Depth Measurement of the Nano-dimensional Surface Damages of the Silicon Wafers in Production of the Submicron Integrated Circuits

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The main tendency of the contemporary microelectronics development is the constant and rapid reduction of the element dimensions (design rules) of the submicron integrated circuits (ICs). In the IC production process a silicon semiconductor wafer is subjected to the various influences, and on its surface thre emerge damages both as a results of the mechanical impacts at the stage of the wafer fabrication and as a result of the radiation processes, in particular, during the ion implantation of the doping admixture. The depth of the surface damages (the disrupted layer depth) of the silicon wafers is their crucial parameter, which is necessary to be controlled during IC production. Awareness of the disrupted layer depth makes it possible to optimize the processes of the silicon treatment and to make the best choice of them, which, in its turn, steps up the good yield and cuts down consumption of the materials. The given work proposed the new method, making it possible to measure up the depth of the nanodimensional damages on the surface of the silicon wafers with the resolution of 1 nm. Also, it ensures measurement of the disrupted layer depth on the surface of the silicon wafers after polishing and is based on usage of the Auger-spectrometer with the precision sputtering of the surface silicon layers and the exit intensity registration of the Auger-electrons.

In the proposed method the disrupted layer depth is measured up by means of the Auger-spectroscopy as per the measured dependence of the quantity of the exiting Auger-electrons from silicon in the process of the ion sputtering of the surface layers. The quantity of atoms in the nodes of the crystal lattice in the region of the disrupted layer is smaller, than in the bulk material. As the disrupted layer is being removed, the intensity of damages falls, the density of the silicon atoms in the analyzed monolayer builds up, the intensity of the Auger-electrons is also on the increase and assumes a constant value, corresponding to the bulk silicon. The exit intensity of the Auger-electrons was determined on the Auger-spectrometer PHI- 660 (USA). The spectrometer PHI- 660 makes it possible to vary the sputtering rate within the wide limits: from tens of fractions of nanometer per minute to 100 nm per minute. In order to determine the optimum sputtering rate a number of experiments were conducted. In progress of these experiments under variation were the parameters of the electron gun: the ion beam current, raster (sweep), a tilt angle of a sample. As a result the optimum etching rate wa selected to be 2,2 nm / min. After removal of the disrupted layer the exit intensity value of the Auger-electrons reaches the maximum value and the further sputtering of the silicon surface layers ceases. Thus, on the sample’s surface a step is formed: it upper part accommodates the initial surface of the analyzed wafer with the disrupted layer, while the lower one – the surface with the removed disrupted layer. The value of this step is equal to the disrupted layer depth. The disrupted layer depth was determined either as per the step on the profilemeter or as per the time and the known rate of sputtering.

Thus, the proposed method ensures the depth measurement of the nanodimensional surface damages and the effective analysis of the disrupted layer depth on the surface of the silicon wafers. The measurement range of the disruptions depth is 0.001–1 um.