The future generation silicon-based devices require junction depths <100 nm. Dopant ions (B, BF2, As) will be implanted in Si at different temperatures, with energies <1 keV (for B) and of some keV (for BF2 and As). However, the successive annealing made for dopant activation produce non-equilibrium dopant diffusion, whose control needs deep knowledge of the microscopic mechanisms ruling this phenomenon. To this end, the following experimental techniques will be used:

(i) secondary ion mass spectrometry SIMS) and spreading resistance profiling (SRP) to measure the annealing-induced chemical and electrical dopant redistribution, respectively, and;

(ii) medium energy ion scattering (MEIS), grazing incidence diffuse synchrotron X-ray scattering (GI-DXS) and transmission electron microscopy (TEM) for damage analysis. The final goal of the research will be the fabrication of an ultra-shallow junction device of high electrical performances.

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OBJECTIVES
The objectives of the research activity proposed here are:
1. The drawing of a comprehensive view of the atomic transport and electrical activation behaviour of dopants implanted in ultra-low energy regime. This will be possible by comparing and simulating the dopant profiles obtained by SIMS and SRP measurements before and after annealing;
2. The achievement of a complete characterisation of the damage introduced in a few 10 nm thick Si surface layers by implants at energies below 1 keV for B and of some keV for BF2 and As. This study will also be performed after annealing. The defect analyses will be determined by analysis and simulation of MEIS and synchrotron GI-DXS spectra, and by TEM imaging. The final goal will be the fabrication of a device with ultra-shallow junctions of high electrical performances.

DESCRIPTION OF WORK
Si wafers will be implanted at different temperatures with dopant ions (B, BF2, As) at energies <1 keV for B and of some keV for BF2 and As. Post-implant annealing will be done by rapid thermal processing (RTP) and spike annealing (SA).
The samples will be analysed by the following experimental techniques:
1. Electrical and chemical dopant profiling by SRP and a (unique in Europe) SIMS, respectively, with high depth resolution and sensitivity. The use of SRP is very important, because a high electrical activation is the basic requirement for the application of ultra-shallow doped layers in the future CMOS technology;
2. MEIS in double alignment mode has the unique capability of providing, also by spectra simulation, depth profiles of damage and of most implanted species with a resolution <1 nm;
3. GI-DXS at ESRF is a technique of surface diffraction particularly adequate to probe ultra-thin layers. Its most important feature is the ability to study atomic defect configurations in a size range from point defects to large clusters or extended defects. The high photon flux available at ID01 beamline makes these measurements possible with strong signal of the diffuse scattering. These measurements will be done before and after RTP and SA, and will be analysed also by codes of molecular static, e.g. the intensity patterns, calculated for given defect structures, will be compared with the experimental ones. Information on defect structure, depth distribution, size and concentration will then be obtained;
4. TEM observations: This technique will be very helpful to determine the onset of the transition from point-like defects to large clusters or extended defects, and to observe, by proper sample preparation, the two-dimensional delineation of shallow doped regions in devices. The 2D investigation is crucial to evaluate the lateral extension of the shallow junctions, which must be limited by the requirements of the future device technology.

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