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Review

# Auger neutralization and ionization processes for charge exchange between slow noble gas atoms and solid surfaces

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ABSTRACT

Electron and energy transfer processes between an atom or molecule and a surface are extremely important for many applications in physics and chemistry. Therefore a profound understanding of these processes is essential in order to analyze a large variety of physical systems. The microscopic description of the two-electron Auger processes, leading to neutralization/ionization of an ion/neutral atom in front of a solid surface, has been a long-standing problem. It can be dated back to the 1950s when H.D. Hagstrum proposed to use the information contained in the spectrum of the electrons emitted during the neutralization of slow noble gas ions as a surface analytical tool complementing photoelectron spectroscopy. However, only recently a comprehensive description of the Auger neutralization mechanism has been achieved by the combined efforts of theoretical and experimental methods. In this article we review the theoretical models for this problem, stressing how their outcome compare with experimental results. We also analyze the inverse problem of Auger ionization. We emphasize the understanding of the key quantities governing the processes and outline the challenges remaining. This opens new perspectives for future developments of theoretical and experimental work in this field.



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## 1. Introduction

Electron and energy transfer processes between an atom or molecule and a surface are extremely important for many applications in physics and chemistry. In nanoscience, ion implantation in microelectronics has become an often used technique for fabrication of nanostructures and focused ion beams are used today for nano-patterning and nano-lithography. In plasma physics, the knowledge of plasma wall interactions is of paramount importance to achieve high temperatures and confined plasmas and also, the sputtering and ionization properties of the vessel walls and the plasma have a strong influence on the plasma temperature. In space science and astrophysics, solar wind exchanges charge and energy with satellites. In surface science, Low Energy Ion Scattering (LEIS) has become a powerful tool for the analysis and characterization of surfaces and chemical composition. Likewise, Ion Neutralization Spectroscopy (INS) is considered to be a technique complementary to photoemission electron spectroscopy (PES). In chemistry, catalytic reactions are extremely sensitive to charge exchange. All these applications make the field of particle–surface interactions a very interesting field. However, from the theoretical point of view, this is in general a problem of great complexity. On the one hand, target and projectile have a complicated internal structure which is revealed during the collision. On the other hand, new structure appears in the interaction of the particle with the surface which in turn is a dynamical (time-dependent) situation. Therefore, a substantial body of work is devoted to the understanding of the relevant microscopic mechanisms leading to charge transfer [1–7].

The two basic charge transfer mechanisms between an atom or molecule and a solid surface are known as resonant and Auger processes. Resonant processes are single electron mechanisms in which an electron tunnels from/to the atom to/from the solid when the energy level of the atom is in resonance with the continuum of states of the solid (see Fig. 1). Resonant processes, being one-electron ones, have been described abundantly in the literature, practically for any atom/solid combination, using different techniques [8–38].

Besides resonant tunneling, the two-electron Auger processes comprise the other fundamental electron transfer processes for ion-surface interactions. In the Auger Neutralization (AN) process