Stability of Chlorine Termination on Ge(100) and Ge(111) Surfaces

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Abstract. The different cleaning solution; HCl and HF solution are used to remove the suboxide and oxide component on Ge surface. The HCl cleaning results chlorine (Cl) termination on Ge surface whereas no Fluorine (F) termination was observed just after HF cleaning. The growth of Ge oxide is studied after treated with HCl cleaning on two surface orientations; (100) and (111), respectively in dry oxygen ambient and cleanroom air by spectroscopic ellipsometry (SE) and x-ray photoelectron spectroscopy (XPS). A clear step and terrace trend was observed for the oxidation growth of Ge (100) and Ge (111) in dry oxygen ambient compared to in clean room air. This trend shows the difference in surface reaction of Ge oxidation as humidity varies. The stability of chlorine termination of Ge (111) than Ge (100) explains the slower growth of oxidation in dry oxygen ambient.

1 Introduction

Scaling down of the planar bulk silicon (Si) metal-oxide-semiconductor (MOS) field effect transistors (FETs) has been confronted its fundamental limit associated with performance, on current, power consumption, and short-channel effects which have the trade-off relationship with each other. Therefore, device structures and materials with high carrier mobility are needed for further continues enhancement in device performance. Germanium (Ge) become an emerging and promising material to replace Silicon (Si) because it has the advantages of high electron and hole mobility compared to that of silicon (Si) [1]. However, controlling the interface defects between Ge and oxide interface is the critical issues for Ge MOSFETs. Recently, researchers have interest of Ge because it can be integrated with Si to fabricate optical communication devices [2]. However, GeO_2 is water soluble and not stable if compared to SiO_2. In addition, the fast native oxidation on Ge surface is one of the key issues that must be overcome. Many efforts have been done to passivate Ge surface to avoid fast oxidation such as organic functionalization of Ge substrates under gas phase of UHV condition [3-13]. Furthermore, various chemical-based methods have been explored to passivate Ge substrate prior to high-k deposition such as sulfur passivation, halogen passivation, and hydrogen passivation [14-19]. Though, the oxygen free was not yet obtained on Ge surface and the kinetics oxidation of Ge is quite fast compared to Si oxidation [20-21]. It is may be due to the lower thermal and chemical stability of Ge hydrides compared to Si hydrides [22]. Notably, the native oxidation of Si proceed layer- by- layer trend with very flat Si/SiO_2 interface and the origin of layer-by layer growth presumably relates to less structural strain at Si/SiO_2 interface [22-23]. Despite it was reported that HF-last Ge exhibits layer-by layer trend in clean room air, the effect of moisture and stability of chlorine terminated on Ge (100) and (111) on the oxidation growth in dry oxygen ambience at room temperature has been not discussed yet.

In addition, the water absorption on the semiconductor surface play important roles nanotechnology and give the effects on the surface chemistry. As for Silicon case, the water absorbed on hydrophilic silicon oxide surface causes large changes in adhesion and friction of nanoscale contact. This paper shows how the effect of moisture in the air affects the growth rate of oxide in Germanium case. However, these studies have not fully elucidated the evolution of absorbed moisture on the Ge oxide surface as function of relative humidity.

To gain better understanding on Ge oxidation, the HCl and HF cleaning are compared in order to remove oxide completely and to prepare good passivation on Ge surface. Furthermore, the growth of oxidation of HCl last Ge is investigated in dry oxygen ambient in room temperature with crystallographic orientation dependence. The effect of moisture and stability of Cl terminated Ge (100) and (111) on the oxidation growth are discussed and compared.

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