Band gap engineering in Ge via nonequilibrium processing

During past decades a spectacular growth of computing power of microprocessors offered by the microelectronic industry was observed. One deals with a kind of positive feedback loop of electronic equipment efficiency and end-user demand of computing power. On one hand, growing expectations of users force continuous increase of efficiency. On the other hand, more and more powerful hardware encourages users to employ more demanding and attractive software and in some sense induces omnipresence of microprocessor based devices, only to make mention of smartphones. The unceasing increase of computing power within years was achieved mostly by continuous miniaturisation of transistors and, hence, increasing density of their packing within the chip. This process is usually described by the Moore's law, claiming that the number of transistors within a single microprocessor doubles every 18-24 months. One should, however, bear in mind that miniaturisation is not without limit - to mention only the technological limit of approximately 10 nm imposed on the transistor channel length by the optical lithography process. Integration of materials characterised by high charge carriers (electrons and holes) mobility with contemporary silicon based technology seems to be a reasonable solution. It would enable production of microelectronic devices with much shorter switching time, in other words faster and more efficient processors. Most promising candidates are germanium and its alloys with tin - materials characterised by high charge carrier mobility. Moreover, both Ge and GeSn are IV group semiconductors, which means that most of our knowledge about silicon processing in the CMOS technology is valid and applicable also in the case of Ge based materials. The fact that GeSn is a direct bandgap semiconductor, hence an efficient light emitter should be also kept in mind, as this feature makes it useful for purposes of optoelectronics. However, in order to enable full integration of Ge and GeSn with silicon based technology several problems need to be solved by the team. These are: (a) low solid solubility of Sn in Ge (b) low efficiency of n-type doping of Ge and (c) extremely fast diffusion of n-type dopants and their deactivation by interactions with Ge lattice defects.

The team members are going to overcome all the above difficulties by applying two complementary techniques: ion implantation and millisecond flash lamp annealing. The first technique enables precise introduction of virtually any dopant into a well-defined region of target material. The second one allows recrystalisation of target material defected during the implantation stage as well as electrical activation of the dopants. Moreover, ultrafast annealing prevents segregation and percipitation of dopant in the form of clusters, which is a typical drawback of conventional thermal annealing. Overcoming of all the above-mentioned obstacles enables fabrication of highly p and n type doped layers in Ge and GeSn, which could open the way for cost-effective integration of ultrafast micro- and optoelectronic Ge based devices with modern silicon technology.