COST Action P9 – Radiation Damage in Biomolecular Systems
Short Term Scientific Mission, Period 11/10/2004 to 07/11/2004
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Beneficiary: Dr Paul Kendall, Department of Physics and Astronomy, Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom
E-mail contact: paul@kendall57.fsnet.co.uk

Host: Prof. Gustavo Garcia, Instituto de Matematicas y Fisica Fundamental, CSIC, Calle de Serrano 113 bis, Madrid, Spain

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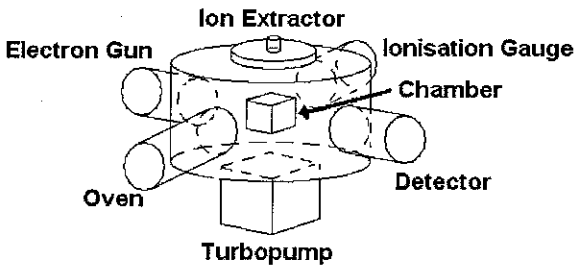
Scientific Report

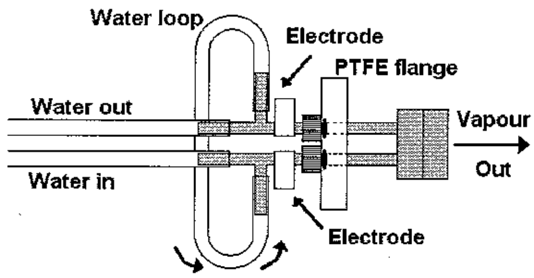
The purpose of my visit to the laboratory of Professor Gustavo Garcia in Madrid was to assist in the development of a piece of apparatus to measure the interaction of biological molecules with electrons. Radiation penetrating biological tissue can cause ionisation resulting in the production of secondary electrons. Clusters of secondary electrons can then interact with DNA with the potential of causing damage. Successful modelling of such interactions requires quanitifiable empirical data. To this end Professor Garcia is developing a piece of apparatus to study electron scattering cross sections from gas phase molecules. A schematic of the system is shown in figure 1.



The electron gun can produce a collimated electron beam with incident energies of between 100 and 5000 eV with an energy spread as low as 100 meV. A series of apertures ensures the beam is collimated with a diameter of ≤ 1 mm. Eventually the detector will be attached to the system via a hemispherical energy analyser to allow the detected electrons to be energy selected. The test molecules: cytosine, adenine, thymine, guanine and uracil (the DNA and RNA bases), are all solid phase at room temperature with melting points in excess of 300 degrees Celsius. Hence an oven for heating the samples is an essential part of the apparatus. The testing of the apparatus in general, and the installation and testing of the oven in particular, were the primary aims of the mission.

The first work carried out was a thorough testing of the electron gun – detector system. This was necessary to ensure that an electron beam could be correctly produced, transmitted through the system of apertures and, finally, detected. This testing also provided a good opportunity to get a hands-on feel for the apparatus. The chamber was opened up for the external connections to be checked before a series of tests were carried out with different configurations to measure the current on various elements inside the chamber. During these tests a number of problems arose and had to be solved: the electron gun and a set of deflector plates had to be replaced. When current had been detected reaching the simple Faraday cup style detector, the next job became to fit a more sensitive type. A channeltron was fitted but under tests failed to work correctly at high voltages so was replaced by the simple detector again. In the end an acceptable amount of current was able to be transmitted through the chamber and the detected current proved stable over extended time periods. This work took a long portion of the STSM as, every time a change to the apparatus was required, the system had to opened and then pumped down again (each time requiring several hours).

When the testing of the electron gun – detector system was complete the oven was fitted to the system. The oven was initially tested to see whether it would hold the vacuum when attached to the system. Two more pieces of work were required before the oven could be fully tested. A water cooling system was required necessitating the connection of the water tap to the oven using several gauges of hose. The connection required a large amount of testing and reworking to prevent leaks, particularly on the connection between the hoses and the oven. A schematic of the oven is shown in figure 2.



The final work was to produce a power supply to heat the oven. This was a homemade construction consisting of 2 transformers to allow an output of 0 to 5 volts to be obtained. Once constructed the oven was connected to the power supply and water cooling system and initial tests were performed. The initial test involved applying a small potential to the oven and observing the temperature change. The oven was observed to heat up quickly at even small potentials while the water cooling proved effective. Further tests using a digital thermometer showed quantifiably that the temperature (measured outside the PTFE flange) increased as the voltage was systematically increased and then decreased quickly when the power supply was switched off but the water cooling left on. The final test possible in the time available during the STSM was to put a quantity of cytosine into the oven and try to heat it up. The ionisation gauge was used to measure any increases in the chamber pressure as should occur when the cytosine vapourised. In this first test no pressure changes were observed when the power supply was turned up to 35 % of maximum. It is unclear whether the temperature inside the oven (at present unmeasurable) was insufficient to vapourise the cytosine or whether the pressure inside the collision chamber was higher than measured and read lower due to the small apertures in the collision chamber. A further test to see whether the current level was reduced when the oven was switched on proved inconclusive and further tests must be made.

The main results of the STSM are therefore:

- the electron gun – detector system has been thoroughly tested in a number of configurations.
- a working power supply has been constructed in order to test the oven.
- a water cooling system has been constructed and connected to the oven.
- the oven heats up effectively when a small potential is applied.
- the system is at a stage where samples (e.g. cytosine) can be introduced into the oven and test measurements made.

In the near future it is to be envisaged that the system will be ready to commence measurements of the interaction between electrons and biomolecules. At that stage it is likely that a number of publications will be written. It is also to be hoped that the collaboration between the Open University and CSIC will continue in this fascinating and necessary field.

I wish to thank COST for awarding the grant that made this collaboration possible. I also wish to extend my thanks to Gustavo Garcia and his group for hosting me and Nigel Mason for his continued support of my career.

Paul Kendall
18th November 2004