Negative Ions for Emerging Interdisciplinary Applications

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Significant progress has been made in the science and technology of negative ion sources, beam extraction, transport and focusing, especially in the context of high energy accelerators and magnetic fusion [1]. Another area of major activities covers ion beam-materials interactions. Negative ions have special merits in these applications because of its capability for self-regulation of charging conditions, especially for interactions with electrically insulating materials [2]. Some important applications in ion beam-material interactions include materials processing, surface analysis by secondary ion mass spectroscopy (SIMS), ion beam lithography and semiconductor device inspection [3,4]. All of these efforts primarily pertain to vacuum environments. A distinct area of activities constitutes formation of ions and ion transport in ambient environmental conditions, i.e., at atmospheric pressures. An important application is ion mobility spectrometry (IMS) [5]. Ions from an atmospheric pressure ionization source in an IMS diffuse through a counter-streaming neutral background in a drift cell under the action of a uniform electric field. This talk will focus on the development of negative ion sources and ion transport in the context of IMS for detection of a wide range of materials at trace level. Additionally, some important applications, especially SIMS imaging for detection of trace materials with sub-micrometer spatial resolution, will be highlighted.

The current state-of-the art of IMS can be significantly advanced if (a) compact ionization sources that yield intense negative ions can be developed, and (b) ions are efficiently transported from the source to the IMS drift cell. The use of carbon nanotubes, nano-electromechanical system (NEMS) based soft-ionization, miniaturized electrospray array, and photoionization forms the crux of some recent developments of compact ionization sources for IMS. The underlying science questions, especially the complex reaction chemistry for ionization, and related selective ionization processes, warrant systematic investigation. This talk will highlight some of these critical problems for negative ions formation and transport. Furthermore, the impact of miniaturized negative ion sources on advancing the IMS technology, especially enhancing sensitivity and selectivity, will be discussed. Some cross-cutting applications of IMS including identification of trace materials for security screening and critical disease detection will be illustrated. This talk will finally highlight an overarching need for high-brightness ion beams and associated transport and focusing. An illustration will be given in the context of SIMS imaging that is relevant to many cross-cutting applications, including biological and medical sciences, semiconductor device inspection, and identification of trace elements in samples from extraterrestrial environments.

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[2] "Charging Substrates Irradiated by Particle Beams," P. N. Guzdar, A. S. Sharma, and S. K. Guharay, Applied Physics Letters, vol. 71, pp. 3302-3304, 1997.

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[4] "Ion Beams and Their Applications in High-Resolution Probe Formation", S. K. Guharay, J. Orloff and M. Wada, IEEE Transactions on Plasma Science, vol. 33, pp. 1911-1930, 2005.

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