Localized and shallow laser doping by excimer laser annealing

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In recent years, Si devices have become more complex as they have become smaller, thinner, and three-dimensional. These structures require more precise doping techniques, such as localized and shallow doping. We have attempted localized and shallow doping by using laser irradiation for introduction and activation of dopants.

Al was used as a dopant and deposited with 6-nm-thickness by sputtering on p- or n-type Si substrates. The deposited Al films on Si substrates were irradiated 10 times with a KrF excimer laser (wavelength: 248 nm, pulse width: 82 ns). The fluence of laser irradiation was varied from 0.1 to 4.0 J/cm^2. After etching the residual Al on the Si substrates, surface roughness and pn polarity were analyzed using atomic force microscopy (AFM) and scanning capacitance microscopy (SCM), respectively. I-V characteristics were measured for diode structures after electrode formation with Al on the irradiated regions.

In the abstract, we report on the doping into n-type Si substrates. The surface roughness (Ra) was about 0.3 nm, which is the same as that of Si substrates irradiated with fluences less than 0.9 J/cm^2. I-V measurements showed rectification for all samples irradiated with fluences less than 1.2 J/cm^2. Detailed analysis of the I-V characteristics of the diodes revealed that the ideality factors were around 1 and 2 for fluences less than and above 0.8 J/cm^2, respectively. Thus, the rectification characteristics are attributed to Al/n-Si Schottky contacts and pn junctions for fluences less than and above 0.8 J/cm^2, respectively. Fig. 1 shows the results of analyzing the formation of pn junctions using SCM. They are the SCM images for unirradiated region (a), irradiated with 0.7 (b), 0.8 (c), and 1.2 J/cm^2 (d). The regions were set so that the left side is the unirradiated region and the right side is the irradiated region. At 0.7 J/cm^2, where the ideal factor began to change to 2, the laser irradiated area partially showed p-type. This partial formation of pn junctions is considered to be caused by the intensity distribution of the laser. At fluences of 0.8 and 1.2 J/cm^2, where the ideal factor was 2, the entire irradiated area showed p-type. These results indicate that good pn junctions were formed at a fluence of 0.8 J/cm^2 while maintaining surface flatness. We will further discuss the dopant concentration profiles in the depth direction using SIMS results and other data.

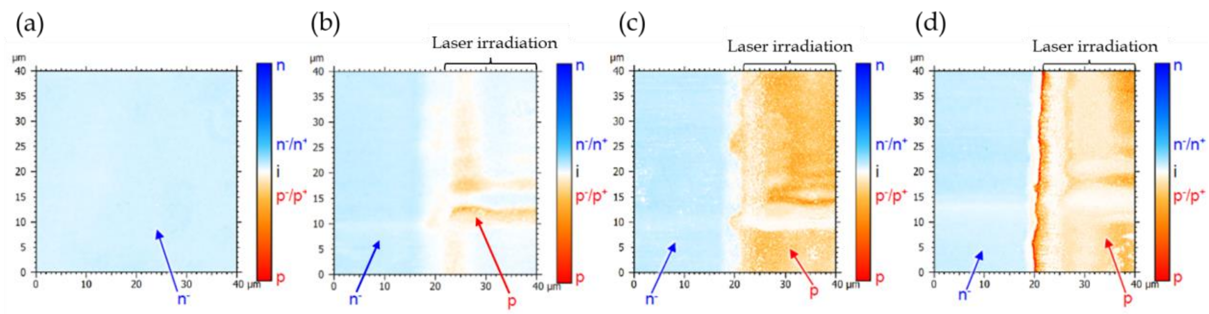

Fig.1 Polarity images by SCM for each fluence condition. (a) unirradiated region, (b) 0.7 J/cm^2, (c) 0.8 J/cm^2, and (d) 1.2 J/cm^2