Modelling of continuous steel coating by self-induced ion plating

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Abstract

The present communication deals with the study of a new physical vapour deposition process developed in order to produce continuous coating of flat products in the steel industry. This technique, called self-induced ion plating (SIP), is based on the evaporation of a metallic target thanks to a magnetron sputtering system. This combination of PVD processes (evaporation and sputtering) allows to obtain a high deposition velocity and a good deposit adherence.

The SIP process operates under high vacuum. Argon gas is ionized between the cathode (metallic target) and the anode (substrate of steel) to produce plasma. The argon ions (Ar^+), created by the collisions that occur between electrons and argon atoms, are accelerated in the sheath of the plasma towards the target contained in a refractory crucible. The bombardment of those ions heats the target and leads to its evaporation.

Another consequence of the bombardment is the electrons extraction out of the target. Those electrons, called secondary electrons, are accelerated in the sheath of the plasma towards the bulk of the plasma and gain enough energy to ionize argon atoms. They are then useful to maintain the plasma.

The plasma created in the process is confined near the target by a magnetic field generated by a magnetron disposed under the target. This confinement has as consequences a power distribution that presents a maximum where the magnetic field lines are parallel to the cathode and an increase of the ions bombardment of the cathode. The non-uniform distribution of the heat flux due to ions bombardement is revealed in experiments by the presence of an erosion track. Very high deposition rates can be achieved with moderate values of the electrical mean power density applied to the target.

The aim of the research work is to develop a numerical simulation model of the SIP process in order to predict the thickness profile of the coating deposited on the substrate. The simulation of the SIP process is based on three coupled models. The first one determines, by a standard finite element method, the magnetic field generated by the magnetron. It makes it possible to define the distribution of the heat flux provided to the target by the ionic bombardment. The second describes the various phenomena of heat transfer (conduction, radiation) which take place in the SIP system. This model gives the temperature field on the target surface. From this temperature field and thanks to the evaporation theory, the third model determines the thickness profile obtained on sheet following its passage above the target. These two last models are developed in Matlab® modules and are integrated in Femlab ®, a tool for the resolution of multiphysic problems in Matlab® language. The simulated results are then compared with the measurements obtained on a pilot installation. The comparison shows that our results do not agree perfectly with the experimental values. This can be explained by probable errors of measurements and by simplifying assumptions introduced into the model. The accomplishment of a new series of tests and the modifications of the model in progress will have to allow to improve the agreement of the profiles of measured and calculated deposit thickness.