PO2030

Increasing the thermal stability of thin films by incorporating co-sputtered nanoparticles

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A new class of nanocomposite materials is created by PVD sputtering a matrix and simultaneously co-sputtering nanoparticles at ambient temperature, enabling the incorporation of nanoparticles into a material in any combination that can be magnetron sputtered.
Current nanoparticle addition methods are limited by the material combinations, thermodynamic considerations and distributions which can be produced. In addition, nanoparticle agglomeration, size and concentration characteristics are often difficult to control.
Using the combination of a classical PVD sputtering magnetron and a nanoparticle source, free control in size and distribution is demonstrated for any choice of sputterable material. The nanoparticle generator operates based on an adaptation of classical magnetron sputtering by forcing agglomeration of the sputtered ions into particles via terminated gas condensation. A quadrupole mass filter is incorporated into the system to measure nanoparticle size distribution and flux during a process, in-situ optimization of process parameters, and a filter to obtain desired size.
To successfully integrate the nanoparticles into the matrix, the pressure set points of various regions of the vacuum system were optimized. These include the nanoparticle aggregation, the substrate zone, the magnetron sputtering the matrix material, and the trajectory of the particles starting from the aggregator exit aperture travelling via the mass spectrometer.
In this work, W nanoparticles were co-deposited into a magnetron sputtered Cu matrix. A random distribution of particles and a 4 nm average diameter was observed by transmission electron microscopy. The spatial distribution can be controlled by varying the deposition parameters. By vacuum annealing we showed that the nanoparticles stabilized the Cu grains up to 500 ºC; while the Cu film without nanoparticles undertook substantial grain growth. The introduction of less than 1 vol.% of nanoparticles was sufficient to keep the nanocrystalline structure of the Cu film unaffected.

Keywords
nanocomposite
nanoparticles