Second Harmonic Spectroscopy of Strained Silicon Layers

R. Carrioles1, R. E. Balderas-Navarro2, K. Arimoto3, N. Usami1

1Photonic Division, Centro de Investigaciones en Optica, Loma del Bosque 115, León 37150, Mexico
2Instituto de Investigación en Comunicación Óptica, Universidad Autónoma de San Luis Potosí, Alvaro Obregón 64, San Luis Potosí 78000, Mexico
3Center for Crystal Science and Technology, University of Yamanashi, 7-32 Miyamae-cho, Kofu, Yamanashi 400-8511, Japan
4Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan

ABSTRACT
Second harmonic generation (SHG) is a well-known surface sensitive optical technique for studying centrosymmetric materials. This is because bulk second order nonlinear optical effects are forbidden, in the dipole approximation, for such materials. One system that has been extensively studied using SHG is silicon. It has been noted that inhomogeneous strain can lead to enhanced nonlinearities in Silicon. This is an attractive candidate for microphotonic devices, since Silicon processing is well-established.

In this report, we work on second harmonic generation (SHG) spectroscopic measurements performed on strained silicon substrates. The sample consisted on vicinal silicon (001) substrate with a 200 nm thick buffer layer of Si0.982C0.018, followed by a 10 nm thick Si layer. The spectra were taken for different polarization combinations using a Ti:Sapphire oscillator.

INTRODUCTION
Surfaces and interfaces play a central role in modern material science and in many technological applications; however, very few non-invasive, in-situ characterization techniques are available to study them. Optical techniques offer an attractive alternative because, in principle, they only require shining light on the sample and collecting the emitted light. Unfortunately, only a few of such techniques are surface sensitive. Second Harmonic Generation (SHG) offers such sensitivity since it is forbidden, in the dipole approximation, from the bulk of centrosymmetric materials but the presence of an interface, or any other symmetry breaking element, will induce a response [1-3]. In this work we implement SHG measurements spectroscopically to study a thin layer of compressively stressed Silicon (Si). This material is thought to hold great promise for optoelectronic devices [4-5]. SHG has been extensively used to study silicon surfaces, including stressed Si [1-3, 6]; however there are no reports on SHG from stressed Si (001).

The experiments were performed using a Ti:sapphire laser (140fs, 80 MHz) tunable from 720 to 950 nm. The beam was focused into the sample by a 10 cm focal length lens. The sample was mounted on a rotational stage to rotate it around its azimuthal position. The SHG was isolated with a BG 39 glass filter and detected using a PMT connected to a photon counter.

The sample was grown by molecular beam epitaxy with the following structure [7]:
1. The substrate consisted of a Si(001) wafer with a 5° offcut towards the [110] direction.
2. A 210 nm thick, fully strain relaxed buffer layer composed of Si0.982C0.018.
3. A 10 nm thick top stressed Si layer.

 RESULTS
The Raman spectra is consistent with a stressed Si top layer.

The strain in the buffer layer was probed by High Resolution X-ray Diffraction (HRXRD). The buffer is fully relaxed.

The strain of the substrate was measured using second order backscattered Raman scattering from the Si substrate.

CONCLUSIONS AND FUTURE WORK
To our knowledge, this is the first spectroscopic Si(001) SHG report. Previous works have been based mainly on Si(111) and not performed spectroscopically. We find that although the signal level is much smaller than with Si(111), it is detectable.

We will perform a Fourier analysis of the azimuthal traces to better understand the different contributions to the SHG signal.

We will study similar sample with no stress induced in the Si layer in order to compare the responses.

REFERENCES

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