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Late 2000s

Usage of strained silicon for high-speed transistors

~ Process Technology ~

The MOS transistor has improved its performance by scaling, but as it entered the sub-0.1μm range, the problem of the physical limit has become apparent such as the difficulty of fine processing, direct tunneling in gate oxide film, velocity saturation of carriers and so on, and improvement of the driving current not depending on the miniaturization has been studied. As one of such researches, a method to increase the carrier mobility by adding distortion to the channel region was carried out, from around 1992. As a method of applying strain, a method of epitaxially forming a Si channel layer on a lattice-relaxed SiGe/Si substrate was studied at first. Since Ge has a lattice constant larger than that of Si, the lattice constant of the SiGe layer increases as the concentration of Ge increases and a tensile stress is applied to the Si layer thereon in the planar direction (biaxial direction). This increases the electron mobility by about 60% and the hole mobility by about 50%.

Since the method using the Si/SiGe/Si substrate led to an increase in the cost of the substrate, and the crystal defects could not be completely eliminated, the methods of locally applying a stress by using ordinary Si substrates was proposed around 2000. First, it was proposed to form a SiN layer having a tensile stress on the gate electrode, thus applying a tensile stress to the NMOS in the channel direction (uniaxial direction), and a compressive stress to the PMOS by changing the formation conditions of the SiN layer. Further, in order to apply stronger stress to the PMOS, a method of applying compressive stress to the channel portion by epitaxially growing SiGe in the source/drain region was proposed around 2004. This technology is used for most of current CMOS today where necessary. Recently, a method of applying tensile stress to a channel by epitaxially growing SiC in the source/drain region of NMOS has also appeared. As a result, the mobility of electrons is increased by about 25%, and the mobility of holes can be increased by about 50%.

Version 2019/1/13