FABRICATION AND CHARACTERIZATION OF POROUS SI AND EMBEDDED POROUS SI FOR PHOTONICS APPLICATION

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Executive Summary

The development of nanoelectronics demands the implementation of new materials that should be Si-compatible but with enhanced electric and photonic properties for further device scaling. Si/Ge can be considered as a useful and promising material for this purpose. However in photonics, Si and Ge suffer from their poor optical properties and cannot compete with the direct bandgap semiconductors(e.g GaAs). Si/SiGe nanostructures need to offer new solutions for improving the optical efficiency of the materials. Ge nanostructures have attracted world-wide attention due to their interesting quantum effects both in electronics and photonics application[1]. A variety of techniques have been employed to grow such structures, the most popular one is self-assembled growth nanometer islands in highly strained system using sophisticated Molecular Beam Epitaxy (MBE) or Low Pressure Chemical Vapor Deposition(LPCVD) techniques[2-5]. However these techniques require sophisticated machine and the cost is very high. In addition, the discovery of room temperature photoluminescence in porous silicon (PS)[6], presents a great interest in optoelectronic studies of this material. Covering or filling the pore network of a PS layer to produce a silicon nanocomposite is a promising process for new potential optoelectronics applications. Hence, there is a need to find a cost effective technique to grow a quality Ge nanostructures for photonics application. In this work, an effective and low cost method of thermal evaporation is used to fabricate the Ge nanostructure while low cost porous silicon will be utilized as the patterned substrate for the Ge nanostructure inclusion. Although there is still lack of commercially valuable Si-based active photonic devices, efficient light sources and detectors based on Si/SiGe would be a breakthrough that will open possibilities for the new system-on-a-chip to incorporate photonic devices with Si nanoelectronics. Si and Ge -based photodetectors are probably the most attractive candidate for this purpose due to possibility of integration into the logic IC chips.Hence, it is therefore of high interest to study the structural and optical characteristics of Ge nanostructure embedded inside porous silicon for effective light emission and detection.

Introduction

1.1 Overview of Porous Silicon

Since the discovery of room temperature photoluminescence from porous silicon (PS) by Canham [6], the structural and optical properties of the PS have been greatly investigated [7-9] and promising electroluminescent devices have been fabricated [10-12]. The research is triggered not only by the potentiality of technological applications but also by the claim that quantum confinement effect is responsible for the increased bandgap energy in porous silicon [13, 14]. Porous silicon (PS) possesses many interesting characteristics such as direct and wide modulated energy bandgap, high resistance, the vast surface with the area-to-volume ratio and the same single-crystal structure as bulk Si. These advantages are suitable for the making of photodetectors[15, 16].

1.2 Overview of Ge and Embedded Porous Si

Germanium has been introduced to silicon-based device in order to overcome the limitation in silicon only device. This procedure offers a tunable bandgap varying from silicon bandgap to germanium bandgap depending on the percentage of Ge in the SiGe alloy. Ever since SiGe technology has been introduced, it has become a subject of intensive research. It's oxide (SiO2) which grows naturally from the host material allows the processing flexibility where one can place more than 108 transistors on a single chip. This exhibits the maturity and stability of the Si-based technology. However the current trend of research is now focusing on the application of Si/SiGe based materials in the photonics area. This is motivated by the idea of having electronic and photonic devices on the same chip. One research interest is manipulating Si/SiGe-based materials for light emission. One way was through growing nano-sized crystal in order to obtain quantum confinement effect to overcome a drawback of indirect bandgap in normal bulk size silicon. By controlling the size of the nano-crystal one can tailor the wavelength of the emitted light.