Effect of Laser Annealing on Absorptance of Black Silicon

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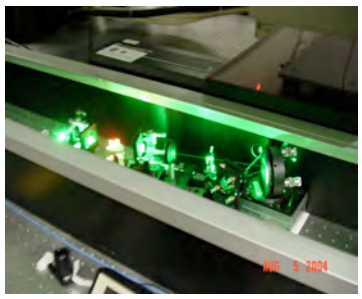
Abstract

We report the use of a femtosecond laser at low fluence for the annealing of black silicon. This removes the necessity for oven annealing, increasing the possibility that the production of black silicon solar cells could be made into a one stage process. Black silicon samples were manufactured in SF_6 and annealed at three different laser fluences. The absorptances of these samples were compared to oven annealed samples at different temperatures. As laser fluence increased the absorptance decreased, a similar pattern to that observed in oven annealing. Annealing is thought to increase the number of free carriers in the black silicon, making it more suitable as a solar cell



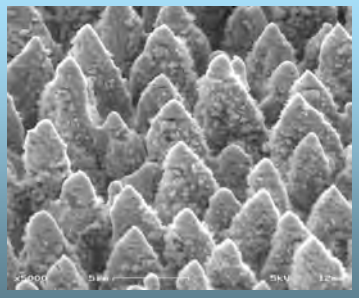
Femtosecond Laser

Manufacture of Black Silicon in SF_6

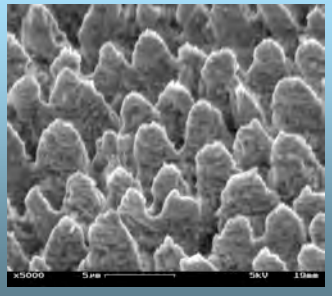
Black Silicon on Silicon Wafer

SEM Photographs of Black Silicon

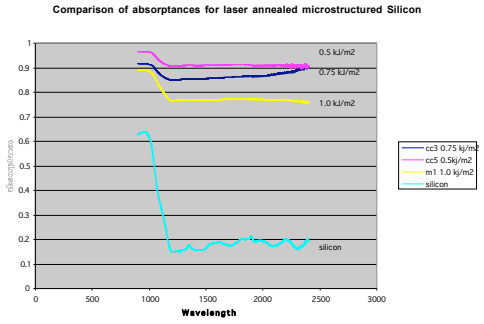
Non-annealed Black Silicon

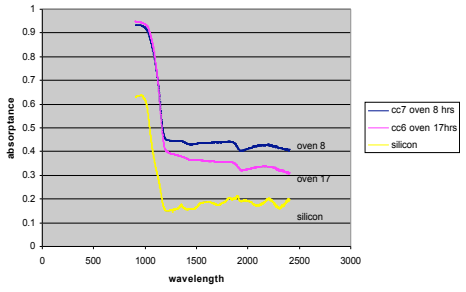


Black Silicon Laser Annealed at 1.0 kJm²



Graph of Absorptance for Laser and Oven Annealed Black Silicon





Laser Annealing Summary

Background

Black silicon is silicon blasted by femto second pulses from a laser which turns it black. This is a very unusual property since normal silicon is transparent to many wavelengths in the visible spectrum which gives it semi translucent qualities. By turning it black the wavelengths have now be absorbed. Light absorption indicates that the surface structure of the silicon has changed and indicates that it may have light properties such as photo diode effect and photovoltaic effects, which gives rise to uses such as photo detectors and solar cells. The absorptance is increased most in black silicon which has been microstructured in the presence of Sulfur Hexafluoride. The annealing of the silicon increases the presence of free carriers with the sacrifice of absorptance. A balance is needed between loss of absorptance and the presence of free carriers. Annealing was previously done in the oven under vacuum, but it was proposed that it can also be done by the laser under low fluences.

Experiment

Black silicon samples were annealed using different fluences. The three samples were of a p-type <100> silicon substrate. They were initially processed using a femtosecond laser with a fluence of 8.0kJ/m2 , 500 shots, 150_m spot size, 250_m/s raster speed in an atmosphere of 500 Torr (mm Hg) SF6. The samples were annealed with laser fluence M1 – 1.0 kJ/m2, CC3 – 0.75 kJ/m2, and CC5 – 0.5 kJ/m2, shots were 1000, spot size 450_m under vacuum using other conditions as above.
The samples were photographed under an SEM and their morphology compared to unannealed samples. Their absorptances were measured using a spectrometer and compared.
Samples were also annealed in an annealing oven at 700 °C (973K) for 8 and 17 hours. Their absorptances were measured and compared to plain silicon.

Conclusion

- We observed decreasing absorptance with increasing fluence of laser annealing.
- This compares similarly with increasing temperatures and annealing times for oven annealing.
- This suggests a one stage process for the manufacture of black silicon.

Acknowledgments

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