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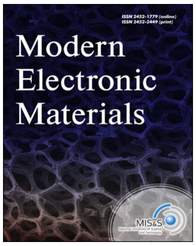

Peculiarities of electronic structure of silicon-on-insulator structures and their interaction with synchrotron radiation

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Abstract
SOI (silicon-on-insulator) structures with strained and unstrained silicon layers were studied by ultrasoft X-ray emission spectroscopy and X-ray absorption near edge structure spectroscopy with the use of synchrotron radiation techniques. Analysis of X-ray data has shown a noticeable transformation of the electron energy spectrum and local partial density of states distribution in valence and conduction bands in the strained silicon layer of the SOI structure. USXES Si $L_{2,3}$ spectra analysis revealed a decrease of the distance between the L'_{2v} и L_{1v} points in the valence band of the strained silicon layer as well as a shift of the first two maxima of the XANES first derivation spectra to the higher energies with respect to conduction band bottom E_c. At the same time the X-ray standing waves of synchrotron radiation ($\lambda \sim 12$–20 nm) are formed in the silicon-on-insulator structure with and without strains of the silicon layer. Moreover changing the synchrotron radiation grazing angle θ by 2° leads to a change of the electromagnetic field phase to the opposite.

Introduction

SOI (silicon-on-insulator) structures are suitable materials for the prototyping of active quantum size effect components for existing super high-speed computer engineering. Furthermore, they have tangible advantages over conventional silicon

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wafers and are used for the development of radiation resistant, heat resistant, low power consuming high-voltage ICs as well as various micro-electro-mechanical (MEMS) devices, diaphragms for pressure sensors and accelerometer panels. Of special importance are devices and ICs based on SOI structures that can be operated at high temperatures. The main commercial application of SOI are CMOS VLSI delivering significantly greater speed and lower power consumption (approx. 3-fold) compared with Si-based circuits [1]. If the SOI technology includes high-temperature anneal, the difference in the thermal expansion coefficients of silicon and silicon oxide (SiO_2) causes tension of the silicon layer adjacent to the oxide [2]. This may change some parameters of the band spectrum due to a change in the lattice parameter of silicon accompanied by a decrease in symmetry [3]. Below we will analyze the effect of tension of the silicon layer on band spectrum parameters by studying the density of states in the valence and conduction bands by ultrasoft X-ray spectroscopy.

Experimental

The test specimens were SOI structures of two types (Fig. 1):

Type I: silicon layer undergoing mechanical stresses in the layer plane ("strained" silicon);
Type II: "unstrained" silicon layer.

The Type I structures consisted of a c-Si (100) wafer, an overlaying 150 nm SiO_2 layer and a 100 nm strained silicon layer coated with a thin layer of natural oxide <2 nm in thickness. X-ray diffraction showed a decrease in the lattice parameter of the strained silicon nanolayer in the direction perpendicular to the tension direction as a result of elastic strain [4].

The Type II structures consisted of a c-Si (100) KDB-20 wafer, an overlaying 300 nm SiO_2 layer and a 100 nm strained silicon layer coated with a thin layer of natural oxide <2 nm in thickness. X-ray diffraction showed no change in the lattice parameter of the silicon nanolayer.

The electron energy spectrum of the valence band of strained and unstrained silicon in the SOI structures was studied using ultrasoft X-ray spectroscopy (USXES). The $L_{2,3}$ USXES spectra of silicon were recorded on a RSM-500 laboratory ultrasoft X-ray monochromator spectrometer. The measurements were carried out at excitation electron energies of 3 keV, the analysis depth being 60 nm. The X-ray tube and the spectrometer were evacuated to approx. 10^{-4} Pa.

The electron energy spectrum of the conduction band of strained and unstrained silicon was studied using X-ray absorption near edge structure spectroscopy (XANES) with the use of synchrotron radiation (SR). The experimental XANES spectra near the Si $L_{2,3}$ absorption band were obtained on a Mark V Grasshopper beamline of the Synchrotron Radiation center of the Wisconsin Madison University (Stoghton, USA). The informative layer depth for the XANES

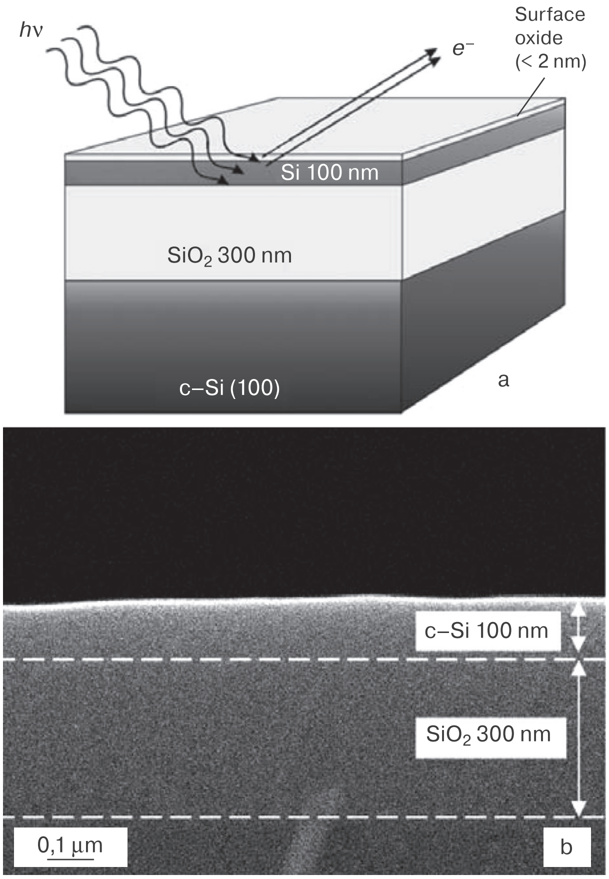

Fig. 1 (a) Schematic of the SOI Structure and (b) electron microscopic image of the real SOI.