Dopant Distribution Observation with SEM and SNDM

SHEET No. 009

Instruments: Environment control AFM AFM5300E, Ultra-high resolution FE-SEM SU9000

Introduction

The dopant distribution of a semiconductor device can be observed with SEM from the low-energy secondary electron contrast image reflecting the surface potential. We already observed an epitaxial impurity sample with concentration steps ($10^{13}/cm^3$ ～$10^{16}/cm^3$) with SEM and scanning nonlinear dielectric microscopy (SNDM) and reported a strong correlation between both observation results.[2] It is well known that the resolution and the stability of dopant observations with SSRM have improved, but also the performance of SNDM observations in a vacuum improved compared to in an atmospheric surrounding. The observation of low concentrations of $10^{13}/cm^3$ ～$10^{14}/cm^3$ and high accurate C-V curve could be realized with SNDM.[3, 4]

This data sheet presents the two dimensional dopant distribution of a SiC MOS FET cross-section observes with SEM and SNDM in a vacuum.

[1] Cho, Y. *et al.*, "Scanning nonlinear dielectric microscope," Rev. Sci. Instrum., **67**, 2297–2303, 1996.

[2] Sunaoshi *et. al.*, "Observation of two-dimensional dopant profiles in semiconductor by SEM", 71st Annual Meeting of the Japanese Society of Microscopy, P_M-06, 2015.

[3] Yamaoka *et. al.*, "Nano-scale physical property observations by AFM: Electromagnetic measurements in vacuum and AFM/SEM observations", The 34th Annual NANO Testing Symposium, 13-18, 2014.

[4] Jing-jiang Yu *et al.*, "Environmental control scanning nonlinear dielectric microscopy measurements of p-n structures, epi-Si Wafers, and SiC crystal defects", ISTFA 2015: Conference Proceedings, 341-348, 2015.

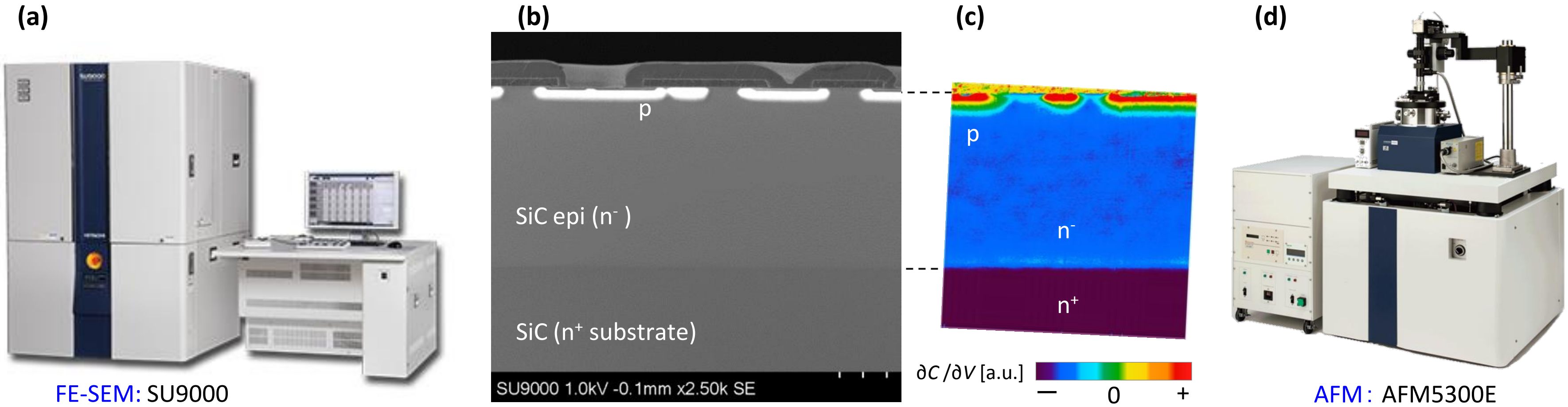
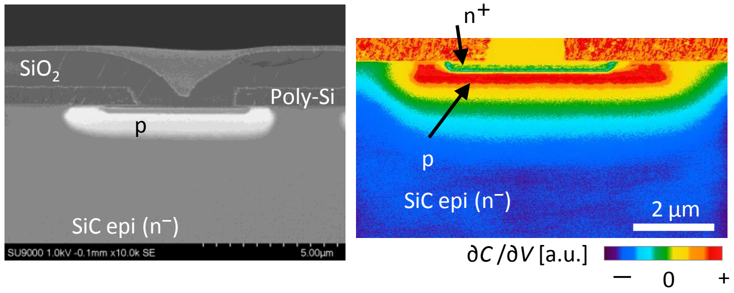


Figure 1: (a) FE-SEM instrument (b, c) SEM and SNDM observation of a SiC MOS FET cross-section (d) AFM instrument

Results

In figure 1, the observation results of a SiC Power MOS FET cross-section with SU9000 and AFM5300E are shown. Both dopant (carrier) concentration distribution images correspond to the device structure. The difference between the n^+ layer of the SiC substrate and the epitaxial n^- layer can be indicated in the SEM image but in the SNDM image this contrast becomes even clearer.

Figure 2 shows the SEM-SNDM overlay image in the vicinity of the pn junction. Due to the prevalence of low acceleration voltage SEM, applications about the visualization of dopant domains are underway. However, SNDM can acquire a clear concentration distribution with high sensitivity as well as a distinction between p-type and n-type dopants.



Summary

Due to the advantage of SEM in high-speed observations of large areas, it can be used to screen the sample before the relatively time-consuming SNDM observation or to confirm the device structure of the ion-milled cross-section. Afterwards a more detailed analysis of the desired area, such as the p-type/n-type evaluations, ∂C/∂V-V curve and C-V curve measurements can be done with SNDM.

※ We would like to express our sincere gratitude to Prof. Yasuo Cho of Research Institute of Electrical Communication at Tohoku University (the inventor of SNDM) for his guidance to develop the SNDM product.

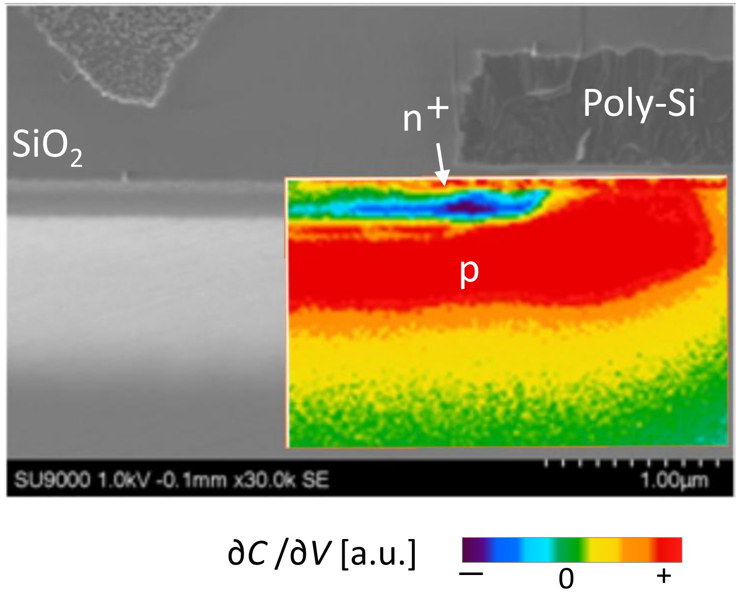


Figure 2: FE-SEM/SNDM observation results of a SiC MOS FET (SEM-SNDM overlay image)

Authors: Hitachi High-Tech Science Analytical Application Engineering Section Tokyo 2 T. Yamaoka
Hitachi High Technologies Application Development Dept. T. Sunaoshi

Hitachi High-Tech Science Corporation

Head Quarter Business department, Shimbashi 1-24-14, Minato-ku, Tokyo 105-0003 Tel.: +81-3-6280-0062