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Cluster Surface science with Rydberg atoms

By Mike Kohlhoff

Quantum physics allows for a large variety of phenomena which in our daily experience of nature are masked by thermal effects. This is the reason why, for example, a gas of atoms at room temperature is well described by a simple classical thermodynamical model.

The motion of an electrical charge from one place to another lies at the heart of most chemical processes. Such charge transfer processes involve the transfer of an electron from an atom or molecule in the gas phase to a metallic surface. They are present in many practical applications such as catalysts for the splitting of water into its components hydrogen and oxygen.

Furthermore, charge transfer occurs from an atom in the gas phase that is in a highly excited (Rydberg) state into a surface over greater separations. Then the process gains importance for studies of cold plasmas and atom chip experiments which employ Rydberg states for the realisation of quantum information processing.

In order to optimally identify the mechanisms involved it is important to have genuine control over the atoms in the gas phase. In our experiments, we have studied the charge transfer from hydrogen Rydberg atoms into a gold metal surface for the first time. The advantage of using hydrogen is its simple structure, which allows easier modelling of this interface system and comparison of experimental results to theoretical predictions.

We used a standard technique to cool hydrogen in a supersonic beam which is directed towards a surface at a small angle. Shortly before the atoms hit the surface they are excited to a Rydberg state, in which the electron is far away from the core, thus making it easier for the electron to "slip away". The Rydberg atoms continue towards the surface until the electron is transferred into the metal at a distance of about one thousandth of the width of a human hair, and the hydrogen atom is ionised. This distance depends on the position of the electron relative to the core, which can be precisely controlled and maintained up to the point of ionisation. This remarkable level of control differs greatly from the previous experiments.

This additional manipulation of the atoms' orientation allows us to characterize the gas-solid system much better than could be done before. In this study the focus was put on changing the properties of the incoming hydrogen Rydberg atoms in order to understand the gas side of the interface system. The next step is to use these atoms as probe tools for different materials.

Tim Softley, who leads the research team, says "Using this powerful technique we can probe the geometrical and electronic structure of surfaces over length scales from nanometers to microns, complementing established methodologies and bringing new insights to this field."

Ref.: Charge Transfer of Rydberg H Atoms at a Metal Surface, Phys. Rev. Lett. **107,** 093201 (2011)