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多結晶 Ge 薄膜トランジスタの電気特性に及ぼす水素および酸素の影響

Impacts of hydrogen and oxygen on electrical properties of poly-Ge TFTs

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[Introduction] Germanium is considered to be a promising material to realize three-dimensional integrated circuits [1], because of its low processing temperature. In fact, solid phase crystallization (SPC) of amorphous Ge (*a*-Ge) has already been demonstrated at a relatively low temperature (<500°C) [2], and the high hole mobility of polycrystalline Ge (poly-Ge) TFT was reported [3], while the on/off ratio of poly-Ge TFT (~10^2) was still much lower than that of poly-Si ones (~10^8) [4]. Therefore, it is required to suppress the leakage current of poly-Ge TFTs. In this work, we discuss the effects of hydrogen and oxygen on the electrical properties of poly-Ge TFTs from the view point of defect passivation in poly-Ge.

[Experiment] n-type Si substrates with termally grown SiO_2 were prepared, and 25-nm-thick *a*-Ge films were deposited on SiO_2. After forming 500-nm-thick SiO_2 on Ge film as the capping layer, two-step SPC method [2] was carried out as follows: The 1st SPC (425°C, 8h) for all samples was performed in UHV at the same time to determine the grain size of poly-Ge, and then, the 2nd SPC (500°C, 2h) was done in UHV, H_2, N_2, or Ar ambient. After removing the capping layer, Ge islands were defined, and Al was deposited and patterned for source/drain on Ge islands. Al was also deposited on the back side of Si substrate.

[Results and Discussion] **Fig. 1** shows bi-directional I_d-V_g characteristics of poly-Ge TFTs, where 2nd SPC was conducted in various ambient. It is clearly observed that the ambient during the 2nd SPC affects threshold voltage and on/off ratio of poly-Ge TFTs, while the field effect mobility does not change significantly. On the other hand, the poly-Ge TFT annealed in H_2 (H_2-A) shows the huge hysterisis, indicating that hydrogen induces the hole trapping states at the poly-Ge/SiO_2 interface during SPC [5]. **Fig. 2** summarizes the threshold voltage of poly-Ge TFT as a function of FWHM of Raman peak for poly-Ge at 300cm^{-1}. Then, it is suggested, in case that Ge SPC is perfomed in the ambient which contains the larger amount of residual oxygen, that poly-Ge film contain apprecable oxygen which may broaden Raman peak and passivate the defects in poly-Ge, resulted in the Vth shift. **Fig. 3** shows the temperature dependence of the conductivities in on-state and off-state of poly-Ge TFTs where the 2nd SPC was performed in UHV or N_2. Assuming that the slopes represent the potential barrier heights at the grain boundaries, they are estimated 0.022 eV and 0.078 eV, in off-state after UHV-A and N_2-A, respectively. Thus, we can consider that the higher on/off ratio in case of N_2-A is attributed to the sperior controllability of the potential barrier height and the carrier density thanks to the defect passivation by oxygen.

[Reference] [1] J. H. Park et al., Appl. Phys. Lett. **91**, 143107 (2007). [2] K. Toko et al., Soli-State Electron. **53**, 1159 (2009). [3] T. Sadoh et al., Jpn. J. Appl. Phys. **46**, 1250 (2007). [4] L.-C. Yen et al., Appl. Phys. Lett. **100**, 173509 (2012). [5] H.-C. Lin et al., J. Appl. Phys. **105**, 054502 (2009).

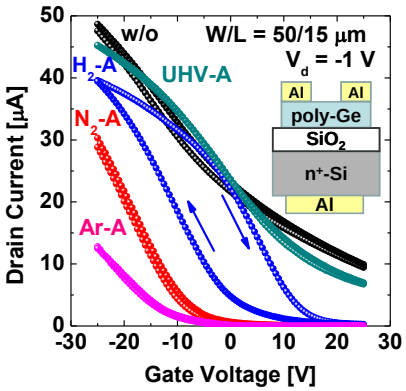

Fig.1 The bi-directional I_d-V_g characteristics of poly-Ge TFTs, where the 2nd SPC was performed in various ambient. Inset is the schematic of poly-Ge TFT.

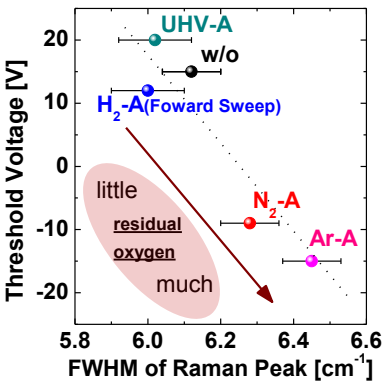

Fig.2 The relationship between the threshold voltage and FWHM of Raman Peak at 300 cm^{-1}. Note that N_2 and Ar contain the larger amount of residual oxygen.

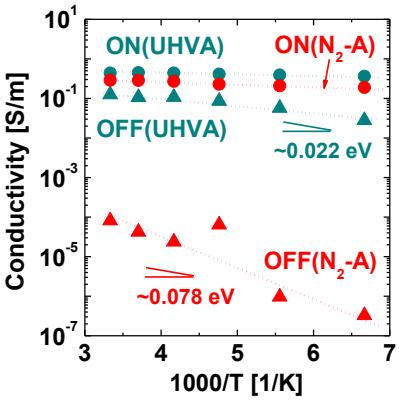

Fig.3 The temperature dependence of the conductivities in on-state and off-state of poly-Ge TFTs, where the 2nd SPC was performed in UHV or N_2.