Effects of the Film Thickness on the Transient Conjugate Optical-thermal Fields in Thin Films Irradiated by Moving Sources in Back and Front Treatments

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INTRODUCTION

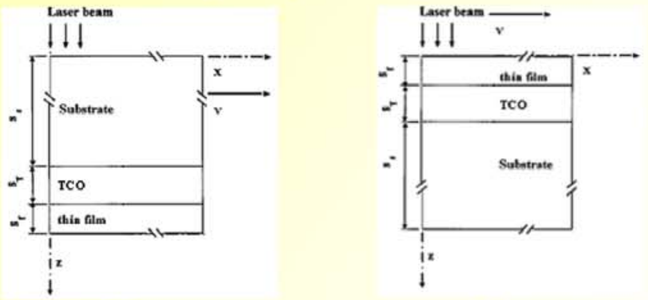
The manufacturing of multilayer thin films deposited on glass substrate is accomplished by means of laser sources. The analysis of thermal conductive and optical fields induced in these structures is of paramount importance so computational investigations of laser interactions with single and multilayer thin films on a glass substrate have been performed.

In this paper a numerical two-dimensional transient analysis of the conjugate optical-thermal fields caused by a moving Gaussian laser source in a multilayer thin film structure on a glass substrate is carried out. Back and front treatment processes have been considered. The workpiece is considered semi-infinite along the motion direction and its optical and thermophysical properties are assumed temperature dependent. The COMSOL Multiphysics 3.4 code has been used to solve the combined thermal and electromagnetic problem. In this way, the optical field is considered locally one dimensional and Maxwell equations are solved in order to evaluate the absorption in thin film. Results, in terms of transient temperature profiles and fields, are presented for different Peclet numbers equal to 1.0, 2.0, 3.0, 4.0 and 5.0 and three values of thin film thicknesses, such as 0.25 μm, 0.50 μm and 1.00 μm.

NUMERICAL MODEL

The investigation is carried out for a solid composed by an amorphous silicon film layer with thicknesses equal to 0.25 μm, 0.50 μm and 1.00 μm. Furthermore, the thickness of TCO layer and glass substrate is 0.6 μm and 50 μm, respectively.

The laser power is set to 0.30 W and a beam radius of 25 μm is chosen. The irradiation distribution is Gaussian and the heat source moves along x axis from $x_0 = 0$. Different constant velocities are considered in order to correspond to Peclet numbers equal to 1.0, 2.0, 3.0, 4.0 and 5.0. Four different grid distributions have been tested to ensure that the calculated results are grid independent. The grid mesh is structured.

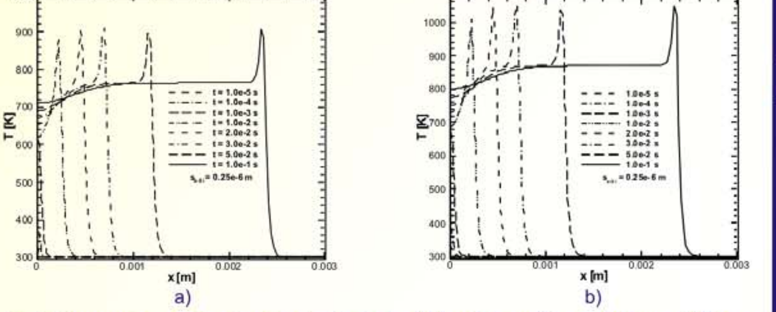


a) b)

Figure 1 - Sketch of the model including the thin film layer and the TCO one on glass substrate: a) back treatment process; b) front treatment process.

In order to analyze the coupled optical-thermal fields an electromagnetic and a thermal model have been developed. This combined problem has been studied by means of Comsol Multyphisics 3.4. The laser beam is orthogonal to the target and impinges the thin film layer in the case of the front treatment and the glass substrate in the case of the back treatment process. The radiative field related to the absorption-reflection-transmission process in the thin film structure is locally one-dimensional and so, suitable boundary conditions in the electromagnetic model have been applied. Thermal radiation is absorbed and the absorption mechanism is represented as a thermal generation in the heat conduction equation. Radiative and convective heat losses from the surfaces toward the ambient are neglected and the thin film can be treated as a semi-transparent material, due to its small thickness.

RESULTS



a) b)

Fig.2 - Temperature profiles at surface for Pe = 1 for different times with s_f = 0.25 μm: a) FT process b) BT process.

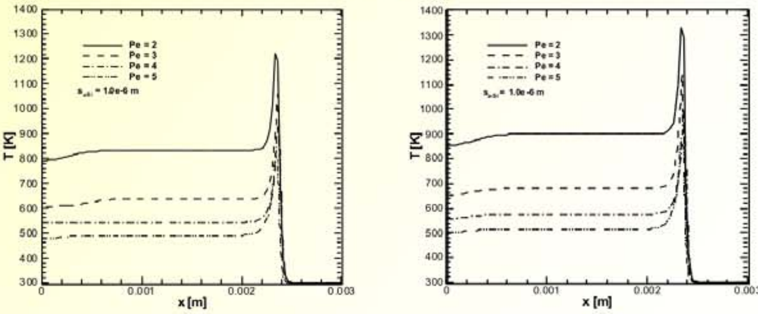


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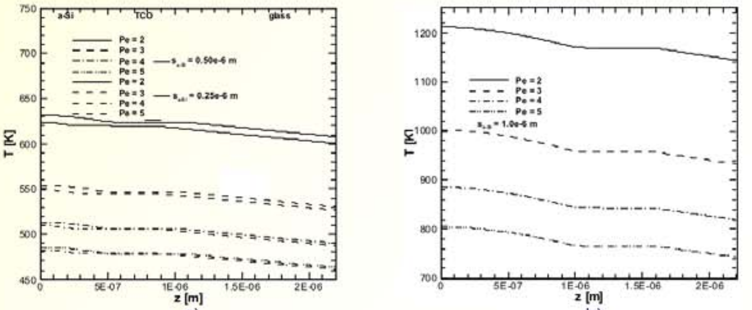
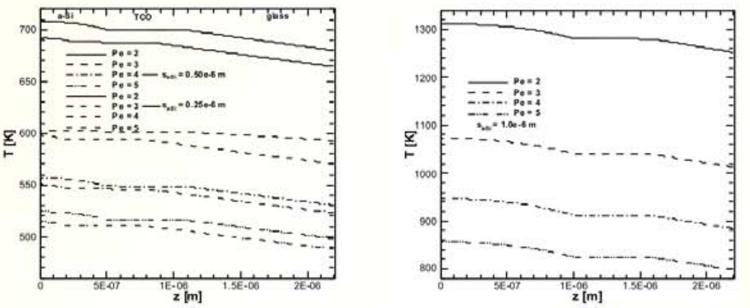
Fig.3 - Temperature profiles at silicon surface for different Peclet numbers at quasi-steady state condition for s_f = 1.00 μm: a) FT process; b) BT process.



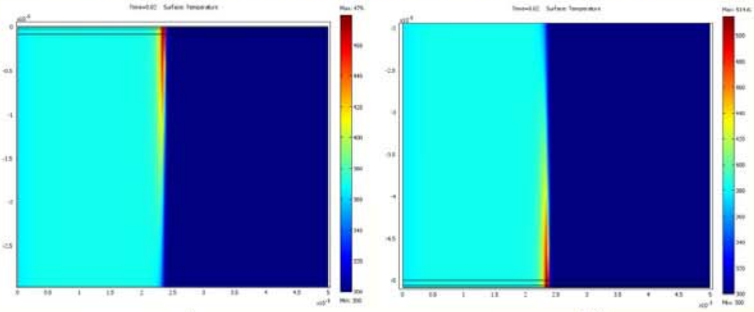
a) b)

Fig.4 - FT process. Temperature profiles along z-direction for different Peclet numbers at quasi-steady state condition for s_f = 0.25 μm and 0.50 μm (a) and s_f = 1.00 μm (b).



a) b)

Fig.5 - BT process. Temperature profiles along z-direction for different Peclet numbers at quasi-steady state condition for s_f = 0.25 μm and 0.50 μm (a) and s_f = 1.00 μm (b).



a) b)

Fig.6 - Temperature fields for s_f = 0.25 μm for Pe = 5.0 at 2×10^{-2} s: a) FT process; b)BT process.

CONCLUSIONS

This paper presents the analysis of the conjugate optical and thermal field induced in a multilayer thin film on a glass substrate by a gaussian continuous moving laser source. The transient two-dimensional analysis was carried out numerically, by means of the COMSOL Multiphysics 3.4 code. Both front and back treatment processes have been considered. Temperature profiles and fields showed that the maximum temperature values reached within the structure at the quasi-steady state condition decrease at increasing Peclet number and reducing the film thickness. The transient analysis showed that the time at which the maximum temperature is attained increased with the Peclet number. Higher temperatures and larger heat affected zones are observed for the back treatment processes.