Modelling the inner life of cell adhesion clusters

Adhesion of biological cells to external surfaces is the fundamental process that ensures that multicellular organisms keep their structural identity over time. Moreover cell adhesion is crucial for many physiological processes, including wound healing and the immune response. A cell settles on a surface in a sequence of steps in which the distance between cell and surface gradually decreases from microns to nanometer over the time course of minutes. This process is active in the sense that a cell commits itself to firm adhesion only if it receives suitable signals when establishing adhesion.

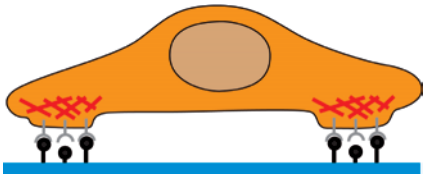
During recent years, it has become clear that these favourable signals also include mechanical cues, which are received through small clusters of appropriate adhesion molecules at the cell-substrate interface. These adhesion molecules appear to be pre-clustered with an average cluster size of three to four molecules, corresponding to a lateral size of nanometres, and then might grow to sizes of 10.000 molecules in a micron-sized cluster, so called "focal adhesions".

The binding dynamics inside focal adhesions is known to be very fast, although it is very difficult to observe it experimentally, due to the 200 nm resolution of optical microscopy. In a recent paper, Thorsten Erdmann and Ulrich Schwarz therefore studied the stochastic dynamics of adhesion clusters of varying sizes in a theoretical model, which is based on well established principles of the physics of cell adhesion.

The two researchers found that for sufficiently small clusters and cell-substrate distances, the adhesion dynamics is characterised by rapid switching between an unbound and a bound state of the adhesion cluster. Such "bistability" has been discussed before mainly in the context of biochemical decision-making, e.g. in cells that decide to divide into two daughter cells.

In contrast, the bistability found in this new study is based on physical binding-unbinding processes and properties of the elastic cellular material. It might allow cells to explore new surfaces by establishing many small and very dynamic adhesion sites. The model also suggests that upon encountering favourable conditions, such transient adhesions could quickly be made permanent by small increases in size and a concomitant reduction in the distance between cell and surface. ■

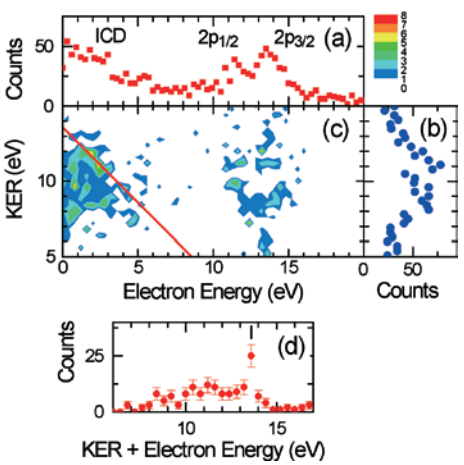
T. Erdmann and U.S. Schwarz, "Impact of receptor-ligand distance on adhesion cluster stability", *Eur. Phys. J.* E **22**, 123 (2007)



▲ This shows a cell (orange, with nucleus) adhering to a substrate (blue, like glass) through two adhesion clusters, each being composed of a number of adhesion bonds, each of which can be either closed or open. It is exactly the stochastic dynamics of opening and closing of these adhesion bonds which is modelled in our work. The structure in red is the actin cytoskeleton which localizes the adhesion bonds into adhesion clusters and also puts them under mechanical stress.

Sequential interatomic decay in argon trimers

We have investigated sequential interatomic decay in the argon trimer Ar_3. Large Van-der-Waals clusters that absorbed X-rays predominantly fragment into singly charged ions and neutrals: highly charged ions are hardly produced. Usually, Auger decay in clusters occurs in the atom that absorbed a photon and thus a highly charged atomic ion is first produced in the cluster. How does this highly charged atomic ion transfer its charge and energy to surrounding atoms in the cluster? In order to clarify the charge and energy transfer mechanism, we have investigated the decay from the argon trimer in the 2p hole state, using electron-ion-ion-ion coincidence technique. The relationship of the electron energy and the kinetic energy release (KER) of the triply-charged argon trimer Ar_3^{3+} in the fragmentation into Ar^+-Ar^+-Ar^+ is shown in the Figure. The distribution of the sum of electron kinetic energy and KER in Figure (d) shows the peak at 13.6 eV. We can assign this peak to the interatomic Coulombic decay (ICD) process following the Auger decay.



The charge and energy transfer mechanism in the argon trimer is found to be as follows. The first-step Auger decay of the 2p hole state in Ar_3 leads to the one-site two-hole state Ar^{++}-Ar-Ar that couples to the two-site satellite state Ar^{+*}-Ar^+-Ar. These states are subject to ICD to the state Ar^+-Ar^+-Ar^+ via the two-site satellite character. This second-step ICD process has been identified unambiguously by the electron-ion-ion-ion coincidence spectroscopy in which the kinetic energy of the slow ICD electron and the KER among the three Ar^+ ions are measured in coincidence. We believe that such sequential interatomic processes that lead to many singly-charged ions can be seen in all clusters, molecules, liquids and solids, especially in biological molecules in living cells. ■

X.-J. Liu, N. Saito, H. Fukuzawa, Y. Morishita, S. Stoychev, A. Kuleff, I.H. Suzuki, Y. Tamenori, R. Richter, G. Prümper and K. Ueda, "Evidence of sequential interatomic decay in argon trimers obtained by electron–triple-ion coincidence spectroscopy", *J. Phys. B: At. Mol. Opt. Phys.* **40** F1 (2007)