Slow Highly Charged Ions for Applications in Nanotechnology

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1. Introduction

Highly charged ions are available from huge accelerators and special ion sources such as Electron-Cyclotron-Resonance (ECR) ion sources or Electron Beam ion Traps (EBIT). Both kinds of ion sources are able to produce ions with charge states quite higher than from classical ion sources. Highest ion charge states up to fully stripped atoms are produced only in EBIT's where the atoms are ionized by successive electron impact ionization in dense electron beams compressed by external magnetic fields up to electron densities of several thousand A/cm^2 (see for instance [1]).

Compared to classical ion beams with very limited ion charge states highly charged ions offer a new physical parameter – the ion charge. With increasing ion charge the potential energy stored in an ion increases and can reach up to some hundred keV. The potential energy stored in a highly charged ion can be deposited within a few femtoseconds into a surface with a 10 nm lateral resolution and 1 nm depth. This is equivalent to a deposited power density of 10^{12} W/cm^2 up to 10^{14} W/cm^2. Therewith surface structures in a nanometre size such as blisters and craters can be produced with unfocussed beams [2]. Even single ion implantation is possible by ion hits using focussed beams. Thus, fields of applications as modification of solid state surfaces, materials analysis and the fabrication of microelectronic devices are expected to benefit from the unique characteristics of highly charged ions applied. Here a wide field of new possibilities is opened if slow highly charged ions are used with very low kinetic energies which interact only on the solid state surface without penetrating into deeper atomic layers.

For the production of slow very highly charged ions up to now EBIT's working with cryogenic (superconducting) magnetic systems for the formation of the focussing magnetic fields have been available. The use of superconducting magnetic coils makes the application of such ion sources difficult and is associated with comparatively large operation expenses. A promising new approach here is the development of a room-temperature EBIT (Dresden EBIT [3,4]) which produces highly charged ions long-term stable at low expenses.