New methodology based on atom probe tomography for FinFET dopant characterization
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Imec presents a new methodology to probe the 3D-dopant distribution inside FinFET devices and extract important parameters like gate overlap and profile steepness. The method, which is based on atom probe tomography (APT), has proven successful in linking dopant distributions with device performance. The tool is useful for optimizing 3D-doping profiles in next-generation FinFET devices.

In non-planar devices like FinFETs, the formation and optimization of 3D-dopant profiles is a major challenge, requiring accurate 3D-dopant profiling metrology. Imec has developed an appropriate methodology with sub-nm resolution that is based on the APT technique. It allows extracting important parameters like dopant gate overlap (i.e., under-diffused dopant depth into the channel) and doping conformality (i.e., similar dopant distribution at top and side walls of the fin). These issues can have a large impact on the FinFET device performance. By using this technique, doping conformality is demonstrated to be a key parameter in controlling gate overlap.

The basic concept of APT is to peel, atom by atom, the surface of a needle shaped sample by means of ionization and field evaporation. The sequence of atomic emission (peeling) and detection then leads to the reconstruction of a 3D volume. As the field of view in APT is fairly limited, a crucial step is to position the area of interest in the final APT tip. Therefore, it was important to perform a judicious procedure for defining and securing the area of interest during annular milling of the APT tip. The FinFET devices used for the experiments were fabricated with a standard process flow in which two different doping steps were used, i.e. self regulatory plasma doping (SRPD) and traditional beam-line ion implantation.

Figure 1: APT image of arsenic (orange) distribution with native oxide (SiO₂) at top and side wall of the fin in the source/drain region.

The APT results on samples with different doping processes are entirely consistent with the device performances (I_{on} vs. I_{off}). APT is also helpful during the optimization of the doping process. In case of non-optimized doping (SRPD process A), APT successfully reveals the non-conformality of the dopant distribution by extracting the dopant profiles at the source/drain region (fig.1). In these samples, the technique demonstrates a much higher doping at the top of the fin, which induces a larger under-diffusion at the top of the fin and thus gate overlap (fig.2). From the electrical measurements, an average gate overlap value of 10nm is deduced, which appears consistent with the 3D measurements.
The conformality in the source/drain region plays a dominant role in the final device performance. We have used the new methodology to further explore doping process optimization (fig.3). The results indicate that the dose at the sidewalls of the fin is the dominant factor influencing the device performance.

These results have been presented at the 2012 VLSI Symposium.

Ajay Kumar Kambham is working towards his doctoral project (PhD) on “Atomic scale characterization of 3D-structures (FinFET’s) with Atom Probe Tomography (APT)”. His responsibilities involve understanding the device process integration conditions/flow then design, develop and optimize the protocol for device Characterization (FEOL) to analyze the 3D-Atomic distribution in
novel devices like FinFET’s. Prior to joining for PhD, Ajay did his Master of Technology in Solid State Materials from Indian Institute of Technology Delhi (IITD) with a thesis project on “Direct wafer bonding and Grinding/Etch back method for fabrication of silicon-on-insulator (SOI) substrate”. He also earned degrees of Masters and Bachelors in Physics from Sri Venkateswara University, Tirupati, India.