Contribution ID: **121** Type: **Plenary**

The functionalization of single atoms addressed by ion beam implantation

Monday, 7 July 2014 10:30 (40 minutes)

The ultimate goal of nanotechnology engineering in solids is the ability to prepare single atoms as full functional quantum devices in a scalable manner. Quantum effects enable to build extremely powerful sensors and still let the promise of a quantum computer. Devices based on defects in diamond play an increasing role in these fields, taking advantage of some recent technological breakthroughs and of the remarkable overall physical properties of diamond, allowing quantum information processing at room temperature. The nitrogen-vacancy (NV) defect center in diamond has attracted a lot of attention in the last decade. It consists of a substitutional nitrogen atom associated to a carbon vacancy as a first neighbor. Due to unique optical and spin properties, single NV centers are nowadays used as magnetometers or single-photon sources and are promising qubits for quantum computing at room temperature [1-3]. The development of new quantum devices, based on the interaction between the spins associated to single NV centers, requires the ability to create scalable arrays of such centers with high-resolution [4].

The key technology to fabricate and operate these devices is the positioning and addressing of single atoms in a solid with high lateral resolution. Whereas the manipulation of single atoms at the surface is possible since several years [5], the three dimensional addressing of single atoms needs more effort. The combination of surface manipulation and overgrowth is one possibility but it is technically very challenging and possible only for a few atoms like phosphorous in silicon. Ion beam implantation allows nowadays placing single countable atoms inside a given solid with a few nanometers lateral resolution. Focusing systems are more and more optimized aiming to reach a lateral resolution limit. Counting single ions is even more challenging, and the development of a deterministic single ion source based on an ion trap could solve this problem.
The paper discusses the hints and possible solutions for a road map of single ion implantation in the future.
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Session Classification: Plenary 1