Variations on the Closed Field Unbalanced Magnetron Sputter Ion Plating Configuration

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1. Introduction

• Closed field unbalanced magnetron sputter ion plating (CFUBMSIP) [1-3] is ideally suited to the rapid and reliable deposition of multilayer coatings. The technique readily accommodates complex alloy structures, deposited from multiple sources of single metal targets, either directly or by reactive methods. Graded interfaces are routinely and easily formed to ensure that stress induced in the coatings is dissipated away from the coating substrate interface [4].

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2. Closed Field Unbalanced Magnetron Sputter Ion Plating (CFUBMSIP)

• The CFUBMSIP process is now widely recognised as a state of the art technique for hard coatings [1] and CFUBMSIP acts to increase the ion current density in magnetron sputter ion plating. Unbalanced magnetrons are used in a configuration where at least one pair of unbalanced magnetrons is of opposite magnetic polarity. This traps the plasma, preventing the loss of ionising electrons and so providing significant plasma enhancement. The ion current is maximised at a relatively low substrate bias voltage (e.g. -50V), so that deposition occurs under low density conditions. In the closed field condition, inductive heating is dissipated away from the coating substrate interface [4].

• Under typical substrate cleaning conditions (low magnetron power and a high, negative, pulsed DC bias potential on the substrate) the substrate bias current is enhanced lower the closed field conditions, and this effect is much more marked (i.e. +65%) for the shorter source to substrate distance, where there is more interaction with the magnetron plasmas.

• In a typical transition mode (intermediate magnetron power and moderate pulsed DC substrate bias voltage) the relative increase in bias current is greater (+82%) at the higher source to substrate distance.

• Under deposition conditions (high magnetron power/low substrate bias) the relative increase in substrate bias current is again much higher (+145%) at the higher source to substrate distance, and this effect is further enhanced when using simple DC substrate bias (+193%).

• At the shorter (120mm) source to substrate distance the individual magnetron plasmas have a more direct interaction with the substrate, whereas at the larger (270mm) source to substrate distance the plasma that develops in the closed field region between the magnetrons is increasingly important – there is less opportunity for plasma species to be lost in the closed field case, enhancing plasma density which supports the increased bias current drawn at the substrate under otherwise identical bias conditions.

3. Some alternative closed field arrangements

• Sometimes a coplanar arrangement of sources is desirable (for example to coat a continuous, flat substrate). In this case partial closure can be achieved by arranging adjacent magnetrons with opposite magnetic polarities, the ideal conditions to grow dense films.

• Pulsed DC Bias is now routinely applied [9, 10] and further improves cleaning and process stability.

• The effect of the magnetic configuration on the bias current was investigated for different deposition conditions. An enhanced plasma region still escapes via that gap and being lost.

• The ion current densities (i.e. the current drawn per unit area of a negatively biased substrate) can be increased 100 fold by the application of CFUBMSIP techniques (when compared to sputtering from a conventional, balanced magnetron source).

• Other deposition conditions (high magnetron power/low substrate bias) the relative increase in substrate bias current is again much higher (+145%) at the higher source to substrate distance, and this effect is further enhanced when using simple DC substrate bias (+193%).

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• A Teer Coatings UDP450 chamber was modified to accept a coplanar pair of similar magnetron sources (i.e. opposite polarity, ‘N+S’) or ‘closed’ (opposite polarity, ‘N+N’) magnetrons. For these experiments the four magnetrons normally mounted vertically were earthed and replaced by blanking flanges in one having a large window to allow direct observation of the magnetron. The magnetrons were operated with independent DC power supplies.

• The substrate was a horizontal steel plate, some 300mm long, positioned at either 120mm or 270mm below the magnetrons. The substrate could be biased with DC or pulsed DC.

• The effect of the magnetic configuration on the bias current was investigated for different typical operating conditions of the magnetrons and bias supply.

5. Conclusions

• CFUBMSIP has proven advantages in the deposition of high quality coatings for many critical applications, including cutting & forming tools, wear components and optical systems. The beneficial aspects of the process are derived from the retention of plasma within the deposition environment.

• In addition to the fully-closed configuration, other variants of the technique provide enhancements over traditional, non-closed field arrangements of multiple magnetrons, and a detailed understanding of a system’s characteristics can be used to dramatically modify the substrate environment, including the ion flux, as indicated by the variation in the observed substrate bias current.

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7. References