Topic number 8

Pulsed electron beams for thin film deposition

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In this work we present results on pulsed electron beams produced in a channel-spark discharge used for thin film deposition. The measured electron beam energy distribution is polyenergetic, having a high-energy electron component at the beginning of the applied high voltage fall and a dominant contribution of lower energy electrons increasing towards later times of the voltage fall. *In situ* diagnostics of ablation plasma produced in PED by fast imaging, optical emission spectroscopy and Langmuir probes showed that the kinetic energy of the species emitted by the target was roughly in the 10 to 60 eV range. These investigations led to the growth of high quality oxide thin films by the precise control of the PED parameters.

The discovery of the “pseudospark” gas discharge in 1979 by J. Christiansen and C. Schultheiss [1] has paved the way for many studies on pulsed electron beams and their application in pulsed-power switching, extreme ultraviolet sources for lithography, compact X-ray sources, microthrusters, high power microwave generation, etc. These pulsed electron beams are produced in low pressure gas discharges (10^{-3} -10^{-1} mbar) for applied voltages up to tens of kV. A pulsed electron beam, which propagates in a self-focused way due to the space-charge neutralization, has typical parameters: currents of tens - hundreds of A, pulse widths of tens - hundreds of ns, and energies up to tens of keV.

The channel-spark discharge [2] has been derived from the pseudospark one by replacing the floating electrodes from multigap pseudospark geometry with a dielectric tube, leading to a stable electron source for a low cost thin film deposition method: the pulsed electron beam deposition (PED). It has common features with pulsed laser deposition, i.e. the pulsed nature of process, the very anisotropic character of the ablation plume and the high energy of species, but uses a pulsed electron beam instead of a laser beam for ablating a target. Due to the specific electron-matter interaction, the range of materials that could be ablated has been extended to those that are transparent to laser wavelengths.

The knowledge of the electron beam energy distribution of the pulsed electron beams used in PED method plays a key role for an efficient ablation of the target surface and thus to the deposition of thin films. Experimental methods have been employed to determine electron beam energy distribution: self-biasing Faraday cup and X-ray radiation at the interaction of the electron beam with a target. Our measurements showed that in the channel-spark discharge the electron beam energy distribution is polyenergetic, spreading from hundreds of eV to the energy eU, where U is the applied high voltage and e is the electron charge. This distribution has a high-energy electron component (more than a few keV) at the beginning of the applied high voltage fall (U) and a dominant contribution of lower energy electrons increasing towards later times of the voltage fall. For U=16 kV, the voltage fall lasts 210 ns and the total beam current has a maximum value of 750 A, from which a current with a maximum value of 400A and pulse width of about 110 ns is carried by electrons having energy higher than 1.84 keV [3]. Tailoring the electron energy distribution function by variation of the discharge parameters has influenced the quality of grown thin films by PED.

In situ diagnostics of ablation plasma produced in PED by fast imaging, optical emission spectroscopy and Langmuir probes demonstrated that the kinetic energy of the species emitted by the target was roughly in the 10 to 60 eV range, leading to high surface mobility for these species. As a result, growth of stoichiometric and crystalline oxide thin films, even epitaxial films at relatively low temperatures, has been obtained. The tuning of the physical properties of thin films was possible by the precise control of PED growth conditions [4].

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