

Technical Brief

SPUTTER COATING INCORPORATING EMITECH K500X, K550X, K575X, K650X and K675X

Quorum Emitech
South Stour Avenue
Ashford
KENT
TN23 7RS

TEL: (01233) 646332

FAX: (01233) 640744

E-Mail: sales@quorumtech.co.uk

Internet: www.emitech.co.uk

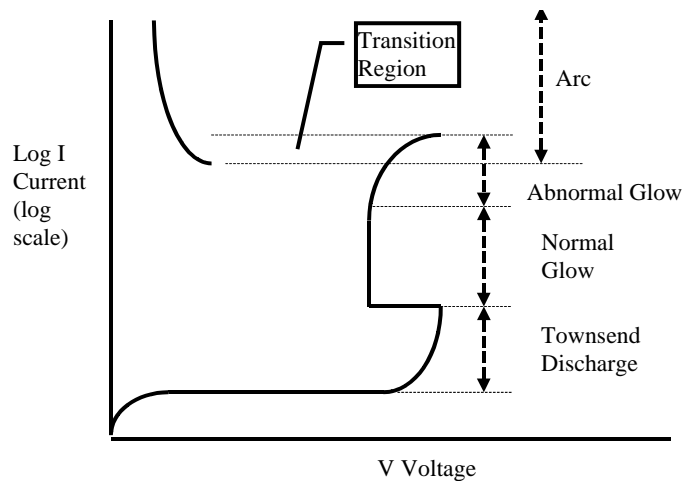
INTRODUCTION

When a target is bombarded with fast heavy particles, erosion of the target material occurs, this is termed sputtering. The arrangements of the systems are such that some of the sputtered atoms will condense on the surface of the specimen to be coated.

The above process occurring in the conditions of a gaseous glow discharge between an anode and cathode is termed sputtering and can be enhanced by the choice of a suitable gas and target material, which together with other developments of the technique, allows the deposition of a suitable coating to increase the electrical conductivity of a specimen, probably the single most common requirement for Scanning Electron Microscopy.

The development of Sputter Coater systems embodies significant empirical design, however, an understanding in classical terms of glow discharge characteristics enhance such designs, and may assist in the comparison of differing systems.

GASEOUS CONDUCTION



Current Characteristics of a Gaseous Discharge.

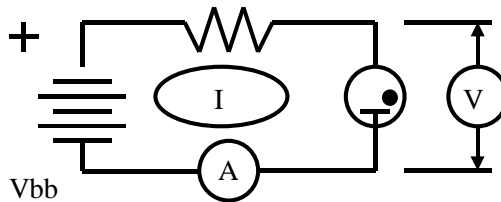


Figure 1

If an inert gas such as argon is included in a cathode gas tube, the free ions and electrons are attracted to opposite electrodes and a small current is produced.

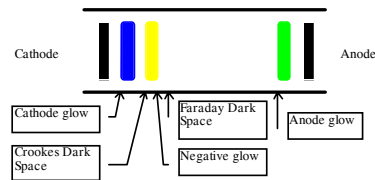
As the voltage is increased some ionisation is produced by collision of electrons with gas atoms, the 'Townsend' discharge. When the voltage across the tube exceeds the breakdown potential, a self-sustaining glow discharge occurs, characterised by a luminous glow.

The current density and voltage drop remains relatively constant, the increase in total current being satisfied by the area of the glow increasing. Increasing the supply voltage increases current density and voltage drop; this is the abnormal glow region.

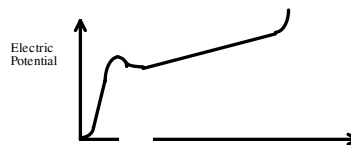
Further increase in supply voltage concentrate the glow into a cathode spot and arc discharge is apparent. The operating parameters of Sputter Coaters are within the glow discharge regions of the characteristic described.

GLOW DISCHARGE

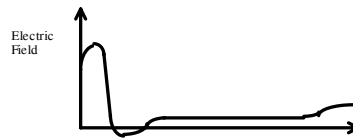
Once the condition for a sustained discharge is met, the tube exhibits the characteristic glow discharge, so called because of the associated luminous glow. It has been established that free ions and electrons are attracted to opposite electrodes producing a discharge; however, for a discharge to be self-sustaining requires regeneration of the electrons by the positive ion bombardment of the cathode. This produces secondary electrons and enhances ionisation. The resulting positive ion excess creates a positive space charge near the cathode. The voltage drop experienced is termed the cathode fall. If the discharge is established in a long narrow tube it exhibits the characteristics indicated.



Physical Appearance of a Glow Discharge



Potential Variation in a Glow Discharge



Electric Field Variation in the Discharge

Figure 2

The positive ion density in the Crookes dark space is very high; as a result a significant voltage drop is experienced between it and the cathode. The resulting electric field accelerates the positive ions, which produce secondary electron emission from the cathode. These electrons are accelerated in the direction of the anode and cause ionisation, generating positive ions to sustain discharge. Subsequently, excitation of the gas results in intense illumination in the negative glow region. From this stage the electrons have insufficient exciting or ionising energy, resulting in the Faraday dark space. Towards the anode, a small accelerating field can produce ionisation and excitation, the gas again becoming luminous.

SPUTTER COATING

It has been indicated that under conditions of glow discharge, ion bombardment of the cathode will occur, this results in the erosion of the cathode material and is termed plasma sputtering, the subsequent omni-directional deposition of the sputtered atoms forming coatings of the original cathode material.

This process is enhanced in Sputter Coaters for use in Scanning Electron Microscopy where one objective is to provide an electrically conductive thin film representative of the surface topography of the specimen to be viewed, such films inhibit 'charging', reduce thermal damage, and enhance secondary electron emission.

The most common arrangement for a D.C. (Direct Current) Sputter Coater is to make the negative cathode the target material to be sputtered (typically Gold), and to locate the specimens to be coated on the anode (which is usually 'earthed' to the system and the specimens are effectively at 'ground' potential). The desired operating pressure (relative vacuum) is obtained by using a suitable applied vacuum, usually a two stage rotary pump. An inert gas, such as argon, is admitted to the chamber by a fine control valve.

OPERATING CHARACTERISTICS.

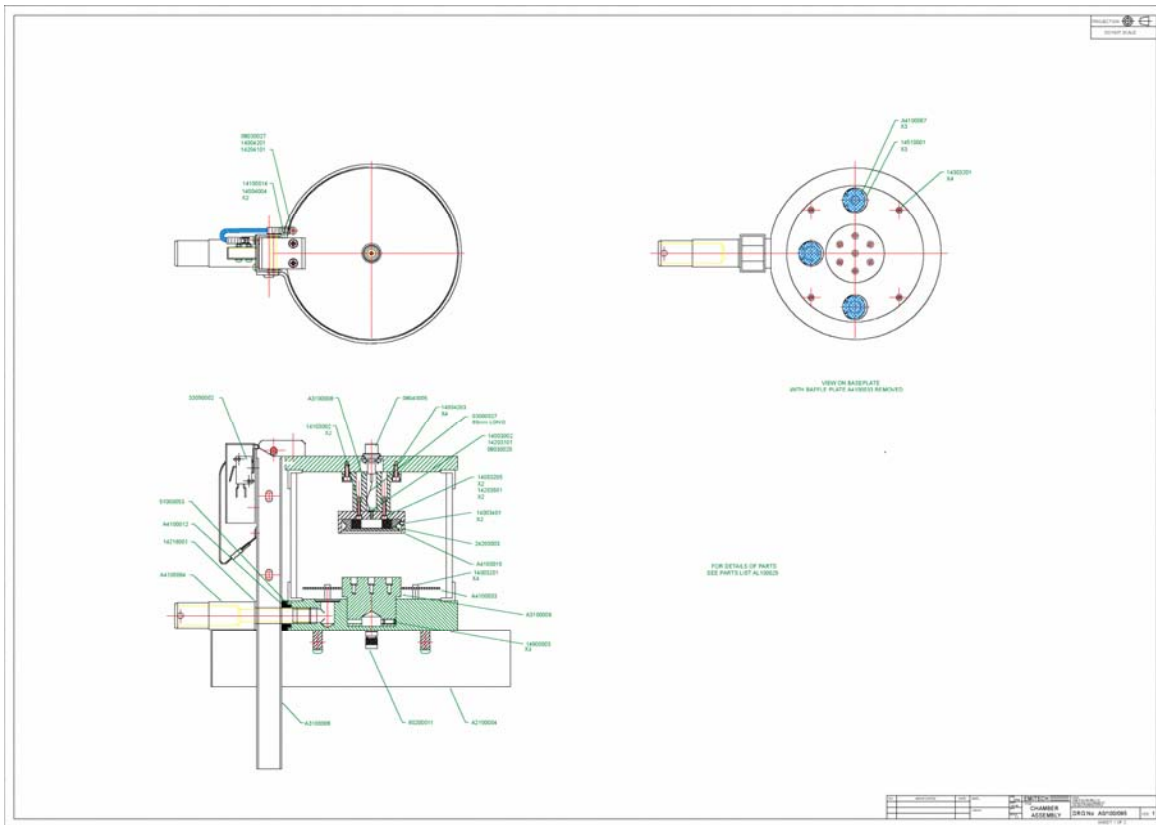
The glow discharge in sputtering is significantly dependent on the work function of the target material and pressure of the environmental gas. A range of target materials are used including Gold, Gold-Palladium, Platinum and Silver, although Gold is the most common having the most effective electrical conductivity characteristics. The sputter head and sputter power supply should be effective over a range of anticipated target materials. The deposition rate is current dependant, and if we operate in the correct glow region of the characteristic previously described, several fold changes in current should be available for a relatively small change in sputtering voltage. The deposition rate should not be sensitive to small changes in pressure, which may be experienced in the system.

If an efficient sputter head design, operating on low voltage and as a result low energy input, is achieved, then radiant heating from the target and high energy electrons, (potentially the most significant sources of damage to delicate specimens) should be considerably reduced. There is also evidence to suggest that such a sputter head system may also produce finer grain size for a given target material. The presence of an inert gas, which will not decompose in the glow discharge, is obviously desirable. Argon, having a relatively high atomic weight, provides a suitable source of ions for effective bombardment of the target material. The effectiveness is also dependent on the mean free path (m.f.p.) that is inversely proportional to pressure. If the m.f.p. is too short,

TECHNICALBRIEF_SPUTTER COATING.DOC
15/11/07
EMITECH K500X, K550X, K575X, K650X & K675X

insufficient energy will be gained for effective bombardment and will inhibit movement of sputtered material from the target. If the m.f.p. is too long, insufficient collisions occur and, in addition, the flow of sputtered material may change from diffusion in the gas to free molecular flow with a reduction in the effectiveness of omni-directional deposition.

If these characteristic of sputter heads are achieved it should not be necessary to cool the specimen stage for the majority of applications. If not, however, such cooling will only serve to reduce the baseline temperature, the thermal conductivity of most specimens we are considering being relatively poor. For sensitive specimens pre-cooling and subsequent reduction of the baseline may still be desirable and there is also evidence to suggest a reduction in grain size of the coating. It may be apparent that Scanning Electron Microscopy requires a versatile system without compromising performance. Specifically, fine grain size, uniform coating and low heat input. Consideration of these characteristics in design and development should enable a suitable coating system to be realised. It was indicated previously that while empirical design may be in evidence, it should now be apparent that efficient production of positive ions for glow discharge is required. The sputter head and its associated power supply should be a primary objective of design and development.



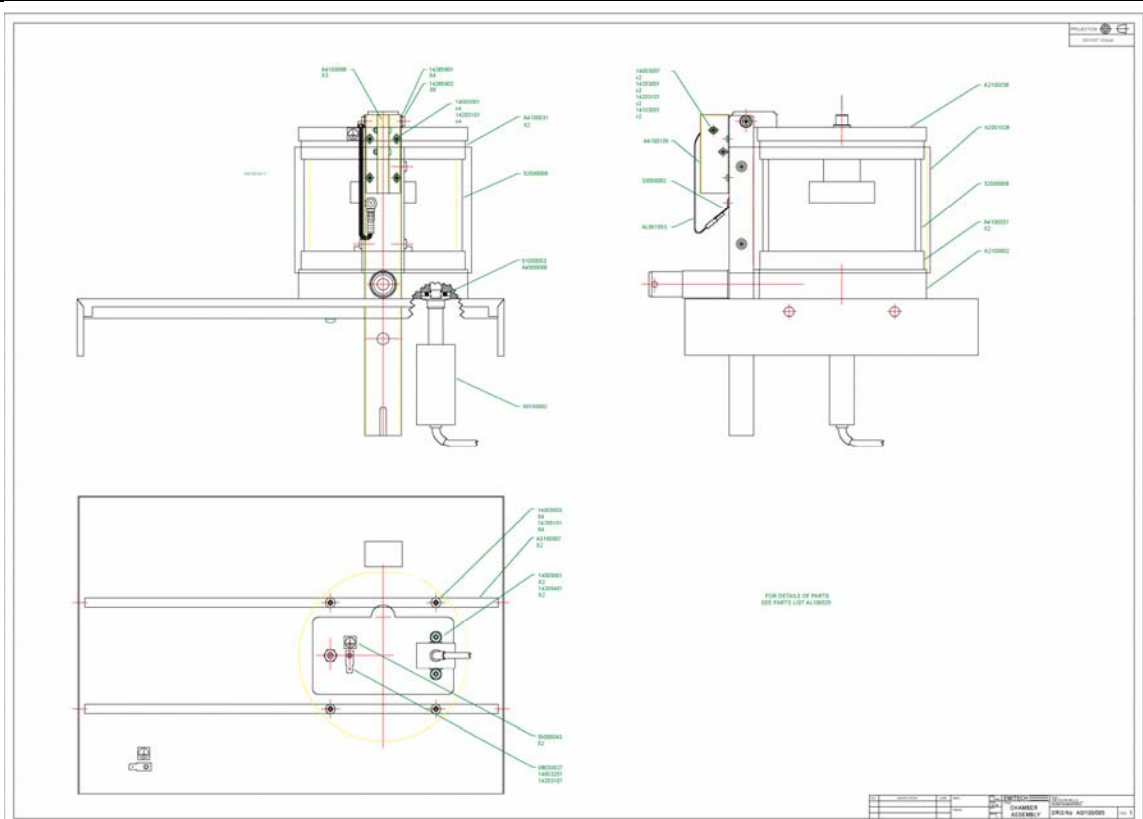


Figure 3

Certain sputter heads can employ an annular magnet and shroud assembly, with disc target. The magnetic lines of force form enclosed loops at the target surface; deflection and retardation of electrons resulting in increased ion yield sputtering efficiency. The power supply employing solid stage switching for applied voltage control.

SPECIFICATION

The overall result is a low voltage head with low energy input. The possibility of thermal damage due to radiant heating and electron bombardment is considered negligible.

Vacuum	0.1	to	0.05 Torr
Sputtering Voltage	100	to	150 Volts
Current	0	to	50mA
Deposition	0	to	50nm/min
Grain Size	Less than		5nm
Temperature Rise	Less than		10°C

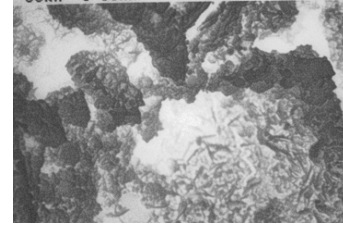


Figure 6: The Micrograph is 3-day old concrete, freshly fractured. This is a typically difficult sample as the surface is highly granular and uneven and therefore susceptible to charging during SEM. However, after coating in the K550X such problems were not encountered. (Coating conditions: Gold, 20mA, 2 minutes, 0.1Torr, coating thickness 11nm).

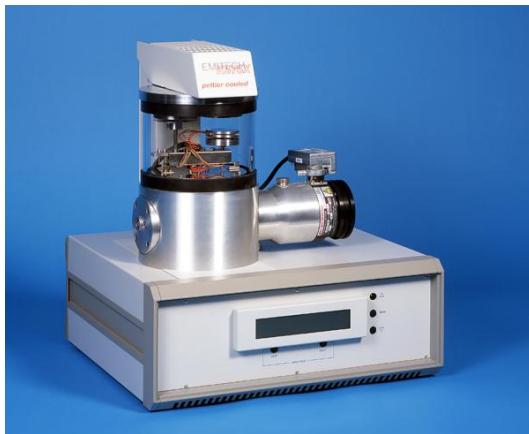


Figure 7: K575X Turbo Pumped System

It is, of course, possible to satisfy very precise parameters by the selection of target material, voltage deposition current and vacuum. Under these conditions, it is possible to achieve thin films to 10nm with grain sizes better than 2nm and temperature rises of less than 1°C. The application of sputter coating has been well established. However, the improved performance of Scanning Electron Microscopy realises the capabilities of this series of Sputter Coaters.

The Cathode target material is commonly Gold. However, to achieve finer grain size, and thinner continuous coatings, it is advantageous to use cathode target materials such as Chromium. To achieve sputtering with this target material requires vacuums somewhat better than those achievable with a Rotary Vacuum Pump. The K575X uses a 'Turbo' pump, backed up by a Rotary Vacuum pump, the complete pumping sequence being under automatic control, the vacuum of the order of 1×10^{-3} mbar.

The twin head version of the above, the K575XT has two sputter heads. These are arranged such that for special coating applications two sequential layers of a target material can be deposited without breaking the vacuum seal in this automatic unit.

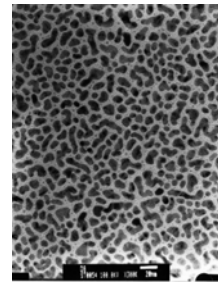
The K675X system employs a magnetron target assembly, this enhances the efficiency of the process using low voltages and giving a fine grain, cool sputtering. There are three such target assemblies in the K675X, positioned to give coating over a large diameter which, together with a rotating sample table, ensures even depositions. This method allows standard targets to be utilised, and avoids the necessity of special large profile targets. The triple-target system is particularly useful in the semi-conductor wafer industry. It has a turbo-molecular pump backed by a rotary vacuum pump.

The integrated instrument panel and plug-in electronics maximise 'up-time' and, with user-friendly designs, ensures satisfactory multi-user discipline. The sputtering parameters can be pre-set, including the gas bleed needle valve, which has electromagnetic valve back-up. The independent vacuum pump is controlled by the instrument throughout the fully automatic coating cycle.

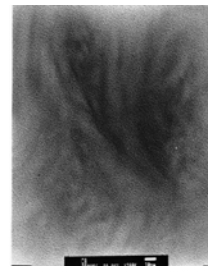
It can be used to sputter coat targets such as gold, and also targets that may need pre-cleaning, or the removal of oxide layers such as chromium. A shutter assembly is fitted as standard, which allows a sputter cleaning and the sputter cycle to be carried out while maintaining the vacuum. The K695X, launched at the start of the new millennium, is specifically designed for the 12-inch wafer market.



Figure 8: K675X Turbo Pump large sample semi-conductor wafers



Gold Sputter Coating, Standard Vacuum System



Chromium Sputter Coating, Turbo Vacuum System.