PROPERTIES OF RARE GAS CLUSTERS AND CLUSTER-SURFACE IMPACT

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Abstract

Clusters of atoms and molecules are new building blocks of matter with dimensions down to the nanoscale. The main strength of the technology involving clusters is in a versatile control over preparation and manipulation with clusters. Cluster beams have proved to be promising for production of novel materials and for modification and processing of surfaces as an alternative to conventional methods involving ion beams or plasmas. Clusters are also very interesting as unique theoretical model systems.

In the present work the design and capabilities of a newly constructed cluster implantation and deposition apparatus supplied by a pulsed cluster source from gaseous precursors is described. Positively charged clusters of rare gases were produced in the source and characterised by means of time-of-flight mass spectrometry. The resolved mass spectra of Ar_n^+ and Xe_n^+ cluster ions up to $n = 160$ revealed the presence of intensity anomalies for $n = 55$, 71, 147 etc. corresponding to clusters with closed atomic shells and subshells. Abundances of these clusters were inverted to find relative dissociation energies. The comparison with the theoretical values indicated the importance of configurational entropies of the surface atoms and vacancies in the quantitative analysis of the cluster abundances.

An effect of single cluster-surface impact was investigated experimentally by implantation of size-selected Ar_n^+ and Xe_n^+ cluster ions into SiO_2/Si(111) and Al_2O_3(1-102) substrates with energies from 3 to 18 keV/ion. The samples after implantation were studied by atomic force, transmission electron and scanning electron microscopy. As a result of energetic cluster impact, nanosize hillocks, formed in the middle of the craters, were found on the surfaces. These structures were called complex craters and found on cluster implantation for the first time. The formation of complex craters was studied depending on a number of experimental parameters, namely: cluster size, implantation energy, type of substrate and cluster species. A model explaining crater and hillock formation in relation to fundamental aspects of cluster stopping is discussed.

Keywords: rare gas clusters, time-of-flight mass spectrometry, magic numbers, dissociation energy, surface entropy, cluster implantation, crater, hillock