EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

4-point probe method

The 4-point probe method is a non-destructive method for measuring the resistivity of a sample. In the case of a thin metal layer, this allows its thickness to be measured. Tokamaks face erosion problems and require a non-destructive characterization method that allows micrometric precision. A collaboration between the IRFM and LAPLACE has made it possible to apply this method to the characterization of components exposed to plasma. The 4-point probe method is already widely used in microelectronics to calculate the electrical resistivity of semiconductors, but other applications are also possible in other fields, such as aerospace and nuclear power, in which erosion issues are also concern.

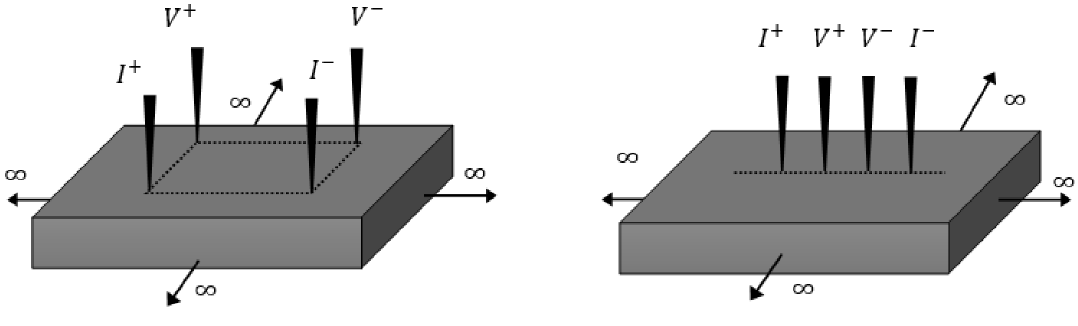
Description of the technology

- The principle of the 4-point method is to measure voltage and current at four points on a sample of a material to determine its electrical resistivity. This method is designed to minimize the effect of contact resistance between the probes and the material being measured, which can distort the readings. Several configurations exist and have been studied, the tips can be aligned or not and have the same gap or not. When the width of the sample is very small compared to the distance between the tips, the resistivity is expressed as :

$$\rho = \frac{\pi d}{\ln(2)} \frac{U}{I}$$

With ρ the resistivity (Ohm.m), d the thickness of the sample, U the voltage (V) and I the current (A).

- So, by knowing the thickness of the sample, it is possible to determine its resistivity. Conversely, it is possible to determine the thickness of the sample if the resistivity is known. Using the appropriate equipment, this method can be used to determine erosion thicknesses in the micrometer range.



Two tip positioning configurations: square and in-line

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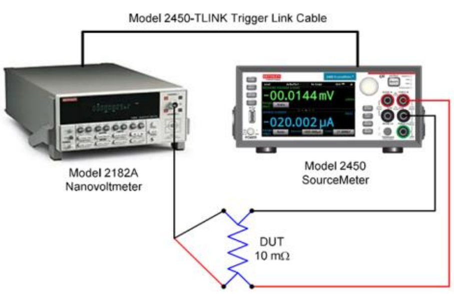
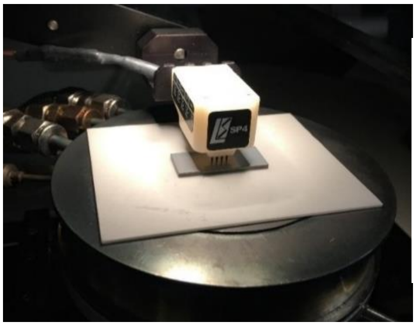
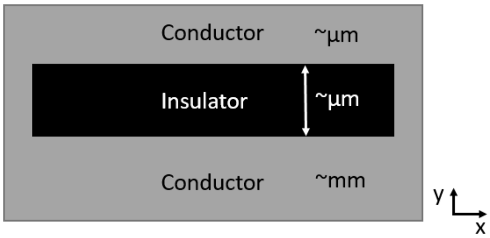
Description of the technology

- The installation consists of a sourcemeter, a nanovoltmeter and a 4-point probe. To increase the sensitivity of the method to obtain better sensitivity, the current must be increased or an insulator introduced to reduce the layer in contact with the tips to just a few micrometres.



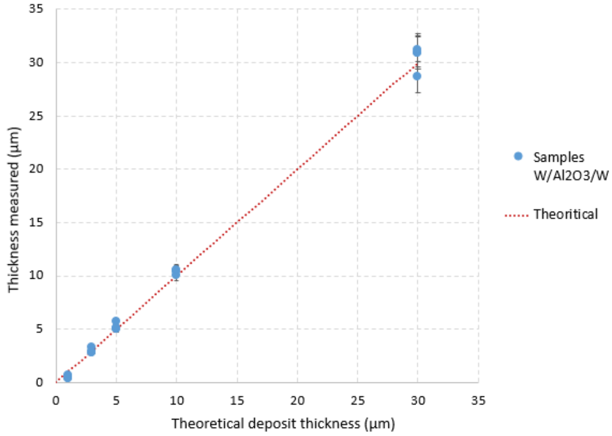


cross-sectional sample



Wiring diagram and photo of the 4-point probe

- A series of 4-point measurements demonstrated the sensitivity and robustness of the method. Measurements were carried out on a series of samples with a tungsten substrate on which an alumina PVD deposit of 5 µm was deposited, followed by a tungsten deposit of between 1 and 30 µm (seethe figure below).



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Innovation and advantages of the offer

Its use for measuring thin layers of conductive materials is only rarely used, but it has definite advantages. The method is non-destructive and requires very little equipment to carry out. The expected accuracy, in the micrometer range, is much sought-after in various fields. The more precise the thickness measurement, the thinner the conductive layer needs to be. The insertion of an insulator deposited by PVD (Physical Vapour Deposition) is possible and gives very good results. So, for thicknesses of the order of 10 µm, the absolute error is of the order of 1 µm.

Non-fusion Applications

The need for non-destructive erosion characterization is highly sought after in many industrial fields. The erosion from plasma thrusters needs characterization in the space industry as well as corrosion in steam generators in the nuclear industry. Otherwise, the method can be used in microelectronics to determine the electrical resistivity rather than the thickness.

EUROfusion Heritage

The adaptation of materials to plasma that results from the use of this technology is innovative and will enable to advance our knowledge of materials and their behaviour in a plasma reactor. The tokamak walls require erosion-resistant materials that can withstand the high temperatures and particle bombardment. Researchers and engineers are actively working on the development of specific materials and coatings to minimize erosion and extend the life of tokamak walls, as part of nuclear fusion research effort. The development and application of the 4-point probe method was envisaged in order to provide a solution for the in-situ, and non-destructive testing, of components exposed to plasma.

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