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論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Low-temperature growth of Ge nanowires for electron device application
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出典(和文)	学位:博士(学術), 学位授与機関:東京工業大学, 報告番号:甲第9570号, 授与年月日:2014年3月26日, 学位の種別:課程博士, 審査員:小田　俊理,波多野　睦子,淺田　雅洋,宮本　恭幸,河野　行雄,Kaustav Banerjee
Citation(English)	Degree:Doctor (Academic), Conferring organization: Tokyo Institute of Technology, Report number:甲第9570号, Conferred date:2014/3/26, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	Physical Electronics 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Philosophy)
学生氏名： Student's Name	Marolop Dapot Krisman Simanullang	指導教員（主）： Academic Advisor(main)	Prof. Shunri Oda
		指導教員（副）： Academic Advisor(sub)	

要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

We have studied the growth of germanium nanowires in a hot-wall chemical vapour deposition reactor via the vapour-solid-liquid mechanism. The nanowires were grown using the single-step and two-step growth technique. In the single-step growth technique, the nanowires were grown at constant single temperature at 300, 280, and 260 ° C. By using this technique, we can draw a direct experimental correlation between the size of gold catalyst and the dimension of the nanowires (i.e. diameter and length) and between the temperature and the diameter and shape of the nanowire. Tapered nanowires which are appropriate for some applications, such as field emitters, were grown at 300 ° C and straight nanowires which are desirable for other applications, such as nanowire transistors, were grown at 280 and 260 ° C. The nanowires grown at 260 ° C have smaller diameter than those grown at 280 ° C albeit they were grown from the gold catalyst with the same size. The nanowires were grown at relatively low temperatures, even ~100 ° C below the eutectic temperature of the bulk AuGe alloy (~360 ° C), which is of great interest in terms of the compatibility with 3D integrated circuits and the likelihood of germanium nanowire growth on plastic substrates. By controlling the growth temperature and catalyst size, we have successfully grown single crystalline germanium nanowires with diameter as small as ~3 nm from the gold catalyst with average diameter of ~3 nm at 260 ° C. In ultra-narrow germanium nanowire with certain crystal orientations, the band gap changes from indirect to direct which can possibly provide significant enhancements in light absorption and emission. It has been suggested that due to the degeneracy between light holes and heavy holes in ultra-narrow germanium nanowire, there is a reduction in the average hole effective mass in the nanowire channel which in turn will enhance the mobility of p-type ballistic germanium nanowire transistor. We showed that the relationship between the growth parameters in our study (i.e. gold catalyst size, temperature, pressure) and the dimension of the nanowire (i.e. diameter and length) are governed by the Gibbs-Thomson effect. We have also shown that the tapering can be circumvented even when the nanowires are grown at relatively high temperature if germane partial pressure is kept low.

We have presented a microscopic study of germanium nanowire using transmission electron microscopy technique. Gold diffusion from the tip to the sidewalls of germanium nanowires occurred at 300 ° C. The presence of gold at the nanowire sidewalls will significantly influence the carrier transport of the nanowire and damage the performance of nanoelectronic devices such as nanowire transistor. Gold diffusion can be circumvented by growing the germanium nanowires at 260 ° C. To examine the crystallinity difference between the tapered and straight structures in a single nanowire, germanium nanowires were grown using a two-step growth technique, whereby growth was initiated at 300 ° C and subsequently lowered to 260 ° C. Crystalline germanium and amorphous germanium coexist at the tapered structure near the nanowire base, whereas the straight structure near the tip contains only crystalline germanium. We have shown that germanium nanowire diameters can be modulated by growth temperature and presented a model to elucidate how the diameter decreases as the growth temperature decreases. Modulated nanowire diameters will be useful for simultaneously observing the band gap increase and the band gap change from indirect to direct in a single nanowire.

A method for the passivation of germanium nanowire surface using aluminum oxide and hafnium oxide deposited via the atomic layer deposition technique has also been presented. Aluminum oxide is more preferable in the passivation of germanium nanowire surface because it does not induce local crystallization that may cause defects to the nanowire as observed in hafnium oxide. We found that the uncoated germanium nanowires were dissolved in isopropanol after around two months since their suspension but germanium nanowires coated with aluminum oxide remained intact even after more than two months since

their suspension.

We have also fabricated devices using uncoated intrinsic germanium nanowires and intrinsic germanium nanowires coated with 3-nm-thick aluminum oxide to obtain some understanding about the basic electrical properties. The current in the devices fabricated using coated germanium nanowires increased after sequential annealing. The current increase was ascribed to the diffusion of germanium into aluminum oxide that affects the barrier thickness. The current in the devices fabricated using uncoated germanium nanowires showed a significant hysteresis when measured under a sweeping voltage. We observed a negligible hysteresis in the devices fabricated using coated nanowires. The absorption of molecules from the ambient, such as water molecules, and charge trapping on germanium nanowire are the main cause of the hysteresis. The ultra-thin aluminum oxide that covered the germanium nanowire served to terminate the charge trapping and protect the germanium surface from ambient molecules and therefore alleviated hysteresis significantly, promising for long-term passivation of germanium nanowire surface.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).