BACKGROUND TO THE OPERATION OF THE PQL PLASMA TECHNOLOGY

A sputter deposition system using the PQL plasma technology essentially differs from a conventional sputter deposition system in that the target is not itself required to generate the gas plasma required for the sputtering process. Instead an attached remote plasma source (the PLS) separately generates the plasma which is guided to the target by a shaped DC electromagnetic field produced by a pair of electromagnets. The PLS is able to generate plasma over a wide process pressure range independently of the target condition or type, and so a far wider range of process options and target materials are supported. Very high deposition rates and highly densified films may also be readily achieved with the PQL plasma source through appropriate adjustment of the enhanced range of process parameters allowed by the plasma generation scheme.

The PLS efficiently generates the gas plasma through the interaction of plasma electrons with a 13.56MHz RF field, inductively coupled from an antenna, in a co-axial DC magnetic field. A proportion of the electrons generated within the PLS at the RF antenna location are accelerated towards the sputter chamber, gaining substantial energy such that they are at or near the optimum energy for sputter gas ionisation. Combined with long path lengths resulting from spiralling motion about the magnetic field lines, this produces a very high efficiency ionisation process and, by a ‘cascade’ electron generation process, a continuous plasma generation ‘tube’ is directed into the sputter chamber.

Visually the plasma ‘tube’ follows the DC magnetic flux lines and can therefore be easily ‘steered’ by adjustment of the relative DC electromagnet settings to be positioned over the target surface. Appropriate adjustment of the PLS set up and DC magnetic field strength can result in a wider or narrower plasma ‘tube’ and substantial alteration of the plasma density at the target. Typically, very high plasma densities in excess of 10^{14} cm^{-3} are achievable with appropriate process settings.

In a 'standard' sputter system using the PQL plasma technology, the target material is in the form of a circular planar target, most usually 100-150mm diameter and 6mm thick (though larger / smaller / thinner targets may be used in a correctly configured system). The plasma 'tube' is guided through 90 degrees such as to lie over the planar surface to be sputtered; an indicative layout is shown below (figure 1).

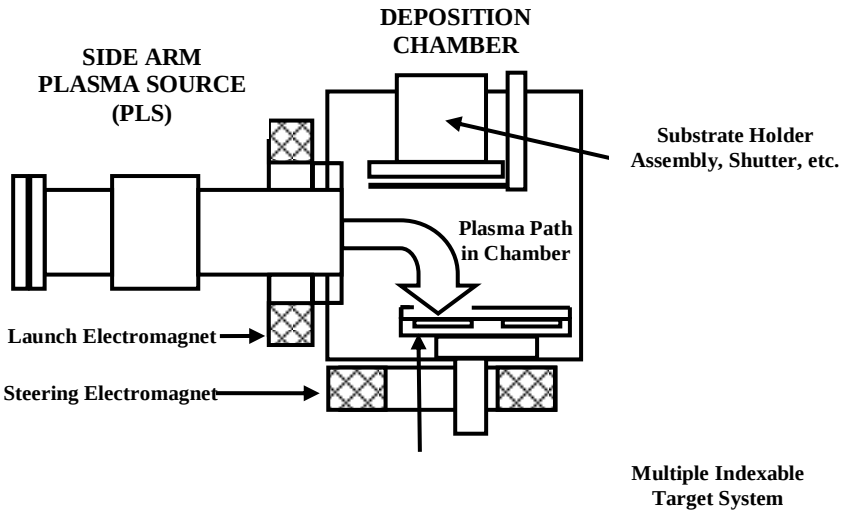

Figure 1: 'Standard' System Layout

In the alternative 'Linear' configuration relevant to the ILH550 system, the plasma 'tube' is guided to surround a cylindrical target assembly – i.e. a co-axial configuration is established (figure 2 – system is shown rotated 90 degrees for comparison with figure 1)

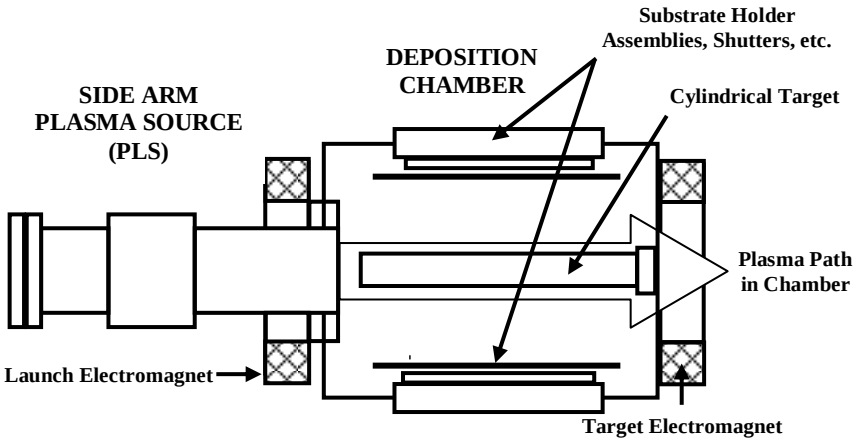

Figure 2: 'Linear' System Layout (ILH550)

Both systems have their merits for particular applications, though both are capable of producing the same high quality thin films and the sputter process and basis is essentially the same for both.

It should be appreciated that the generation of the plasma is effectively independent of the target material or status. Thus the PLS can be prepared, operated and adjusted to the required process conditions without the target being operational in any way. Equally, the plasma ions produced by the Sidearm Plasma System are individually of low energy and will not cause sputtering of the target (or any other surfaces) unless an appropriate bias – DC or RF induced – is applied.

These two factors allow the user to set up a wide range of sputtering conditions for a given system configuration. The PLS may be run at very low RF power and magnetic field strength to produce a low plasma density (e.g. less than 10^{12} cm^{-3}), up to maximum RF power and magnetic field settings to produce a very high plasma density (e.g. 10^{14} cm^{-3}). Independently (subject to target power supply limitations) the target may be voltage biased to just above the sputtering threshold (for very slow deposition) to maximum bias without significantly changing the plasma density. Using these techniques, sputter deposition rates for a set target / system configuration can be controllably varied over more than 3 orders of magnitude within a deposition cycle, allowing very accurate, optimally fast layer deposition to be achieved. In addition, an optimal plasma density may be set to ‘plasma assist’ the deposition process.

Target sputtering essentially occurs in an otherwise conventional manner, allowing the use of standard rotation / tilt / scan mechanisms to achieve highly uniform coatings.

It is important to note that the visible plasma ‘tube’ is the region of generation and delineates the region in which the great majority of plasma electrons are confined. Plasma ions are not confined by the DC magnetic field and are thus present over a far larger volume (with little opportunity to neutralise except at surfaces within the system), providing a uniform, low energy – but high density - ion source in the vicinity of the target.

OPERATION

OPERATION OF THE PLASMA SOURCE (PLS) - IMPORTANT NOTES

The following notes are provided to elucidate certain key elements of the PLS operation and to assist in indicating the process scope that the system allows. They are not intended to be a definitive process definition, as the exact process requirements will depend upon the user's process and system configuration.

A PLS fitted sputter deposition system should be essentially operated in the same manner as a conventional planar or magnetron based sputter deposition system, excepting that the PLS will need to be active in order to generate plasma and hence allow sputtering of the target. The following points should be noted.

1. **Normal sputter process operating pressure for the Plasma Source is between $1x10^{-3}$ mbar and $1x10^{-2}$ mbar**. The normal sputter gas is argon. It is possible to achieve a sputter process outside of these limits, but care will need to be taken e.g. to ensure that the plasma strikes correctly, that RF reflected power is acceptable and that the sputter process is stable.

CAUTION

Operating the PLS in sputter mode outside of the above pressure regime may result in abnormal operation and may damage the system or other elements within the system, e.g. targets and substrates. The user is responsible for ensuring that processes using abnormal pressures are compatible with the PLS capabilities.

2. **Before applying RF power to the Sidearm Plasma Source, it is important to ensure that sputter gas is present and that at least the 'Launch' electromagnet is operating** (at appropriate values). It is equally important to turn off the RF power prior to turning off the electromagnet(s) and the sputter gas.

CAUTION

Applying RF power to the Sidearm Plasma Source without at least appropriate sputter gas pressure and launch electromagnet current may result in excessive reflected RF power. Whilst the RF supply should prevent this from rising to damaging levels, continued operation in this manner is inadvisable.

3. **The Plasma Source is capable of generating very high current densities (>30mA.cm^{-2}) over the entire target surface and care should be taken not to overheat and damage targets through application of excessive bias voltage and thereby excessive power.**

RUNNING A REACTIVE DEPOSITION PROCESS WITH THE PLASMA SOURCE

WARNING

The Plasma Source has been designed only to accommodate reactive processes based upon the use of argon, oxygen and nitrogen.

The use of gases other than these may result in hazardous conditions and/or damage to the system.

The user must also be aware of the potential risk of generating hazardous by-products additional to those originating from normal target sputtering.

The user is responsible for assessment of this risk and for taking the appropriate precautions to ensure the safe operation and maintenance of the Plasma Source, including hazardous waste disposal.

The PQL plasma source (PLS) is capable of running inherently stable reactive sputter deposition processes, for instance the deposition of alumina by sputtering an aluminium target in a partial oxygen gas ambient. Unlike most conventional sputter systems, this can be achieved without the need for feedback control of the reactive gas flow. This is, in part, because the Plasma Source is able to generate an essentially invariant gas plasma at or near the target independent of the target bias or behaviour. When coupled with uniform target utilisation to minimise target 'poisoning', this allows inherently stable process conditions to be established in which near ideal compound films can be deposited at high rates from elemental targets.

PQL have extensive in-house expertise and experience in the deposition of thin film dielectrics and other compounds by reactive sputter deposition and have been able to achieve stable processes in all cases. PQL are available for consultation and assistance in the development of reactive sputter processes should this be required.

ADJUSTMENT OF DC ELECTROMAGNET SETTINGS

CAUTION

Significantly changing the standard DC electromagnet current settings will alter both the plasma source operation (such that RF retuning may be required) and the position and path of the plasma ‘beam’ within the user's system. Adjustments should therefore only be made by personnel trained and experienced in the maintenance and use of the system.

The ILH550 uses two water cooled, DC current supplied electromagnets as part of the plasma source operation. Subject to adequate water cooling, both electromagnets are capable of being run with DC currents in excess of the supply capability of the system (200A nominal).

The DC currents to each electromagnet may be adjusted by the user in order to alter the plasma density (e.g. to assist in achieving low sputtering rates) or interaction with the substrate (e.g. as a simple pre-clean).

For either electromagnet, unless the intended revised settings are already known to be compatible with correct PLS operation, adjustments should be made with the PLS operating (i.e. producing plasma). The following should be observed:

1. Monitor the PLS reflected RF power during adjustment. **DO NOT ALTER THE ELECTROMAGNET DC CURRENT SETTING(s) SUCH THAT THE INDICATED RF POWER EXCEEDS 50W.**

2. Ensure that the changed visible plasma ‘beam’ does not intercept any chamber walls, the target end cap or other elements within the main chamber that might be detrimentally affected by either the plasma itself or the high temperatures that will be generated by intercepting the very high electron flux.