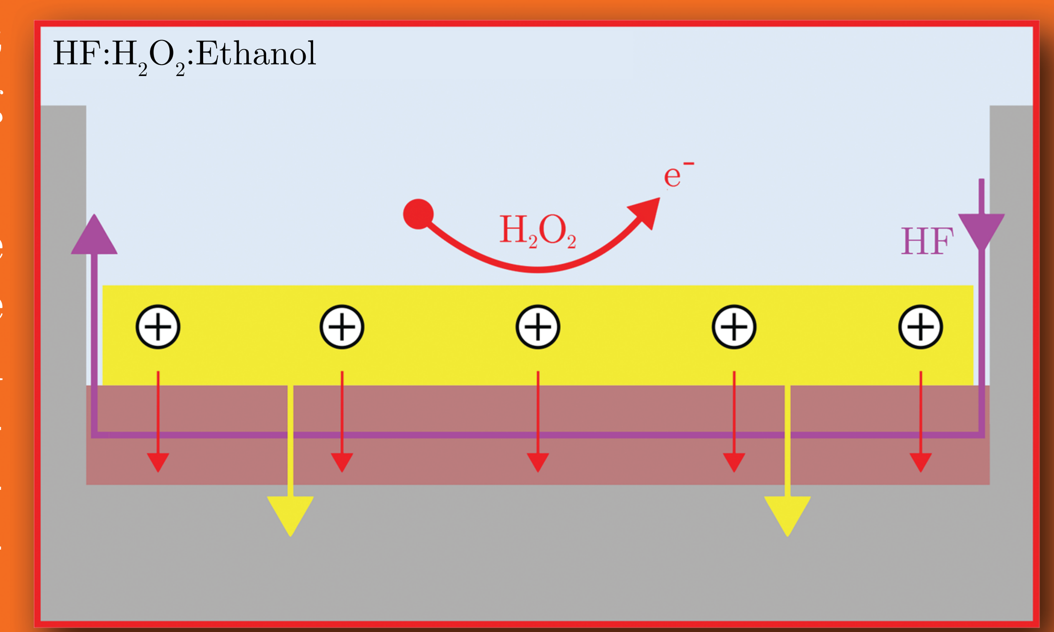
Nanosphere Lithography



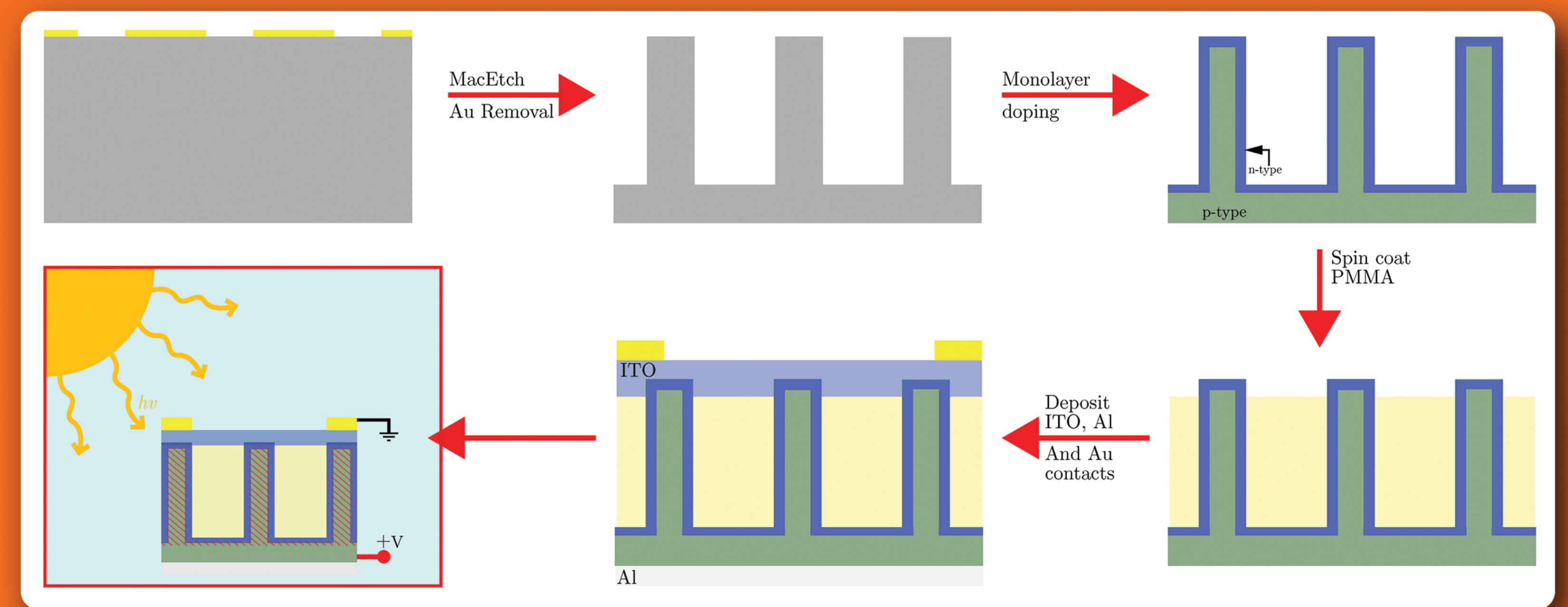
- Charged polystyrene nanospheres are injected at the interface between water and hexane.
- The self-assembly of these polystyrene nanospheres is driven by long-range electrostatic forces, forming a non-close packed monolayer at the interface.
- Nanosphere pattern is transferred by withdrawing the substrate through the interface.

Metal-Assisted Chemical Etching

- A simple and low-cost method for fabricating silicon nanostructures.
- H_2O_2 is reduced at the gold surface, holes are generated and injected through the gold, oxidizing the underlying silicon, which is then dissolved by the HF.

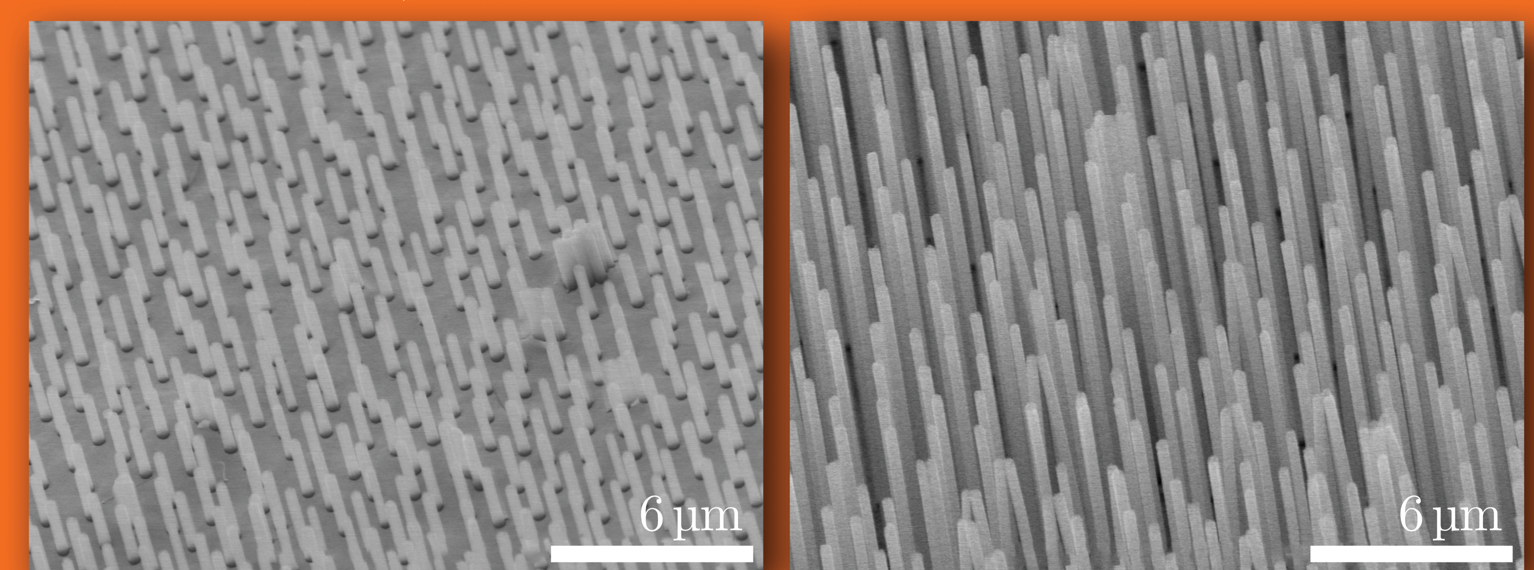


Process Flow



Nanowires

- Nanowires were etched with an etch rate of approximately 100 to 150 nm/min.



Acknowledgements

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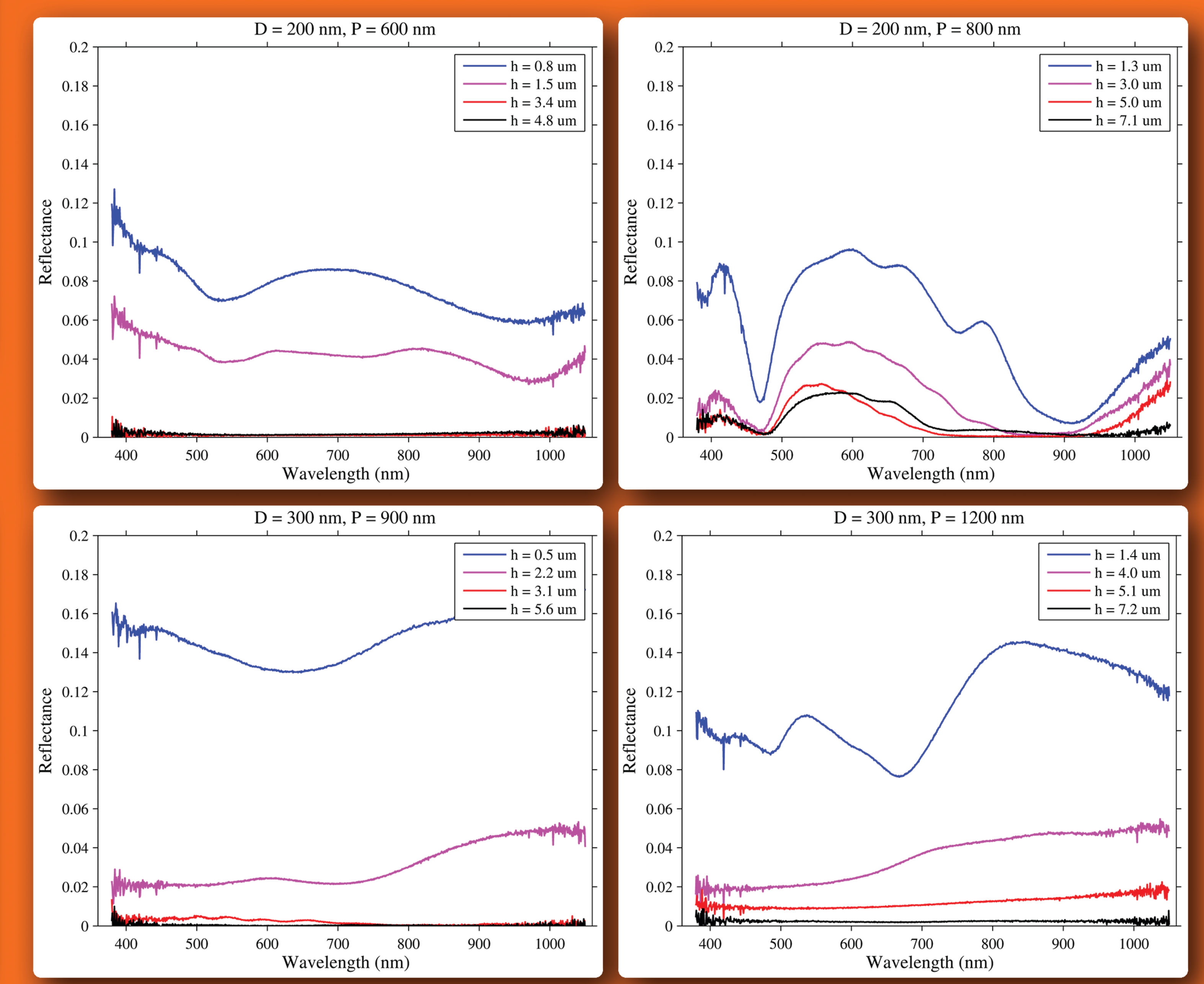
Optical Characterization

- The optical reflectance properties of various NW arrays as a function of NW diameter, pitch, and height were studied. Bare silicon has a reflectance of approximately 35% over this range.



Solar Cell Test Results

- A nanowire device with short (1.6 µm) wires, in a 300 nm diameter, 900 nm pitch arrangement showed slight rectification and light-generated current.
- Poor device performance is likely due to lack of surface passivation and the resulting surface charge depletion along NW sidewalls.
- Larger wires failed to show observable rectification, which may be a product of the non-optimized MLD process.