IN DEPTH RESOLVED ANALYSIS OF SIMOX MATERIALS BY OPTICAL CHARACTERIZATION TECHNIQUES

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Between the different techniques for the structural characterization of SOI materials, special interest has been given to the optical ones, as Raman scattering and Infrared spectroscopy. This is due to their ability for the analysis of both the top silicon and the buried oxide layers. So, Raman scattering measurements allow to study the crystalline quality of the different Si regions in the structure, observing the presence of strains and structural defects as precipitates. On the other side, Infrared spectroscopy constitutes a more suitable technique for the characterization of the buried oxide layer. These measurements are made in the middle infrared spectral region, where the spectra are characterized by the presence of absorption peaks related to the different optical vibrational modes of the Si-O bond unit, which are very sensitive to the structural characteristics of the oxide. However, in general, these techniques give information which corresponds to an average of the whole layer under study, being difficult to determine the characteristics of the different regions of the layers, as the surface and interface regions (which characteristics are critical for the final device performance). In the case of Raman spectroscopy, a first approach for the in depth analysis of the layers can be done by comparing the spectra obtained using different excitation wavelengths (and, so, different penetration depths) /1/. Nevertheless, this has the problem that in all the spectra the main contribution comes from the surface region, and it is limited by the available lines of the laser.

In this framework, in this work we have performed an analysis of bevelled SIMOX samples obtained by different processes by Raman scattering and Fourier Transform Infrared (FTIR) reflection-absorption spectroscopy techniques. In both cases, measurements have been made with a microscope, which has allowed us to directly observe the different regions of the silicon and buried oxide layers on the structures.

MicroRaman measurements have been performed with an excitation wavelength of 457.9 nm (penetration depth of about 300 nm). These measurements show the existence of structural differences in the Si regions of the different samples, related to the technological processes. So, the analysis of the spectra measured at different points of the bevel surface allows to determine: a) the distribution in depth of residual strains in the Si regions, b) the possible presence of precipitates and c) the existence and distribution in depth of thermal effects, directly related to the thermal conductivity in the different regions. This is done by the analysis of the changes of the Raman spectra with the excitation power, which allows to study the dependence of the spectra on the temperature gradient induced in the scattering volume by the excitation laser /1/. So, in figure 1 are plotted the spectra obtained from a sample at different points of the bevel surface (excitation power 0.25 Mw/cm^2). The spectra from the surface region of the top Si layer are very similar to that obtained in bulk Si, although the peaks are broader and shifted towards lower frequencies. These changes increase very much as the measuring point approaches the Si/SiO$_2$ interface. For the points closer to buried oxide there is a splitting of the spectra, with a peak at higher frequencies very similar to that from bulk Si. When the buried oxide is reached, the spectra become very similar to bulk Si.

The changes observed in these spectra indicate the presence in the different regions of the top Si layer of a distribution of tensile strains which depends on the temperature gradient. So, changes increase with the excitation power. Although for this sample the penetration depth is similar to the thickness of the top Si layer (about 300 nm), the main contribution to the spectra comes always from the region closer to the bevel surface. Changes induced by the temperature gradient increase towards the

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Si/SiO_2 interface, which suggests a lower thermal conductivity in the region of the top Si layer closer to the interface. The splitting of the spectra for the measurements in this region is due to the contribution of the Si below the buried oxide. These changes are sensitive to the process of obtention of the sample, which shows the dependence of the quality of the interface region on the technological parameters. The presence in the samples of an interfacial region with higher thermal effects (indicating a lower thermal conductivity in this region) is an important feature which may be critical for the final device performance.

The structural characterization of the buried oxides has been made by Infrared microscope reflection measurements directly performed on these layers. The comparison of the characteristics of the TO_3-LO_3 and TO_4-LO_4 vibrational peaks in the IR spectra gives information about the structural characteristics of the oxides. In figure 2 are plotted the IR absorbance spectra measured in different samples (a: single implant sample and b: multiple implant sample) together with their theoretical simulation assuming the parameters of a thermal oxide /2/ (curve c). As it is shown, there is a good agreement in the position and relative intensity of the LO_3 and TO_3 peaks, which indicates the high quality of both buried oxides. However, there are differences between the spectra, essentially due to the presence in the experimental ones of a shoulder in the TO_4-LO_4 vibrational region, which indicates a higher contribution of these vibrational modes. This has been related to the existence of disorder induced vibrational coupling effects in the buried oxide from SIMOX structures. Although these effects are lower for the multiple implant material, previous measurements performed on single implant structures /3/ have shown the ability of this process for the obtention of buried oxides with structural characteristics very close to those of a thermal oxide. The measurements performed suggest a lower structural "quality" of the buried oxides of the studied samples in terms of disorder when compared to a thermal oxide.

In conclusion, the analysis performed on bevelled samples allows to obtain a more detailed and accurate information which complements that coming from the application of the used techniques on the whole structures, achieving a deeper understanding of the physical structure of SIMOX materials.

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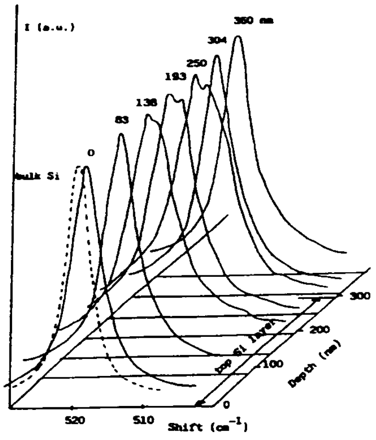

Figure 1

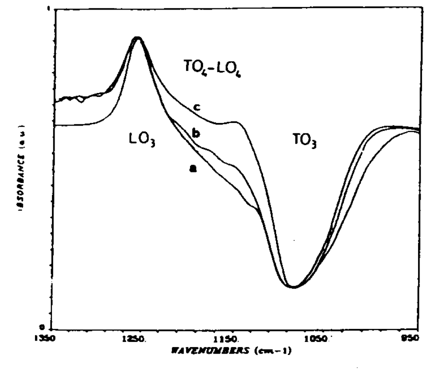

Figure 2