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Investigation of accelerated neutral atom beams created from gas cluster ion beams

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ABSTRACT

A new concept for ultra-shallow processing of surfaces known as accelerated neutral atom beam (ANAB) technique employs conversion of energetic gas cluster ions produced by the gas cluster ion beam (GCIB) method into intense collimated beams of coincident neutral gas atoms having controllable average energies from less than 10 eV per atom to beyond 100 eV per atom. A beam of accelerated gas cluster ions is first produced as is usual in GCIB, but conditions within the source ionizer and extraction regions are adjusted such that immediately after ionization and acceleration the clusters undergo collisions with non-ionized gas atoms. Energy transfer during these collisions causes the energetic cluster ions to release many of their constituent atoms. An electrostatic deflector is then used to eliminate charged species, leaving the released neutral atoms to still travel collectively at the same velocities they had as bonded components of their parent clusters. Upon target impact, the accelerated neutral atom beams produce effects similar to those normally associated with GCIB, but to shallower depths, with less surface damage and with superior subsurface interfaces. The paper discusses generation and characterization of the accelerated neutral atom beams, describes interactions of the beams with target surfaces, and presents examples of ongoing work on applications for biomedical devices.

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1. Introduction

As characteristic dimensions of microdevices have been becoming ever smaller, much effort has necessarily been directed toward developing improved techniques for producing various surface modification effects to shallower and shallower depths without altering subsurface bulk properties of the target materials. The gas cluster ion beam (GCIB) technique which originated at Kyoto University is a versatile method for producing a wide range of very shallow surface modification actions by use of van der Waals bonded gas cluster ions which are accelerated to have high total energies but with only relatively low energies of constituent atoms within the clusters [1,2]. This paper introduces a new concept for achieving more shallow, more uniform and less damaging processing of surfaces by altering the normal GCIB technique so as to create beams of coincident but unbonded energetic neutral gas atoms having average energies which can be controlled over a range from less than 10 eV per atom to beyond 100 eV per atom. This new technique, which is referred to as accelerated neutral atom beam (ANAB), is presently being employed for processing of biomaterials, but it is also found to offer improved nano-level processing characteristics for applications in optics, semiconductors and analytical instrumentation. Development to date has involved primarily Ar as the source gas, but tests have been conducted to demonstrate that the approach remains valid for other elemental and molecular gases.

2. Method of accelerated neutral atom beam generation

In standard GCIB apparatus, gas at pressure is expanded through a small nozzle into vacuum to form gas clusters typically comprised of a few hundred to several thousand atoms. Clusters which exit along the central axis of the nozzle are directed to pass through a small skimmer into a second vacuum chamber while most of the non-clustered gas emerging from the nozzle is removed by the nozzle chamber pump. Gas clusters which pass through the skimmer are made positively charged by electron impact ionization and are then accelerated through a high potential before allowing them to transport to a target at ground potential. Additional beamline components may be employed for focusing to overcome space charge effects and for elimination of monomer ions which might be present as contaminants within the beam. Standard equipment practice is to use a stationary beam with mechanical translation of the target to obtain process uniformity. Beam currents are monitored for dose control.

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