Modeling of the nanoparticle size segregation in magnetron discharges

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The charge and forces applied on an isolate NP in conventional magnetron discharges were established using basic models. In the field of nanoparticle production where the control of sizes is a sensitive issue, the goal was to explain why for a given plasma, there is a size segregation in NP depositions inside the device. First, 2D measurements of the plasma parameters were performed and correlations with the magnetic field lines and strengths were shown. The plasma parameters were then used to calculate the 2D variations of the negative charge of an isolated NP and the resulting electric and ion drag forces applied on it. The termophoretic force due to the discharge gas temperature gradients, induced by the sputtered atom thermalization was also established. The force balance was studied for the average size measured on the grounded guard ring i.e. the anode located around the cathode. It is shown that only the electric and thermophoretic forces have an influence. Near the guard ring, the particle is mainly pushed by the electric force towards the guard ring. In the lower mid-plane of the plasma, the thermophoretic force due to large temperature gradients is always dominant and pushes the particle towards the coldest regions in particular, towards the anode plate parallel to the cathode. Therefore, in the plasma region separating both electrodes, the particle can have enough space and time to grow by accretion, this reinforcing the role of the thermophoretic force proportional to the NP square radius. In magnetron discharges, this can also explain why the average size of NPs deposited on the anode plate where the collection of NPs is usually made is larger than on the guard ring located around the sputtering source.