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## High rate carbon deposition using an HIPIMS arc mixed mode

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Carbon coatings are used in a wide range of applications. Important key properties are the controllability of the $sp^3$ fraction, a reasonably high deposition rate and a low macroparticle content. Carbon coatings are often deposited by conventional magnetron sputtering or vacuum cathodic arc using a carbon target. Sputtering produces macroparticle-free films, but the deposition rate, as well as the ionization of the flux, are low. The latter limits the $sp^3$ fraction. Films grown by vacuum cathodic arc show high $sp^3$ fraction due to the high ionization degree, but suffer from the incorporation of macroparticles. Magnetic filtering to reduce the macroparticle content, however, adds process complexity and reduces the deposition rate. The advantages of the two processes can be combined in a new high power impulse magnetron sputtering (HIPIMS) mixed mode process. Carbon films grown on unbiased substrates exhibited a $sp^3$ fraction of 50-60%, but the deposition rate was low. By using a power supply with rapid turn off at a chosen current set point we achieved control over the transition from the magnetically confined glow discharge (HIPIMS) to an arc discharge with very high but controlled current density (mixed HIPIMS arc mode) operating by applying the same constant voltage square wave pulses. The arc is quenched rapidly by setting the current limit to prevent the formation of large macroparticles normally produced by cathodic arcs. The deposition rate of the carbon films in the mixed HIPIMS arc mode at a duty factor of less than 1% was found to be greater than for conventional RF sputtering. When grown with negative substrate bias, the films contain graphitic nano-clusters which are preferentially oriented with their c-axis normal to the film surface. We propose a mechanism for the formation of the clusters and their oriented layers.

**Keywords**
pulsed plasmas
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