Structural Breakdown of Suspended Strained Silicon NanoWires by Exposure during Scanning Electron Microscopy Analysis

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Nowadays, strained silicon nanowires (sSiNWs) are used as conduction channel in 3D MOS transistors, such as FinFET and JunctionLess, which are fabricated using the sub-22 nm node technologies. The sSiNW structure presents superior electrostatic control of the 3D MOS gate and the strain enhances the carrier mobility in the conduction channel [1,2]. Suspended membranes of sSiNWs on sSOI (strained Silicon-On-Insulator) substrates (see schematic in Figure 1) have been obtained to extract the strain in sSiNWs using Raman spectroscopy [2]. In this work, we have fabricated these suspended membranes of sSiNWs, with different dimensions, on sSOI substrate, such as presented in schematic in Figure 1 [2]. Using Raman spectroscopy (Figure 2- see peak position at 515 cm^{-1}), the strain level in this substrate before the nanofabrication was identified. The fabrication process steps (Figure 1) are: RCA cleaning, E-beam lithography and dry etching in RIE system, to define the sSiNWs, organic cleaning, to remove the electron-resist, and buffered HF etching, to remove the buried oxide under the sSiNW to get the suspended membranes with nano dimensions. From schematic of suspended sSiNW membrane (Figure 3), the a, b, A and B dimensions are defined as, respectively, NW width, pad width, central NW length, overall membrane length [2]. To identify the obtained suspended nanostructures (Figure 4-left), we have used SEM microscopy of the FIB-SEM dual beam system. During the exposure of these suspended membranes of sSiNWs by electron radiation at 2 kV and 0.21nA, we have observed the structural breakdown after some time (Figure 4-right). This effect is the innovation of this work. The breakdown times have been measured for suspended membranes of sSiNWs with different dimensions for the a (between 112 nm and 239 nm) and b (between 725 nm and 1450 nm) widths. Theses membranes have the fixed dimensions for A and B lengths. Thus, the values of a/b dimension ratios of suspended membranes versus breakdown times were plotted, which are presented in Figure 5. In this Figure, there are three different regions for different a/b ratios of about: in I - 0,07 for times between 40s and 90s; in II - 0,12 for times between 60s and 100s; and in III - 0,15 for times between 220s and 300s. Based on these values, the a/b ratios are increased with the breakdown times. COMSOL simulations will be performed to understand this structural breakdown effect. In future works, we intend to obtain these suspended membranes of sSiNWs on different sSOI substrates with different strain levels to verify if this structural breakdown effect occurs. This effect can be related to the strain level of SiNWs and SEM analysis can identify this level, as an alternative to Raman spectroscopy.

[1] A. Khakifirooz and D. a. Antoniadis, 2006 Int. Electron Devices Meet. 1 (2006).

[2] R. A. Minamisawa, M. J. Süess, R. Spolenak, J. Faist, C. David, J. Gobrecht, K. K. Bourdelle, and H. Sigg, Nat. Commun. **3**, 1096 (2012).

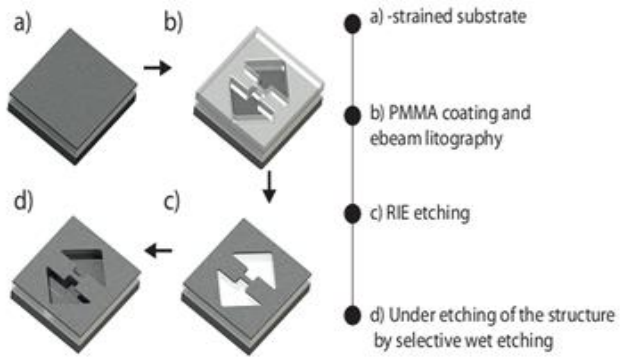

Figure 1- Suspended membranes of sSiNWs on sSOI substrate (in d) and the fabrication process steps (right).

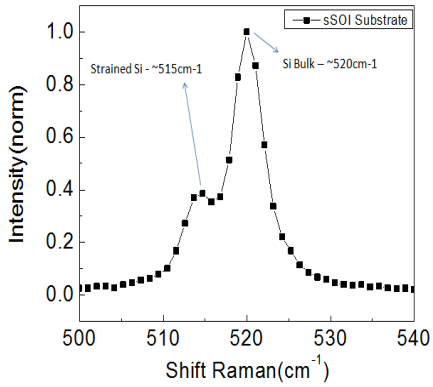

Figure 2- Raman Spectra of sSOI substrate - shifted peak at 515cm^{-1}, indicating an initial strain in comparison with bulk silicon at 520 cm^{-1}

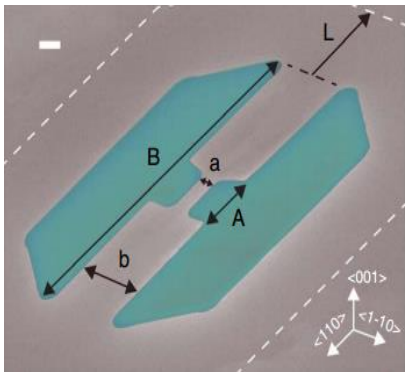

Figure 3- Strained silicon nanowire with dimensions (image from [2]*).*

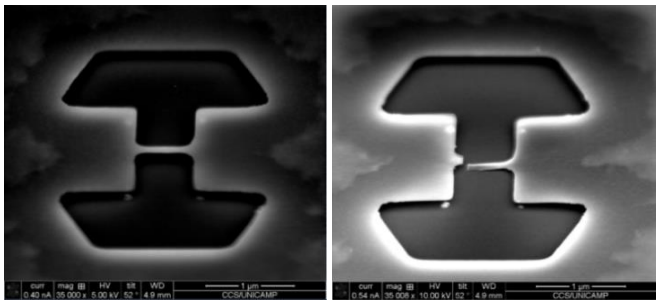

Figure 4- SEM Images of Suspended membranes of sSiNWs on sSOI substrate: left:before; right: after strucutural breakdown.

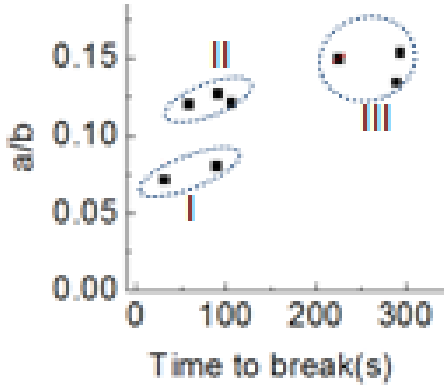

Figure 5 – Plot of a/b dimension ratio of suspended membranes versus breakdown time.