

15 the target displaces particles of the surf
target; these particles are deposited on the
a suitably placed substrate to form the coating

20 It is known that the intensity of
discharge can be increased significantly
so-called magnetron effect, which caused the
electrons to be trapped in a region where the
field is crossed by an added magnetic field
the basis of magnetron sputtering, which
25 deposition rates approximately ten times
non-magnetron electrodes and also allows sputter
take place at much lower gas pressures. Magnets
placed to produce lines of force passing
above the surface of the target.

30 Ion plating is a well known process
metal vapour produced in a vacuum system is
deposited onto a substrate whilst simultaneously the surface is
bombarded with ions. The ion bombardment improves
35 the adhesion and the structure of the coating

typically less than 1 atom in 1000 is ionised
15 abnormal glow discharge. The ion current to
samples is low, and is not sufficient to produce
dense coatings required in many applications,
though the samples are held at a high negative
potential.

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The ionisation can be increased in several ways.
For example, the supply of ionising electrons can be
increased by means of a hot filament and an electrode
which is positive with respect to the filament.
25 hollow cathode can also be used to provide a constant
supply of electrons.

Rather than use additional filaments and
electrodes to provide ionisation enhancement,
30 convenient to use a vapour source that itself can act
as a source of ionisation.

A hot filament electron beam gun evaporator, a
resistance heated crucible, and a simple diode sputtering
35 electrode are commonly used deposition sources which
create little extra ionisation. On the other hand,

15 magnetron which has inner and outer magnets
which the field strength of the outer magnets is
higher than the field strength of the inner magnets.
The 'extra' field lines leaving the outer magnets
prevent electrons escaping from the magnetron discharge
20 prevent them from drifting to the various electrodes
of the chamber. These electrons cause ionisation
in the vicinity of the electrically biased substrate
the ions so formed are attracted to the substrate by
the substrate bias, and the substrates receive a
25 ion current than in a situation where the forces
are balanced. However, the intensity of ionisation
will still be less than is desirable for the deposition of
dense coatings, unless the outer magnet field is
exceptionally strong.

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It is thus clear that there are means for
creating ions for sputtering or ion plating.

The aim of the invention is to provide a
35 magnetron sputter ion plating system, with a high
intensity of useful ionisation.

linking them so as to prevent the escape of electrons from the system between them so that these electrons are not lost to the system and are available to increase the ionisation at the electrically biased substrate.

It will be appreciated that magnetrons having an inner pole and an outer ring pole are well known. The inner pole can be a single magnet, or a line or a series of magnets. The outer "ring" pole can be formed by a single magnet or several separate magnets side by side. The "ring" need not be cylindrical or circular but could be of square or rectangular shape, or of any suitable figure.

The linking of the two magnetrons by magnetic traps traps electrons in the system and increases the rate of ionisation which occurs. We can thus produce practical magnetron sputter ion plating systems which give significantly increased ionisation using either balanced magnetrons or unbalanced magnetrons with magnets of moderate field strength.

The electric field may be provided substantially radially between the substrate magnetrons the substrate being at a negative potential. The negative potential of the substrate may vary from zero up to substantially higher values, e.g. -1000V.

The magnetron poles may comprise a target source material from which ions are produced.

Preferably there are an even number of magnetrons.

The system may further comprise a pumping system to control the pressure of an ionising gas, such as argon, in the system.

According to a second aspect the system comprises a method of magnetron sputter ion coating of a substrate to be coated comprising providing a first magnetron having an inner ring pole and an outer ring pole of opposite polarity, and a second magnetron having an inner and outer ring pole of opposite polarity, with the outer ring pole of the first magnetron being of the same polarity as the inner ring pole of the second magnetron.

side,

Figure 3 illustrates schematically a version of a magnetron sputter ion plating

Figure 4 shows the improvement in ion the embodiment of Figure 3 in comparison with a known system;

Figure 5 illustrates another embodiment of the invention;

Figure 6 shows a magnetron sputter ion plating system similar to that of Figure 3, but with a different arrangement of the sputtering cathodes;

Figure 7 shows a still further embodiment of the invention;

Figure 8 shows another embodiment of the invention which is similar in some ways to the embodiment of Figure 1; and

Figure 9 is a graph comparing the ion current density to a substrate against the bias voltage applied to the substrate for a number of different magnetron sputtering ion plating systems.

Figure 1 also shows an electrically biased substrate 7 to be coated, target shrouds 8 of sputtering material covering the exposed faces of the magnetron poles, and the magnetic field B. The magnetrons have a soft iron backing plate 9 to complete internal magnetic circuits.

As will be seen from Figure 1, the magnetic field B fully surrounds the substrate 7 and serves to form a ring within which electrons are trapped. Since the electrons cannot escape the system they are available to enhance the ionisation associated with an electrically biased substrate, creating a higher electron density than was previously possible.

Figure 2 illustrates two magnetron pole assemblies disposed side by side, the magnetic flux B bridging the gap between the assemblies and preventing the escape of electrons through the gap between the assemblies.

Turning to Figure 3, this illustrates a practical form of the invention. Three magnetron assemblies 10, 11, 12 are provided approximately

15 In use an inert gas such as argon is p
the chamber of the system and electrons are a
in the chamber by a potential difference appl
magnetron targets 8 to ionize the gas, prod
electrons and argon ions. The argon ions
20 the chamber bombard the targets 8 of source
and produce a coating flux of source mater
argon ions also bombard the substrate. Th
field lines B serve to form a continuous barr
electrons diffusing from the magnetron disc
25 ensure that these electrons are not lost to
without performing their useful function of
the glow discharge associated with the
electrically biased substrates, increasing
current to the substrate.

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 Figure 4 illustrates the improvement
present invention can achieve. Line X show
current available for different bias volta
arrangement similar to that of Figure 3, but
35 magnetron pole assembly being identical (fo
all three magnetrons having outer magnet

15 of the four magnetrons, for example the system may have
the overall cylindrical shape of a dustbin and a
pumping port may be provided at the base of the
dustbin, with the magnetrons, and substrate, above the
base.

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The magnetic field B forms a continuous ring
surrounding the substrate and traps electrons in a
ring. Since an even number of magnetron pole
assemblies is provided the flux ring can be continuous.

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There is an advantage in providing an even number of
magnetrons. Six or eight magnetron pole assemblies
are also considered good configurations, but clearly
more could be provided if desired. Adjacent magnetron
assemblies would have outer magnet assemblies of opposite polarity.

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Figure 6 illustrates a system similar to that of
Figure 3, but modified to alleviate the loss of
ionising electrons at the region between the two
magnetron assemblies near to the pumping port.

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components have been given similar reference numerals.
An electrode component 25 is provided between the

electrodes of similar polarity in a coating
15 provide a barrier to the electrons escaping
magnetron discharges, and so increase the i
ionisation and the ion current to the e
biased substrates.

20 Figure 7 illustrates another embodime
invention which has six magnetron pole assem
next-neighbour outer pole assemblies havin
polarity.

25 Figure 8 shows a magnetron sputter i
system having four magnetron pole assemblies
and 33. Pole assemblies 30 and 32 have
polarities, but pole assembly 33 presents po
same polarity to the adjacent portions
30 assemblies 30 and 32. Some magnetic fi
lines 34, are not closed and escape t
However, pole assemblies 31 and 33 also hav
field lines 35 connecting their regions o
polarity. A reasonable degree of magnet
35 still exists and we still achieve increased i

15

all of the same polarity and
ferrite magnets.

Line 41 -

Three pole assemblies
(unbalanced), all of the same
polarity and using ferrite ma

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Line 42 -

Three mixed or alternating
polarity magnetron pole assem
(unbalanced), with ferrite ma
(as in the embodiment of Figu

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Line 43 -

Three mixed or alternating
polarity magnetron pole assem
(unbalanced), with ferrite ma
plus a dummy, or additional,
assembly (as in the embodimen
Figure 6).

30

Line 44 -

Four mixed or alternating pol
magnetron pole assemblies
(unbalanced) with ferrite mag

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in Figure 3 and 5 have been used for the deposition of titanium nitride and other hard coats. The ionisation produced by the 'mixed' magnetron is important in depositing coatings with high adhesion and hard dense structures.

The ion bombardment of the substrates during the glow discharge process, the ions formed in the glow discharge and the substrates being attracted to the substrates by the negative electrical bias voltage applied to the substrates. This bias voltage can be a DC voltage. Radio Frequency power can be applied to the substrates in order to produce an induced negative voltage. The radio frequency technique is necessary when the substrates are of an electrically insulating material and/or when the coating material is electrically insulating, but can also be used when the coating material and the coating material are electrically conductive. The improvements in coating adhesion and coating density brought about by the increased ionisation in the mixed magnetron polarity arrangement occur for both DC and RF substrate bias.

and are near enough to each other so that magnetic field lines (B) extend between the outer ring poles of the magnetrons linking them so as to prevent the loss of electrons from the system between the magnetrons that these electrons are not lost to the system and are available to increase the ionisation at the electrically biased substrate.

2. A system according to claim 1 characterised in that the outer poles are angularly spaced relative to the position of the substrate (7;7') to be coaxial so that they subtend a substantial angle at that substrate.

3. A system according to claim 1 or claim 2 characterised in that it comprises a plurality of magnetrons the adjacent outer poles of which have opposite polarities.

4. A system according to any preceding claim characterised in that the magnetrons (1,2;10,11) are arranged around the substrate (7;7') and the substrate has a generally central position between the magnetrons.



8. A system according to any one of claim 1 to 7 characterised in that there are an odd number of magnetrons.

9. A system according to claim 8 in which an additional magnetic electrode is used to control the magnetic field between two adjacent poles of the magnetrons with outer pole pieces of the same polarity.

10. A system according to any preceding claim characterised in that there are at least three magnetrons.

11. A method of magnetron sputter ion plating a substrate to be coated comprising providing a first magnetron having an inner ring pole and an outer ring pole of opposite polarity, and a second magnetron having an inner and outer ring pole of opposite polarity, with the outer ring pole of the first magnetron being of opposite polarity to that of the second magnetron; electrically biasing a substrate to be coated so as to make it a cathode to attract sputtered ions.



