Abs. 1309, 206th Meeting, © 2004 The Electrochemical Society, Inc.

Electrical Properties of B-doped Polycrystalline $Si_{1-x-y}Ge_xC_y$ Film Deposited by Ultraclean Low-pressure CVD

Hyunyoung Shim, Masao Sakuraba and Junichi Murota*

Laboratory for Electronic Intelligent Systems, Research Institute of Electrical Communication, Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan
*Corresponding Author :Tel.&Fax : +81-22-217-5548
E-mail : murota@riec.tohoku.ac.jp

Polycrystalline(poly)-$Si_{1-x-y}Ge_xC_y$ as a gate material has attracted much interest to achieve low power consumption and high performance of devices by the control of threshold voltage because of its variable work function [1,2]. However, little is known about electrical properties of poly-$Si_{1-x-y}Ge_xC_y$. In the present work, the electrical properties and heat-treatment effects of B-doped poly-$Si_{1-x-y}Ge_xC_y$ are investigated, and B segregation at grain boundaries in poly-$Si_{1-x-y}Ge_xC_y$ is discussed.

About 350 nm-thick poly-$Si_{1-x-y}Ge_xC_y$ ($x \leq 0.62$, $y \leq 0.008$) films were deposited at 500-650°C in a SiH_4-GeH_4-SiH_3CH_3-H_2 gas mixture using an ultraclean hot-wall LPCVD system [3]. The substrates used were *p*-type Si wafers of 8-12 Ωcm with mirror-polished (100) surface. The oxide film was thermally grown on the substrates before poly-$Si_{1-x-y}Ge_xC_y$ deposition. $^{11}B^+$ was implanted at 35keV and the dose was adjusted to concentration of $1.5\times10^{20}cm^{-3}$. The samples were heat-treated in N_2 at 600, 700, 800, 900 °C for 1h, or 900 °C for 1h followed by 700 °C for 24h, where the surface was covered with low-temperature CVD SiO_2. Ge and C fractions were determined by X-ray photoelectron spectroscopy (XPS). Grain size and crystallization degree of the films were measured by X-ray diffraction (XRD). Resistivity, carrier concentration and hall mobility were evaluated by van der Pauw method.

The resistivity in B-doped poly-$Si_{1-x-y}Ge_xC_y$ films decreases with increasing heat-treatment temperature up to 900 °C (**Fig. 1**). This results from the crystallization and redistribution of B in the film. The resistivity decreases with increasing Ge fraction and increases with increasing C fraction. The grain size scarcely depends on the Ge and C fraction in the present condition at 900 °C (**Table 1**). On the other hand, the crystallization degree of poly-$Si_{0.52}Ge_{0.48}$ and $Si_{0.52}Ge_{0.48}$(C) (C fraction 0.008) is larger than that of poly-Si (Table 1). Since resistivity of B-doped epitaxial Si is almost the same as those of B-doped epitaxial $Si_{0.52}Ge_{0.48}$ and $Si_{0.52}Ge_{0.48}$(C) at B concentration of $1.5\times10^{20}cm^{-3}$ [4], it is considered that the resistivity is influenced by existence of Ge, C and B at grain boundary. In the case of B-doped epitaxial films, the carrier concentration is nearly equal to B concentration up to approximately $2\times10^{20}cm^{-3}$ regardless of the Ge fraction and C fraction ($y<0.016$) [4], and scarcely changes by heat-treatment [5], while the carrier concentration of B-doped poly-$Si_{1-x-y}Ge_xC_y$ heat-treated at 900°C increases with increasing Ge fraction and decreasing C fraction (Table 1). By subsequent heat-treatment at lower temperature of 700°C for 24h, resistivity increases (Fig. 1), and B atoms are deactivated (Table 1). Because the degree of poly-Si is larger than those of the others, it is suggested that B segregation at grain boundaries is suppressed by existence of Ge or C, and carriers are trapped at grain boundaries under the existence of C.

References

[1] T.J. King, J.P. McVittie, K.C. Saraswat, J.R. Pfiester, IEEE Trans. Electron Devices 41 (1994) 228.
[2] H. Shim, M. Sakuraba, T. Tsuchiya, J. Murota, Appl. Surf. Sci. 212 (2003) 209.
[3] J. Murota, T. Matsuura, M. Sakuraba, Surf. Interface Anal. 34 (2002) 423.
[4] T. Noda, D. Lee, H. Shim, M. Sakuraba, T. Matsuura, J. Murota, Thin Solid Films 380 (2000) 57.
[5] J. Noh, S. Takehiro, M. Sakuraba, J. Murota, Appl. Surf. Sci. 224 (2004) 77.

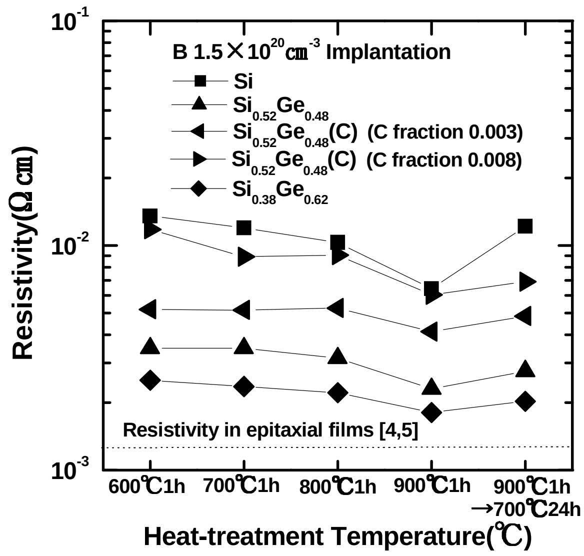

Fig. 1. Heat-treatment temperature dependence of the resistivity in B-doped poly-$Si_{1-x-y}Ge_xC_y$ films.

Table 1. Characteristics of B-doped poly-$Si_{1-x-y}Ge_xC_y$ films heat-treated at 900 °C with/without subsequent heat-treatment at 700°C for 24h.

	poly-Si	poly-$Si_{0.52}Ge_{0.48}$	poly-$Si_{0.52}Ge_{0.48}$(C)
Grain size (nm)	25-55	34-40	33-39
Crystallization degree (A.U.)	1	2.2	2.0
Resistivity (Ωcm) 900 °C 1h	6.4×10^{-3}	2.3×10^{-3}	6.0×10^{-3}
Resistivity (Ωcm) 900 °C 1h +700 °C 24h	1.2×10^{-2}	2.8×10^{-3}	6.9×10^{-3}
Carr. conc. (cm^{-3}) 900 °C 1h	6.9×10^{19}	1.1×10^{20}	5.5×10^{19}
Carr. conc. (cm^{-3}) 900 °C 1h +700 °C 24h	3.6×10^{19}	9.2×10^{19}	4.2×10^{19}