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Alternate Substrate Materials For Nanoscale MOSFETs

Amit Chaudhry*
Institute of Engineering and Technology, Panjab University, Chandigarh, India

As per the predictions of International Technology Roadmap of Semiconductors (ITRS), there is a strong need for the replacement of the silicon as a substrate material in a nanoscale MOSFET. Germanium, SiGe, III-V materials or Graphene have been seen as a potential replacement to silicon. This is required to take the Moore's law ahead in the sub nanoscale technologies. The Moore's law is also being followed as a performance oriented scaling of the transistors calling it "More than Moore's" law. In conventional silicon MOSFETs, the mobility is seriously affected by the vertical and horizontal electric fields in the MOS device at the nanometer scale. The reduction in the carrier mobility reduces the drain current and eventually the speed of the transistor. The main advantage of using these alternate materials is to increase the carrier mobility in a MOSFET.

Germanium or SiGe semiconductor in the MOS substrate is introduced in the sub 90nm technology. As the technology node shifts to the lower technology, these materials fail to provide the benefits of the enhanced mobility as required. As the technology node shifts to the lower technology, the SiGe material fails to provide the benefits of the enhanced mobility. As the technology moves ahead to sub 45nm node, there is a requirement of other materials such as III-V semiconductor (GaAs, InGaAs, GaN) are required to increase the carrier mobility. The compound semiconductors have very high electron mobility than the silicon. However, there are other issues with III-V materials i.e. integration of III-V with the existing silicon technology, low hole whole mobility and growth of a dielectric with low interface defect density on a III-V substrate need to be addressed very seriously before this technology can be used in the mainstream nanoelectronic digital devices. For use in much lower technologies, there is a need for even higher mobility material than the III-V material. Graphene is a carbon based material having carrier mobility of a very high value and has a potential to be used as a silicon replacement. But the problem with this material is that it does not have a bandgap and hence the device madeup of this material cannot show switching action. So, the digital operation of the graphene based MOSFET is not a successful one. For that purpose, the graphene material based devices are used in high frequency applications where the switching action is not a major issue. To use graphene in digital devices, it has to first converted into a graphene nanoribbon material which has a low finite bandgap. So, whatever devices which are being explored in the research labs around the world are using graphene nanoribbon material which has a low finite bandgap.

All the materials described above have both advantages and disadvantages and hence their implementation in the MOS technology is to be carefully done. So, the microelectronic industry is still keeping its finger crossed over the suitable selection of the material to be used as a replacement of the silicon from the microelectronics forever.

***Corresponding author:** Amit Chaudhry, Institute of Engineering and Technology, Panjab University, Sector-25, Chandigarh, India, Tel: 91-172-2534995; E-mail: amit_chaudhry01@yahoo.com

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