electrons within the plasma during the fusion reaction, some will escape and it will be even more difficult to prevent energetic neutral atoms bombarding the walls.

At present it seems that the effects of the light ions and atoms present the most serious problem. In the first place they cause erosion of the walls by sputtering; they also become implanted in the walls and can blister and flake the surface. Release of atoms from the wall by sputtering is a serious problem because the presence of elements heavier than hydrogen in the plasma would increase the rate at which it radiates energy away as light or X rays. The plasma then becomes cooler and fusion more difficult. Solutions to this problem are on the one hand to reduce the sputtering of the walls by the choice of appropriate materials, and on the other to clean the heavy impurities produced by sputtering out of the plasma, or at least to prevent them reaching the hot central region where fusion is going on.

Sputtering of metals by light ions has been intensively studied for many years now, and for ions above 10 keV the main characteristics such as the yield of sputtered atoms and their angular distribution as a function of particle energy are reasonably well known. Below these energies, data are scanty and theories unproved, but it may be that at the lower energies the majority of bombarding particles will strike the wall. This possibility will clearly receive more attention from the sputtering fraternity, as will the difficult measurement of the energy distribution of sputtered atoms. Increasingly they will be thinking of peculiar effects such as chemical or reactive sputtering, which has emerged again after a few years out of fashion.

The processes responsible for the breaking up of the surface of metals when atoms of hydrogen and helium are energetically implanted into them are now becoming clear. There is a complex interplay of lattice defects and impurity atoms which can, in certain conditions of temperature and bombardment, cause gas-filled bubbles to form in the wall. It is thought that the stresses set up in the surface by radiation damage make the bubbles join up to form blisters which burst and form a flaky surface. Parts of the story are very familiar to those who have been in the nuclear materials game before. Fuel element swelling in fission reactors involves a similar set of processes.

Some unwelcome fluctuations in vacuum pressure have been turning up in plasma experiments and they seem to have their origin in the plasma-surface interaction. It seems to be a complex case of implantation and sputtering resulting in the release of gases and vapours (for example, $N_2$, $O_2$, CO, $H_2O$) from the walls. Various schemes are in train to 'condition' the walls by bringing them in contact with low temperature plasma to release the gases beforehand. But because of implantation the walls can develop an embarrassing memory, releasing impurity gas when least wanted, or eating up the hydrogen fuel gas from the reactor.

Acting on the reasonable assumption that after the materials scientists have done their best the plasma will still contain a certain amount of impurity, plasma physicists have designed 'divertors' to clean out the impurities. The principle is to draw off the outer skin of the plasma, known as the scrape-off layer, into side chambers through electromagnetic canals. There the impurities are separated from the hydrogen fuel which is eventually returned to the main chamber. The scrape-off layer intercepts the heavy impurities on their way from the walls, and provided it can be skimmed off fast enough by the divertors, the central plasma can be kept clean. The pros and cons of the alternative divertor designs were debated at length last week by the proud owners of tokamaks from Japan, Germany, France, USA and Britain. Clearly these divertors do work and we were shown that they can reduce the concentration of impurities in the main plasma by almost an order of magnitude.

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# Intermolecular forces

*from Graham Richards*

To activists in the field, the subject of 'intermolecular' forces is limited to the study of interatomic potentials and more specifically the interaction between rare gas atoms. Knowledge of the intermolecular potentials would allow bulk properties of gases such as viscosity, thermal conductivity and diffusion behaviour to be simply calculated; at present this process is essentially reversed and the determination of these bulk properties is necessary in order to calculate the intermolecular potential.

Although the repulsive part of the potential can be calculated from accurate *ab initio* Hartree-Fock calculations, reasonably direct measurements which lead to microscopic potentials were not available until the observation of dimers by spectroscopic means.

The dimeric species, $Ar_2$, was first observed by Tamaka and Yoshino (*J. chem. Phys.* **53**, 2012; 1970) and the electric absorption spectrum later photographed at a dispersion sufficiently high to permit rotational analysis by Colbourn and Douglas (*J. chem. Phys.*, **65**, 1741; 1976). From a knowledge of the energy levels of the dimeric molecule the potential curve which gives rise to those levels can be deduced using the well-known Rydberg-Klein-Rees method.

Now Aziz and Chen have combined all the previous data to produce a simple precise intermolecular potential for argon (*J. chem. Phys.* **67**, 5719; 1977). The new potential fits both the accurate spectroscopic data and the high temperature viscosity values of Maitland and Smith (*J. chem. Eng. Data* **17**, 150; 1972). It is able to predict faithfully accurate data on second virial coefficients, thermal conductivity, thermal diffusion and collision cross sections.

With what must be almost the last word on the Ar-Ar potential having been said, it is possible for experimentalists to extend the scope of the problem and look at more complicated partners, particularly exploiting the properties of lasers which can be used to simplify the spectra of diatomic species.

An example of this is a study of the electronic spectrum of NaNe by Ahmad-Bitar *et al.* (*Phys. Rev. Lett.* **39**, 1957; 1977). The molecule which is only held together by weak Van der Waals forces was created by using the cooling produced on expansion in a supersonic jet. The beam of molecules issuing from the nozzle was crossed at right angles with a laser beam working in a single mode. This procedure avoids Doppler broadening in the resonance fluorescence spectrum which can be observed. Photons from the laser are absorbed and then re-emitted from the molecule without any redistribution of energy in the excited electronic state.

In NaNe, the depth of the potential well was shown to be about 8 $cm^{-1}$ compared with approximately 100 $cm^{-1}$ in the case of $Ar_2$, making NaNe the most weakly bound molecule yet studied by high resolution spectroscopy.

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