Growth of InAs/GaAs quantum dots on GeOI substrate for silicon photonics

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Host Professor: Y. ARAKAWA

Keywords: quantum dots, GeOI, silicon photonics

Context For the development of future high-performance CMOS-based photonic systems on silicon, III-V-based lasers with low threshold current and high temperature stability integrated with silicon is required.

Objectives In order to benefit from the advantages of both GeOI for integrated circuits (GeOI proposed as a future platform for monolithic integration of III-V devices with Si) and QDs for the optical source (Low threshold current and temperature stability), there is a great interest in the fabrication of GeOI-based quantum dot lasers in the telecommunication band of 1.3 µm.

Methods The GeOI wafers were obtained by the Smart-Cut-™ technology (CEA-Soitec). We compare the QDs grown on different substrates on the basis of their structural and optical quality at 1.3 µm at room temperature (RT).

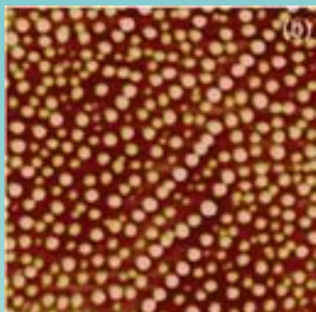

Fig. 1: 1×1 µm^2 AFM image of uncapped InAs QDs grown on GaAs/GeOI substrate

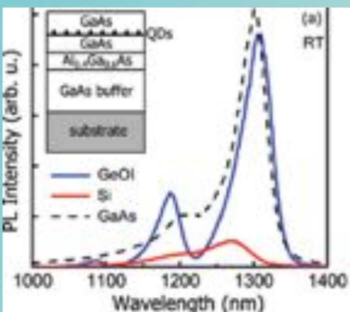

Fig. 2: RT PL spectra of the InAs QD samples grown on silicon (red curve), GaAs (dashed curve), and GeOI substrate

Results We demonstrated the growth of GaAs on GeOI with low defect density and high structural quality. We show that GaAs grow on GeOI substrate presents better structural and optical quality than GaAs grown directly on Si substrate.

We demonstrated for the first time, the growth of InAs/GaAs QDs on this GaAs/GeOI with a density above 10^{10} cm^{-2} and emission in the 1.3 µm band which is the desired wavelength for laser. The photoluminescence intensity of QDs on GeOI is similar to the QDs grown on GaAs substrate (use for several photonic applications) and much higher than QDs grown on Silicon substrate. These results show the suitability of GeOI platform for the monolithic integration of QD-based and other III-V devices on silicon substrate and are very promising in view of the fabrication of laser devices.

Fabrication and application of nanowire based biosensors

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Host Professor: B. J. KIM
Keywords: Si-nanowire, FET biosensor, cancer detection

Context

Nanowires have attracted much interest as essential parts for functional electronic devices because of their potential applications in nanoelectronics and nanophotonics. The high surface/volume ratio and one-dimensional morphology of the nanowires makes them very good candidates for sensitive biomolecular or chemical sensors. Thus, silicon nanowires fabricated by a bottom-up approach have been used since 2001 for the detection of pH level, DNA and proteins [1]. However, to go towards a widespread use of biochips, we need to be able to fabricate high-sensitive nanowires by a top-down approach, compatible with CMOS technology, in order to face the integration challenge.

Objectives

The aim of this project is to implement top-down fabricated silicon FET nanowires (Fig.1) in a biochip for the detection of metastatic related cancer markers. First devices have been fabricated and used to detect mouse immunoglobulin (Fig.2) at a concentration of 1µg/mL [2]. In next experiments, their sensitivity will be improved and they will be integrated in a microfluidic biochip to detect cancer markers at a ng/mL concentration.

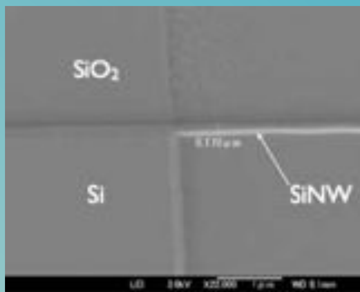

Fig.1: Silicon nanowire

Methods

Nanowires are fabricated using only a standard low-cost MEMS fabrication process based on the combination of LOCOS (local oxidation of silicon) technology and wet etching, without using nanolithography. Nanowire surfaces are silanized and modified with antibodies. The binding of antigens is then detected by measuring the resulting change of FET drain current.

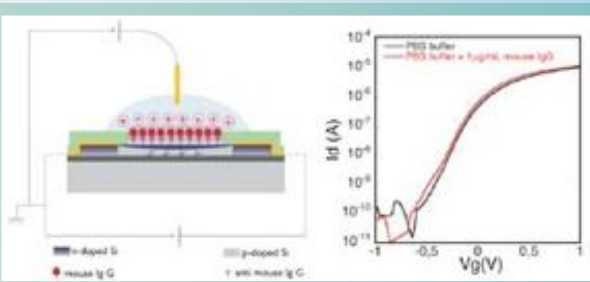

Fig.2: Detection of mouse immunoglobulin G with FET silicon nanowires

References and Publications

[1] Patolsky F. et al. Materials Today, vol. 8 (4) pp. 20-28, 2005.
[2] Ginet P. et al., ASPEN'09, Kitakyushu, Nov. 2009.

Non contact atomic force microscopy in liquid for the imaging of biological samples

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Keywords: liquid AFM, nanobiotechnology

Context

Atomic force microscopy (AFM) enables high resolution imaging of samples, down to the atomic scale, in vacuum, air, as well as in liquids. In recent years, the imaging in liquids has rapidly improved, and AFM provides now a unique opportunity to investigate the structure and properties of biological samples in their natural environment.

Fig. 1: Home-made AFM head

Objectives

We aim to adapt a new liquid AFM and develop methods for the imaging of biological samples. More specifically, we started by imaging lipid membranes as a model of cell membranes.

Methods

A liquid AFM using laser Doppler velocimetry, is developed in the laboratory [1] (fig. 1). This AFM uses a non contact mode and a phase modulation technique for imaging. It allows to achieve high resolution images in water as well as the imaging of large vertical features while having a low interaction forces with the sample. This AFM is modified to be able to image biological samples in the best conditions.

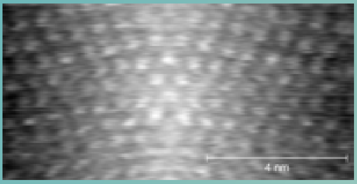

Fig. 2: Mirror image of mica in water

Results

A new AFM has been build for imaging in water [2]. This AFM has achieved atomic resolution of mica, molecular resolution of lipids bilayers, and has shown a very high stability for the imaging of big and high aspect ratio features like gold corrugation or nano holes in Aluminium oxyde.

References and Publications

[1] Nishida S., et al., Review of scientific instruments, 79, 2008.
[2] Hoel A., et al., Seisan-Kenkyu, 61(2), 2009.

Surface phonon polariton heat transfer

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Keywords: phonon polariton, heat conduction, IR source

Context

Surface Phonon Polaritons (SPP) are surface waves produced by the coupling of atomic vibrations with the electromagnetic field. Because they are monochromatic waves in the Infra-Red, SPP might be able to provide monochromatic sources just based on simple heating. At ambient temperatures, they also might produce abnormal heat conduction phenomena related to ballistic regimes of transport and to wave confinement usually observed at ultra-low temperatures.

Those waves are strongly enhanced when they couple between themselves. This was proven by recent measurements of the heat flux between a microsphere and a hot surface [1]. Considering heat transfer in the propagative direction of SPPs, quite recent works have tried to show heat conduction improvement in nanofilms [2]. But the coupling is not favoured in this configuration because the film is dissipating the electromagnetic energy and the coupling distance is too small, i.e. in the nanometer scale.

Methods

We have designed by modeling a microstructure that allows for strongly enhancing the coupling between SPPs. We have started experimental works to prove their contribution to heat conduction.

Results

The first theoretical results reveal a very strong enhancement of the SPP wave Free Path depending on the structure dimensions as shown in Figure 1.

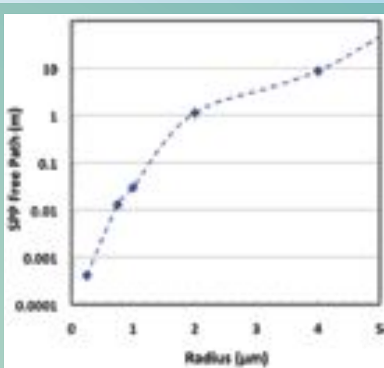

Fig. 1: SPP free path

References and Publications

[1] Rousseau E. et al., Nature Photonics, 3, 514, 2009.
[2] Chen D.-Ze A et al., Phys Rev B, 72, 155435, 2005.