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Formation of neodymium oxide by thermal oxidation of sputtered Nd thin film on Si substrate

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Abstract This paper aims to report on the formation of neodymium oxide by thermal oxidation of sputtered metallic Nd thin film deposited on Si substrate. Sputtered Nd thin film on Si substrate followed by thermal oxidation in O_2 ambient at a fixed duration of 15 min for various temperatures (500–1100 °C) has been investigated systematically. The structural and chemical properties of the formed thin films were evaluated by X-ray diffraction analysis, Fourier transform infrared analysis, Raman analysis and high resolution transmission electron microscopy analysis. It was found that cubic phase of Nd_2O_3 film was formed along with orthorhombic phase of $Nd_2Si_2O_7$ and multiple phases of SiO_2 which consists of monoclinic, tetragonal, and hexagonal phases. Based on the electrical results, sample thermally oxidized at 900 °C revealed the highest electrical breakdown field of 5.26 MV/cm at the lowest leakage current density of 2.19×10^{-6} A/cm^2 together with lowest Q_{eff} and average interface trap density. This is attributed to the lowest Nd-silicate content, the largest SiO_2 and the smallest $Nd_2Si_2O_7$ crystallite size, and highest barrier height.

1 Introduction

Continuous development of modern electronic device technology leads to reduction size of silicon (Si)-based ultra-large-scale-integrated (ULSI)circuitry based on Moore's law. This scenario has led to downscaling of gate dielectric, i.e. silicon dioxide (SiO_2), thickness to a nanometer in metal-oxide-semiconductor (MOS) device [1, 2]. As a result, huge leakage current directly tunneling through the oxide may be occurred [3]. As reported by several literatures [4–7], the allowable maximum leakage current density in a MOS device is in the range of100–1000 A/cm^2. As tunneling increases exponentially with reduced thickness of SiO_2, high dielectric constant (k) material has been proposed as an alternative for replacement [8, 9] in order to minimize the occurrence of leakage current while maintaining low equivalent oxide thickness (EOT) [10].

Several high k oxides such as hafnium oxide (HfO_2), zirconium dioxide (ZrO_2), alumina dioxide (Al_2O_3) and several rare-earth oxides (REOs) together with their silicates and aluminates were studied using various preparation methods [10–13].The k value of an oxideis highly dependent on the deposition methods used, its thickness, its purity, and post-deposition treatment [14–18]. Deposition methods such as molecular beam epitaxy (MBE), radio frequency (RF) sputtering, atomic layer deposition (ALD) and metal–organic chemical vapour deposition (MOCVD) tend to form interfacial layer consist of SiO_2 and metal silicate [17–20]. Eventhough, SiO_2 can increase the leakage current, but silicate layer leads to lower current leakage; since silicate layer scavenge thicker SiO_2 [12, 21]. At the same time, treatment such as post-deposition annealing (PDA) affect physical properties of films in terms of surface roughness, thickness of interfacial layers and defect density; thus, it alternate the electrical properties such as capacitance, breakdown voltage and leakage current [11, 22, 23].

Of several investigated high k oxides, neodymium oxide (Nd_2O_3) is one of the potential REOs to replace SiO_2. This is because this type of oxide has k value of 10–15 [11, 24–26], possesses large bandgap of 5.8 eV [27, 28], and

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