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. Recently, germanium (Ge) channel has attracted much of the attention for the development of MOSFETs due to the higher carriers mobility than Si. However, the precise control of the Ge surface and oxide/Ge interface is the most critical issues for the development of Ge-channel MOSFETs. The quality at the interface between the Ge channel and gate dielectric degrades with increasing native oxide thickness. Understanding the native oxidation is required to provide a good passivation on Ge surfaces. GeO$_2$ can be useful; however the basic understanding of Ge thermal oxidation is needed. The suppression of Ge oxide desorption is thought to be a key to obtaining a high FET performance. Therefore, understanding the mechanism of native and thermal oxidation on the Ge surface is necessary in obtaining a good quality at the interface between the channel and the gate dielectric.

This thesis describes a series of experiments in the study of mechanism of native and thermal oxidation of Ge surfaces. The main contributions of this thesis are:

1) To study the growth of native oxide on Ge surfaces after treated with Hydrochloric (HCl) acid and Hydrofluoric (HF) acid and to investigate the influence of crystallographic orientation and conduction type on the oxide growth.

2) To study the kinetic of thermal oxidation of Ge(100) and (111) surfaces in dry oxygen ambience and characterize the chemical bonding features of Ge oxide.

3) To study the thermal oxidation mechanism of Ge(100) surfaces in dry oxygen ambience.

This thesis consists of seven chapters. Introduction and research background were described in chapter 1 followed by an overview of all Si oxidation models and literatures of Ge oxidation in chapter 2. The samples preparations in this work were described in chapter 3. Chapter 4 discusses a preliminary study on the native oxidation on Ge surfaces. The native oxide growth on different crystallographic orientation and the effect of conduction type of Ge substrate have been studied by high-resolution x-ray photoelectron spectroscopy (XPS) and spectroscopic ellipsometry (SE). The wafers were treated with either 50% HF (HF-last surface) or 30% HCl acid (HCl-last surface). The result shows that the native oxidation of both HCl- and HF-last Ge(100) surfaces exhibit likely layer-by-layer fashion. The native oxide growth of the n-Ge(100) is
significantly faster than the p-Ge(100) at the early stage of native oxidation. This can be explained by the formation of an $O^{2-}$ ion through free electron transfer from the Ge to the adsorbed $O_2$ molecules, which induces the surface electric field that can initiate the oxidation.

The chemical bonding features on thermal oxidation of Ge(100) surface was shown in chapter 5. It is found that the generation of an oxygen-defect region in the Ge oxide layer at temperature of 490°C. Annealing at 375°C after GeO$_2$ growth was effective at eliminating the oxygen deficiency.

Following this chapter, the mechanism of thermal oxidation was discussed based on experimental results and were presented in chapter 6. To get an insight of mechanism of oxidation clearly, a trial estimation was made by applying the general oxidation equation proposed by Deal and Grove to experimentally–obtained result for Ge(100) surface. The result shows that the logarithmic relationship as a function of $(t+\tau)/x_0$ based on general oxidation equation proposed by Deal and Grove was obtained in the oxidation temperature range from 490°C to 575°C. For the case of the oxidation at temperature as low as 375°C, a linear relationship was obtained, however the value of intercept of $A$ is negative which is different from the situation of the Si oxidation. Thus, the contribution of germanium monoxide (GeO) desorption must be considered in thermal oxidation of Ge surface and particularly for oxidation over 400°C at atmospheric pressure. The GeO desorption was also confirmed from the XPS analysis of the Si surface which was oxidized simultaneously with the Ge(100) surface. Thus, the Ge thermal oxidation at atmospheric pressure cannot be explained simply by the Deal-Grove model, in which the contributions of thermal desorption of GeO must be taken into account. Furthermore, the extinction coefficient of GeO$_2$ film in various thicknesses also has been examined to check the GeO$_2$ bulk defect states.

To understand the mechanism of Ge oxidation more clearly, the crystallographic orientation dependence on Ge oxide growth was investigated. The surface orientation dependence on the growth of thermally grown germanium dioxide (GeO$_2$) has been studied at oxidation temperatures of 375, 490, and 550°C in dry oxygen ambience at atmospheric pressure. The $n$ value corresponding to the slope was extracted in a log-log plot of oxide thickness versus oxidation time. The result shows that $n$ value of Ge(100) is higher than Ge(111) for higher oxidation temperatures of 490 and 550°C which indicates that the oxidation rate of Ge(100) is higher than Ge(111) while oxidation at 375°C shows a similar value which indicates no significant difference in the Ge surface reaction rate of the $O_2$ molecules between Ge(100) and (111) surfaces. The Ge oxidation model has been proposed in the last section of chapter 6, which considering the diffusion of Ge atoms through the oxide to the surface occurs, and they desorbs as GeO molecules from the GeO$_2$ surface. This process occurs obviously in thin film of GeO$_2$. Lastly, the recombination process takes place where $O_2$ molecules recombine with GeO molecules resulting in the growth of GeO$_2$ layer.

Finally, the conclusion and future prospects of the research are presented in Chapter 7.