New surface chemistry may extend life of technology for making transistors

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Researchers at the University of Illinois at Urbana-Champaign have developed a technique that uses surface chemistry to make tinier and more effective p-n junctions in silicon-based semiconductors. The method could permit the semiconductor industry to significantly **extend the life of current ion-implantation technology for making transistors**, thereby avoiding the implementation of difficult and costly alternatives.

To make faster silicon-based transistors, scientists much shrink the active region in p-n junctions while increasing the concentration of electrically active dopant. Currently about 25 nanometers thick, these active regions must decrease to about 10 nanometers, or roughly 40 atoms deep, for next-generation devices.

The conventional process, ion implantation, shoots dopant atoms into a silicon wafer in much the same way that a shotgun sends pellets into a target. To be useful, dopant atoms must lie close to the surface and replace silicon atoms in the crystal structure. In the atomic-scale chaos that accompanies implantation, however, many dopant atoms and silicon atoms end up as interstitials – lodged awkwardly between atoms in the crystal.

Ion implantation also creates defects that damage the crystal in a way that degrades its electrical properties. Heating the wafer – a process called annealing – heals some of the defects and allows more dopant atoms to move into useful crystalline sites. But annealing also has the nasty effect of further diffusing the dopant and deepening the p-n junction.

“We developed a way of using surface chemistry to obtain shallower active regions and enhanced dopant activation simultaneously,” said Edmund Seebauer, a professor of chemical and biomolecular engineering at Illinois. “By modifying the ability of the silicon surface to absorb atoms from the substrate, our technique can control and correct the defects induced during implantation.”

Inside the active region, atoms sitting on lattice sites have bonds to four neighbors, which saturates the bonding capacity of the silicon atoms. Atoms sitting on the surface have fewer neighbors, leading to unused, or “dangling” bonds. Atoms of a gas such as hydrogen, oxygen or nitrogen can saturate the dangling bonds.

“These dangling bonds can also react with interstitial atoms, and remove them from the crystal,” Seebauer said. “The process selectively pulls silicon interstitials to the surface, while leaving active dopant atoms in place. The preferential removal of silicon interstitials is exactly what is needed to both suppress dopant diffusion and increase dopant activation.”

Seebauer and his colleagues – chemical and biomolecular engineering professor Richard Braatz and graduate research assistants Kapil Dev and Charlotte Kwok – use ammonia and other nitrogen-containing gases to saturate some of the dangling bonds and control the ability of the surface to remove interstitials.

“The amount of surface nitrogen compound formed, and therefore the number of dangling bonds that become saturated, can be varied by changing the type of gas and the degree of exposure,” Seebauer said. “As an added benefit, nitrogen compounds are also quite compatible with conventional chip manufacturing processes.”

Through computer simulations and experimental verification, the researchers have shown that "defect engineering" by means of surface chemistry can extend the life of current ion-implantation technology and create smaller, faster electronic devices. Seebauer will present the team's latest findings at the 51st International Symposium of the AVS Science and Technology Society, to be held Nov. 14-19 in Anaheim, Calif.

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Source: University of Illinois at Urbana-Champaign