The influence of impurities on the formation of nanocone structures on silicon surface irradiated by low energy helium plasma

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Black silicon is a prominent material in solar cell applications. The conventional methods to fabricate black silicon is reactive ion etching (RIE) [1] or neutral beam etching [2]. However, these methods usually need complicated processes that involve several different ion species with high energies, i.e., hundreds of electron volts, which may cause surface damages. Recently, by using helium plasma irradiation on doped silicon with relatively low ion energy around 50 eV, black silicon was obtained due to the formation of cone structure on the surface. Sputtering is considered as the main mechanism for cone formation [3, 4]. However, the complete mechanism of the cone structure formation has yet to be fully understood.

In this study, nanocones have been formed by the exposure to helium plasma in the linear plasma devices Co-NAGDIS. We conducted helium plasma irradiation with various sample temperatures and ion fluences. Two different types of nanocone structures were formed on the surface. By X-ray photoelectron spectroscopy measurement, impurity seeds, originated from sample mask, were found to play an important role in the formation of silicon nanocones. Moreover, we measured the height distribution of the Si sample from the covered region to the center of the irradiated region. The erosion depth was reduced with heavily covered molybdenum impurity. Bubbles and amorphous structures were observed on some of the nanocones indicating that other physical processes (such as surface diffusion) occurred during the nanocone formation besides sputtering. Based on these results, we will discuss the mechanism of the cone structure generation.

[1] X. Liu, P.R. Coxon, M. Peters, B. Hoex, J.M. Cole, and D. Fray, Energy Environ. Sci. 7 (2014) 3223-3263.
[2] S. Samukawa, Jpn. J. Appl. Phys. 45 (2006) 2395-2407.
[3] S. Takamura, Y. Kikuchi, K. Yamada, S. Maenaka, K. Fujita, Y. Uesugi, Jpn. J. Appl. Phy. 55 (2016) 12301.
[4] S. Takamura, T. Aota, H. Iwata, S. Maenaka, K. Fujita, Y. Kikuchi, Y. Uesugi, Appl. Surf. Sci. 487 (2019) 755-765.