Modelling of continuous steel coating by Self-Induced Ion Plating (SIP)

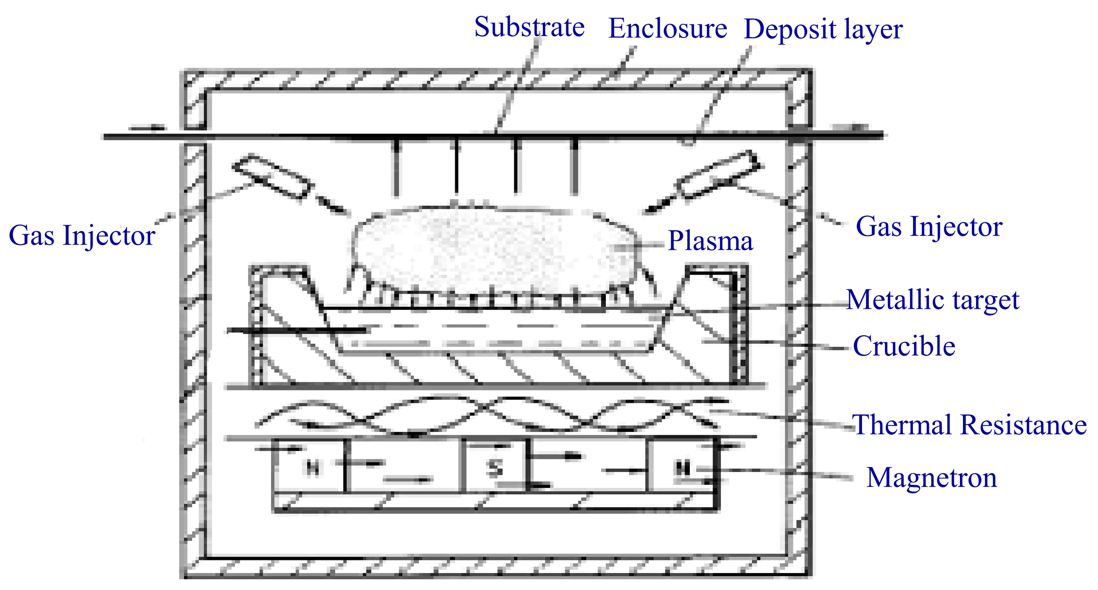
A. Contino[1], V. Feldheim[1], P. Lybaert[1], B. Deweer[2], H. Cornil[2]

[1]Faculté Polytechnique de Mons, Thermal Engineering & Combustion Laboratory, Mons, Belgium

[2]Arcelor Innovation - Research Center of Cockerill Sambre, Liège, Belgium

RDCS Groupe Arcelor

Self-Induced Ion Plating (European Patent N° 0780489)



- a new physical vapour deposition process to produce continuous coating of flat products in the steel industry
- a process based on the evaporation of a metallic target thanks to a magnetron sputtering system

Objective

Numerical simulation model of the SIP process

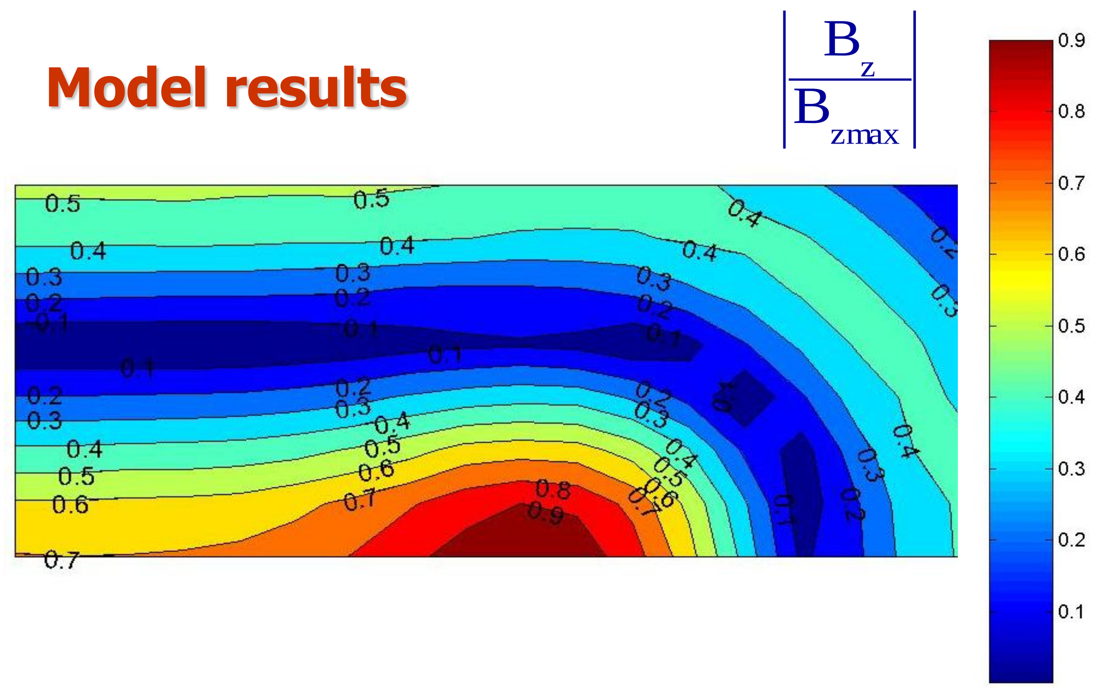
⇒ prediction of the coating thickness profile obtained on the substrate

Simulation models and results

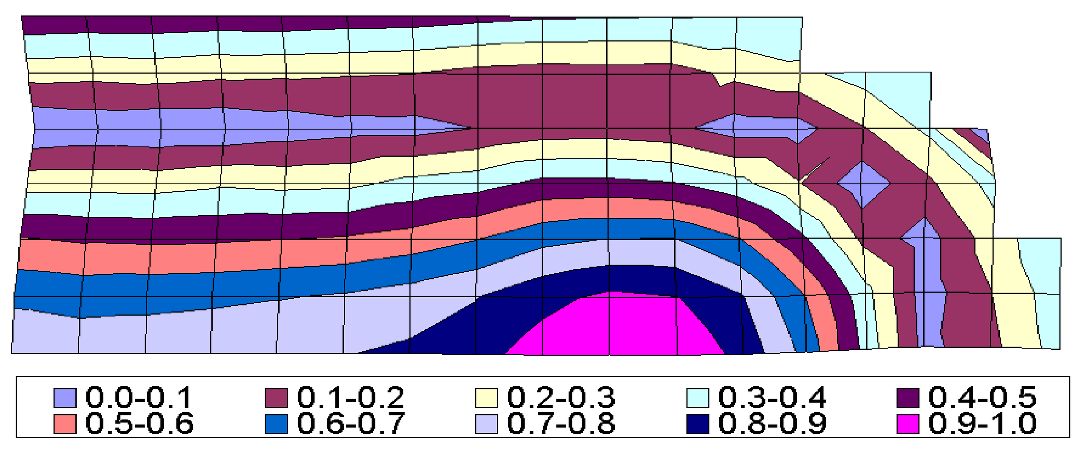
Magnetic Model → Magnetic Field ⇓ Ionic bombardment heat flux $q(W.m^{-2}) \propto \left\{\frac{B_{xy}}{\sqrt{B_{xy}^2+B_z^2}}\right\}^3$ → **Heat transfer Model** → Temperature field on the target surface → **Evaporation Model** → Coating thickness profile

- Magnetic field generated by the magnetron determined by a standard finite element method with Femlab 2.3.®

Model results $\left|\frac{B_z}{B_{zmax}}\right|$

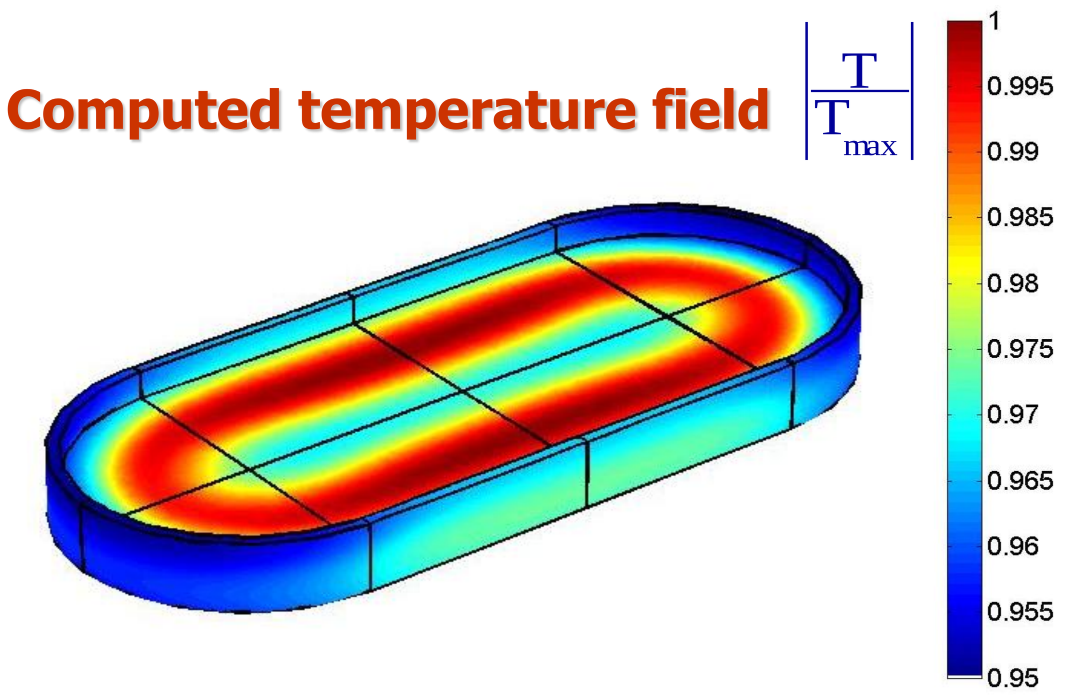


Measurements $\left|\frac{B_z}{B_{zmax}}\right|$

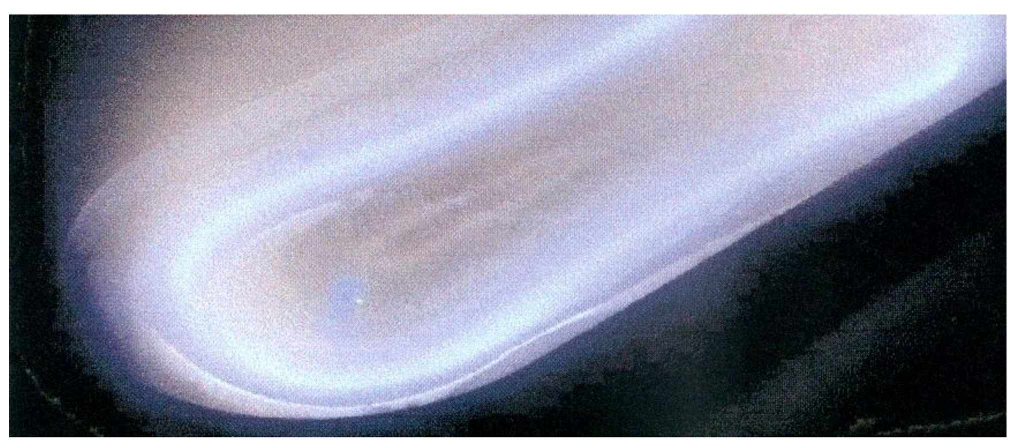


- Creation of a specific Matlab® module to compute radiative heat transfer using the zone method
- Coupling with standard finite element conduction model of Femlab 2.3.®

Computed temperature field $\left|\frac{T}{T_{max}}\right|$



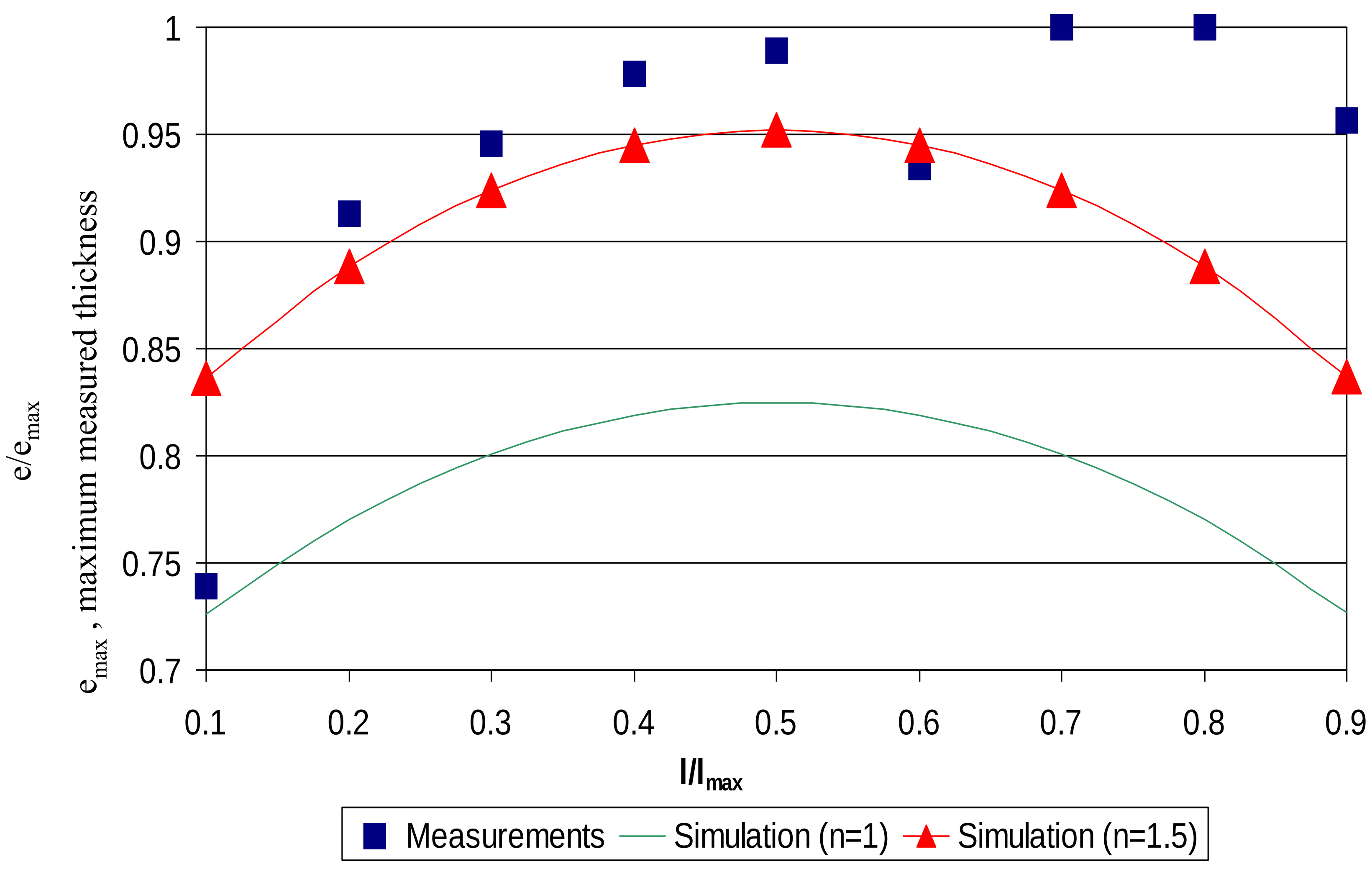
Picture of the target

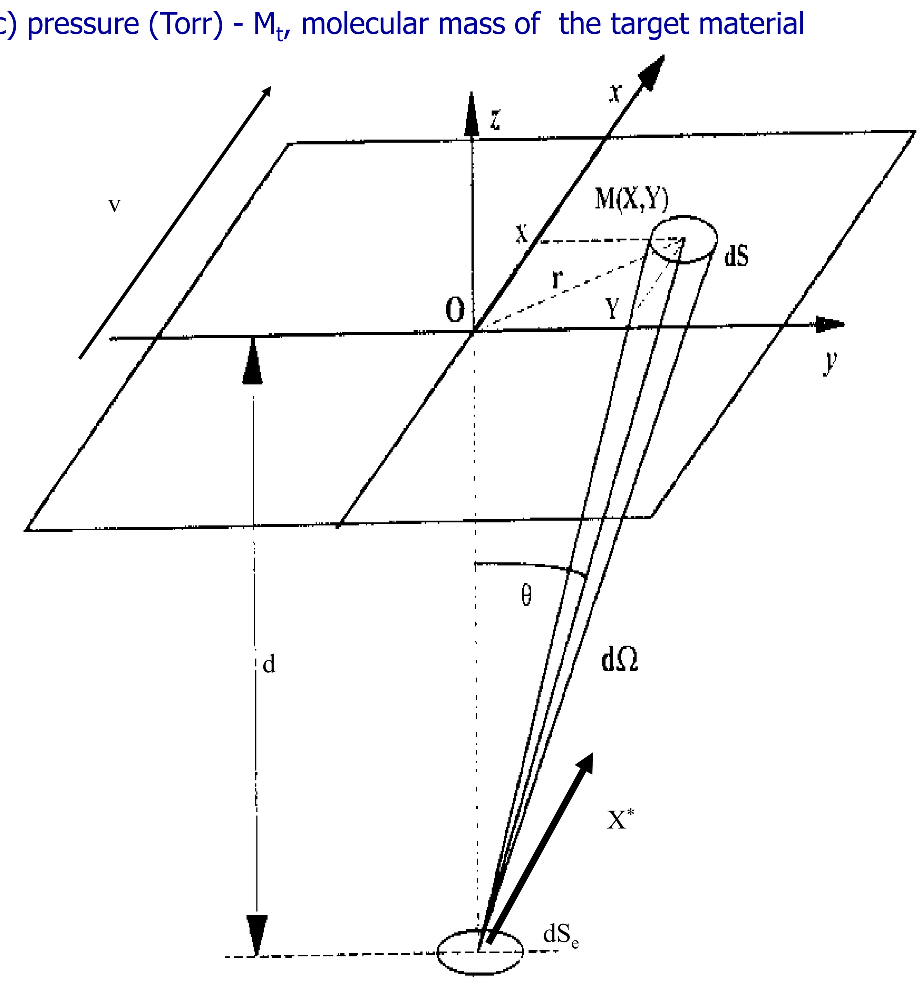


- Thickness profile obtained on the substrate given by $e(X,Y)=\int_0^{\infty}\frac{J_d(x^*,y)}{\rho_e}d\tau$ with $x^*=v\tau$

$$J_d=\int_{S_e}\frac{(n+1)J_e}{2\pi}\frac{d^{(n+1)}}{(r^2+d^2)^{\frac{(n+3)}{2}}}dS_e \quad \text{and} \quad J_e=5{,}834\,10^{-1}\sqrt{\frac{M_t}{T_e}}(p_v-p_{stat})$$

ρ_e, density of evaporated material - v, velocity of the substrate - τ, the time - $J_{d(e)}$, deposited (evaporated) mass flux - $P_{v(stat)}$, vapour (static) pressure (Torr) - M_t, molecular mass of the target material





Conclusions

No perfect agreement between measured and computed results because of

- probable measurements errors ⇒ New series of tests projected
- simplifying assumptions introduced into the model ⇒ Modifications of the model in progress

Thermal Engineering & Combustion

POLYTECH. MONS