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High Contrast SEM Observation of Semiconductor Dopant Profile using TripleBeam® System

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Low-energy Focused Ion Beam (FIB) processing is a key technique to acquire high quality images. The TripleBeam® system to reduce Ga ion milling related damage has been developed [1]. This system has been applied to lamella preparation for several types of materials such as silicon semiconductor integrated circuits and ceramics. This application includes cross sectional high contrast Scanning Electron Microscope (SEM) observation. Experiments conducted by our group have shown that cross sectional observation of high contrast dopant profiling on a SiC semiconductor specimen using Ar ion milling is possible [2]. Despite our success, multiple complex steps with several systems were used for the study such as the use of a FIB, Ion Milling system and a SEM, therefore the throughput was degraded. This paper discusses the high contrast observation of dopant profiling in semiconductor using a triplebeam® system.

The Hitachi NX2000 FIB-SEM TripleBeam® system was used for sample preparation in this study. Figure 1 shows the general view of the NX2000 and the diagram of the TripleBeam® system. A FIB, SEM, and an Ar ion column were installed on the same specimen chamber, designed with each beam to coincide at the same point. The purpose of this system is to reduce FIB induced artifacts which can be removed by using low acceleration Ar ion milling. A commercially available SiC semiconductor device was used for this experiment. Initially, we compared the cross sectional SEM image quality on the condition of three different FIB acceleration voltages, 30 kV, 10 kV and 5 kV. After processing the sample by 5 kV FIB, Ar milling was performed at 0.5 kV at each incidence angle to improve image quality by reducing FIB induced damaged material. All SEM images were captured at 1 kV.

Figure 2 shows the SEM observation result of dopant along the gate and substrate interface after FIB processing. Fig. 2(a) shows a low magnification image of the device, the right images are enlarged images of the area surrounded by the white dotted box from the leftmost image. The accelerated voltages applied for FIB processing are (a) 30 kV, (b) 10 kV and (c) 5 kV respectively. The contrast level of dopant was higher as the acceleration voltage decreased. In Fig. 2(c), we can see the p-type and n-type layers across a SiC *p-n* junction. The damage layer on the specimen was reduced by low acceleration FIB processing, therefore it became possible observe the dopant clearly. Figure 3 shows the SEM observation result of dopant after low acceleration Ar ion milling. The acceleration voltage and incident angles are (a) 0.5 kV, 10°, (b) 0.5 kV, 30° respectively. Under the condition of (b), it is clearly observed that the dopant profiling is evident. As a reason for this, the low acceleration Ar milling removed the damage layer caused by FIB processing. The image contrast was slightly decreased however the intensity difference is enhanced by Ar milling. We expect that the correlation between the dopant profiling from SEM observation and actual concentration of dopant and carrier of this SiC device is established by use a reference sample with known concentration of dopant. Our data suggests that the TripleBeam® system using Ar ion milling is an effective tool for SEM observation of dopant profiling on SiC semiconductor devices.

References:

[1] H. Takahashi *et al*, Proc. 16th International microscopy congress (2006), p. 1104.
[2] T.Sunaoshi *et al*, Proceedings of the 2016 IEEE 23rd IPFA, p.148.

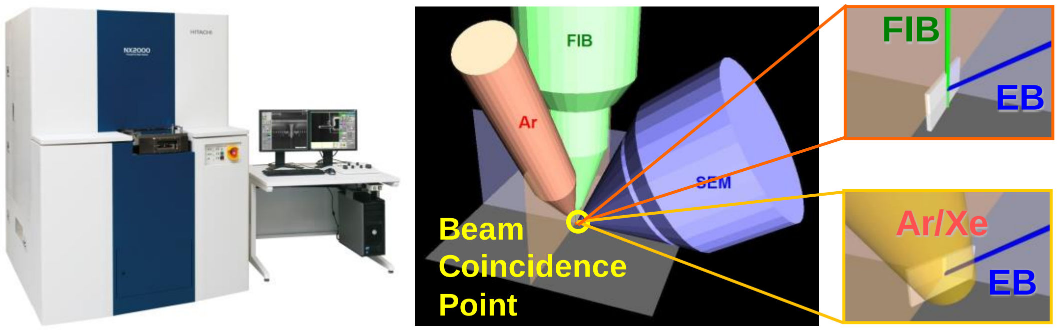

Figure 1. Schematic diagram of NX2000 triplebeam® system.

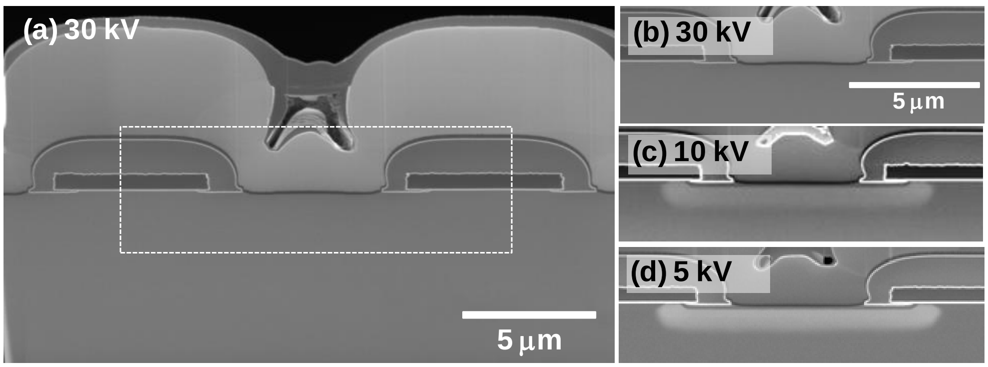

Figure 2. Dopant profiling at each accelerate voltages of FIB ((a) 30kV, (b) 10 kV, (c) 5 kV).
Instrument: NX2000, SEM Acc.v.: 1 kV

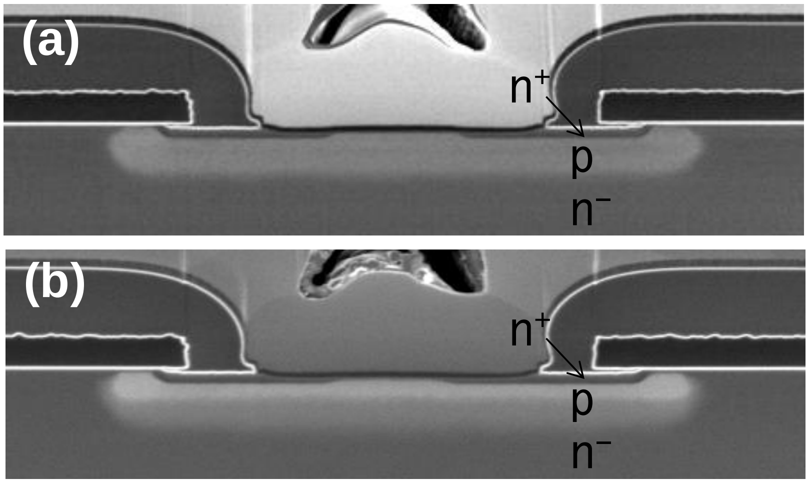

Figure 3. SEM observation results of dopant profiling using Ar milling.
Instrument: NX2000, SEM Acc.v.: 1 kV

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