Time and space resolved electron temperature distribution in a Penning-type opposed target magnetron during pulsed DC sputtering

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The Penning-type opposed target magnetron is a sputtering source for thin film deposition where the parallel electric and magnetic fields in front of the targets result in a high level of electron confinement in 'magnetic bottle' between the targets. This high electron density gives rise to very intense ionisation of the sputtering gas and also significant ionisation of the sputtered metal leading to a degree of self sputtering. Asymmetric pulsed DC bias was applied to the targets at a frequency of 50 kHz with off times (where the target bias goes positive) in the μs range. Time and space resolved measurements with 200 ns resolution of the optical emissions from the plasma during the pulses have been used to characterise the development of the sputtering process. Measurements of electron temperature have identified various stages in the process including the onset of sputtering due to Ar ions which relates to a peak of high electron temperature up to ~20 eV and the development of self-sputtering due to ionised metal atoms which correlates to a second, lower temperature, peak. As the pulse continues, the electron temperature declines to a level of a few eV similar to that which is found in DC sputtering. The spatial position of the regions of highest electron temperature are also explained with relation to the behaviour of the secondary electrons generated at the targets. The differences between non-magnetic (Cu) and ferromagnetic (Fe) target behaviour will be described.