Bond movies

In January 2020 Professor Ute Kaiser (University of Ulm) and Professor Andrei Khlobystov (University of Nottingham) recorded the first movie of a bond breaking and forming

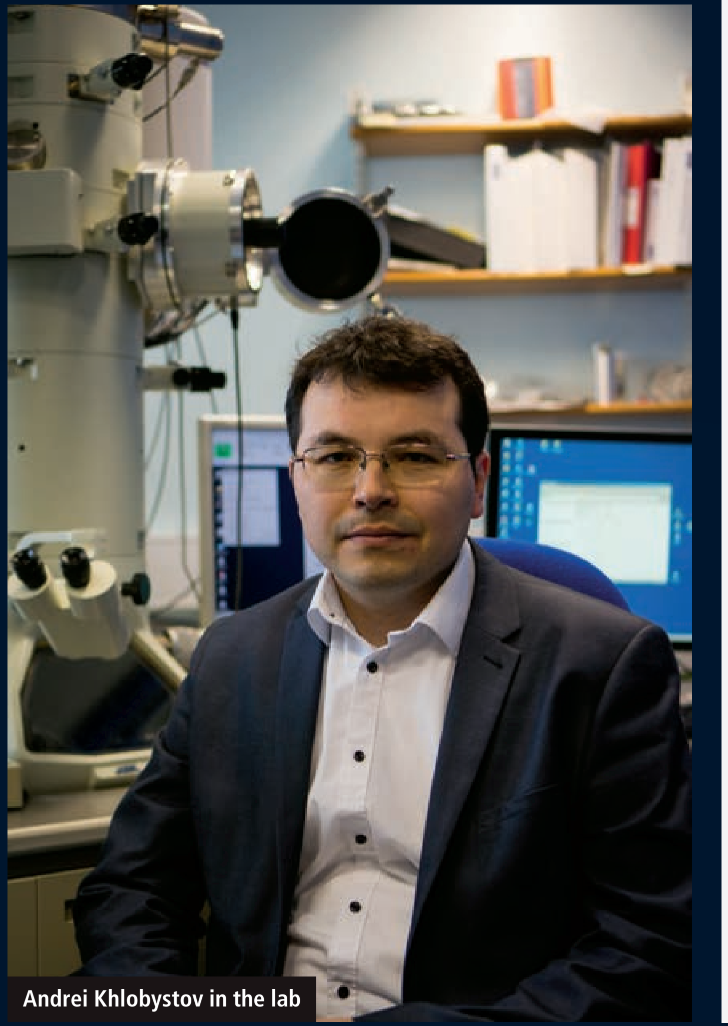
EXAM LINKS

This 'In pictures' is relevant to the following A-level exam topics:

- making and breaking bonds
- electron microscopy
- transition metals
- carbon nanotubes

Most chemical bonds are 0.1–0.3 nm in length (where 1 nm is equal to 1 × 10^{-9} m), making imaging difficult. Kaiser and Khlobystov used an instrument called a SALVE (sub ångström low-voltage electron microscopy) transmission electron microscope (TEM). Electrons have a much shorter wavelength than light, so electrons can overcome the diffraction limitation of visible light and are used in microscopes to see smaller objects more clearly. In the movie, a rhenium molecule (Re_2) is seen. Over time the vibrations of the molecule cause the shape of atoms to change from circular to elliptical (a 'squashed' circle) until the bond breaks. Later the bond reforms.

The movie allows us to see the bonding that occurs in transition metals (d-block elements found in the centre of the periodic table). Transition metals can form single, double, triple, quadruple and quintuple bonds. In this movie the rhenium atoms mainly formed quadruple bonds.



Andrei Khlobystov in the lab

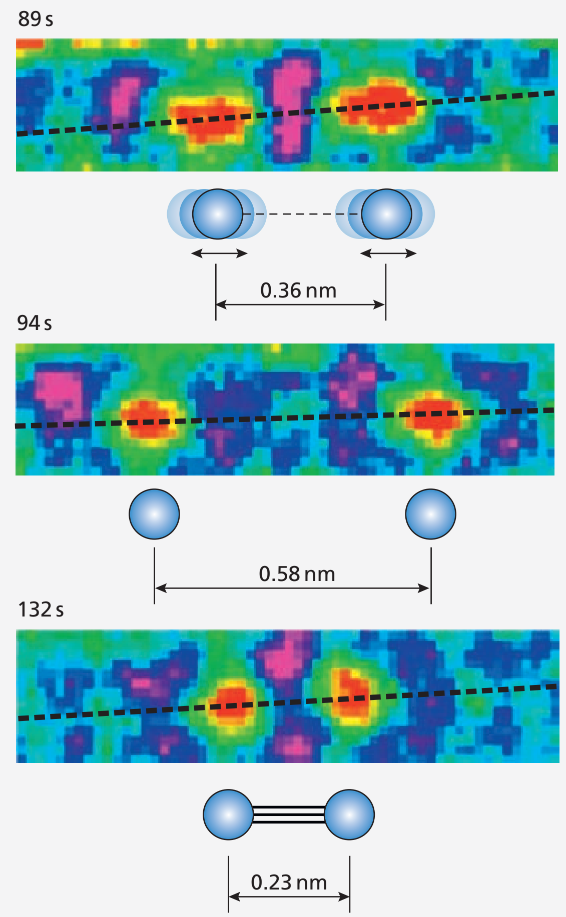
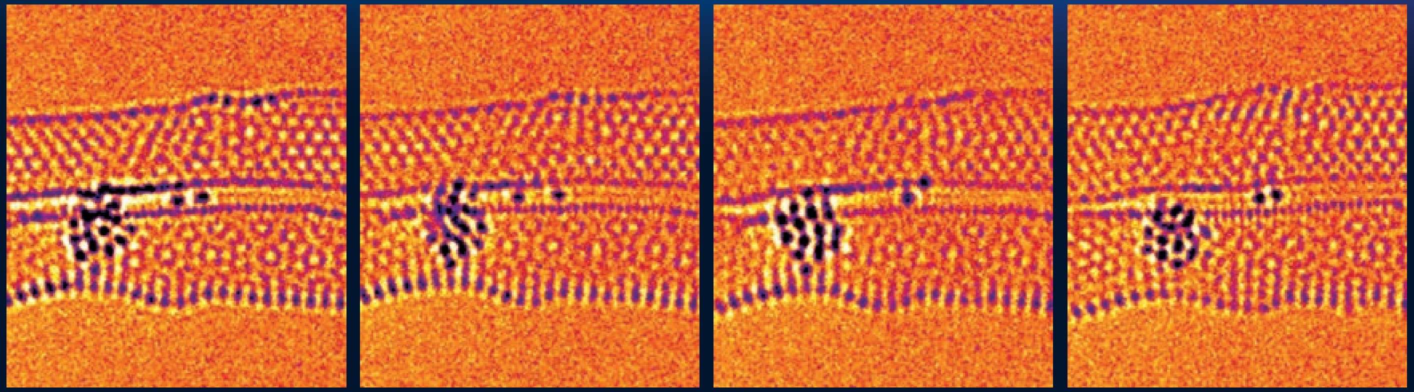


Figure 1 False colour images showing two rhenium atoms (red) from high resolution TEM images taken at 89 (just before the bond breaking), 94 (bond is broken) and 132 seconds (bond re-formed) of a movie sequence. The bonding state of the Re_2 molecule and distances between the Re atoms are represented underneath



Stills from the movie: two rhenium atoms (the black dots at the centre of each image) are seen to move in relation to each other in the gap between two carbon nanotubes

The rhenium atoms were kept in place using carbon nanotubes (a nanoscale cylinder made of carbon atoms bonded together, see Chemistry Review, Vol. 15, No. 1, p. 34). The movie shows the rhenium atoms as black dots 'following each other' along the carbon nanotube structure in real time.

Ute Kaiser (right) with Kecheng Cao, a student who performed the transmission electron microscopy

Reception

The ability to 'film' bonds breaking and forming could revolutionise the analysis of how reactions occur. Dr Stephen Skowron, a postdoctoral research assistant at the University of Nottingham, said that this movie provided 'new fundamental insights into transition metal chemistry', an area of chemistry that is important for catalysis (where a substance — known as a *catalyst* — is used to speed up reactions without being used up). According to the University of Nottingham, the research team hopes that electron microscopy could become 'a general method for studying chemical reactions, similar to spectroscopic methods widely used'.

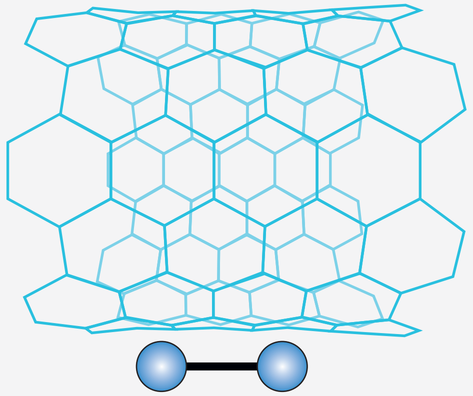


Figure 2 An Re_2 molecule adsorbed on a nanotube surface

ChemistryReviewExtras

Download this poster at www.hoddereducation.co.uk/chemistryreviewextras

Imogen Howard is studying chemistry at the University of York and is the editorial assistant for Chemistry Review. She would like to thank Andrei Khlobystov at the University of Nottingham for his assistance.