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A novel method for simulating laser-solid interactions in semiconductors and layered structures

R.K. Singh ... J. Narayan

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Abstract

We have developed a new implicit finite difference method to simulate the interaction of intense nanosecond laser beams with semiconductors and metal-coated ceramic structures. This method is based upon a higher order implicit finite difference scheme with a smaller truncation error and is not restricted by any stability criterion, thereby allowing faster convergence to the exact solution. The temperature-dependent optical and thermal properties of the irradiated material as well as the temporal variation in the laser intensity have been taken into account. Finite difference equations have been set up for accurate determination of the temperature gradients at the liquid-solid interface, which control the melt-in and resolidification velocities. A new formulation is introduced to accomodate the effect of pulsed laser irradiation on layered composite structures (e.g. metal-coated ceramics) by incorporating the boundary conditions at the composite interface.

Using this method, the thermal histories of laser-irradiated materials were predicted. The effects of variation in the pulse energy density, pulse duration and substrate temperature on the maximum melt depths, solidification velocities and surface temperatures were computed. The calculations on the depth of melting were found to be in good agreement with experimental results where complete annealing of the ion implantation damage was used as a measure of the melt depth. The surface temperatures and melt lifetimes in metal-coated ceramics were determined in order to understand the laser mixing process. Simple energy balance considerations were applied to calculate some of the effects of laser irradiation on materials. From these energy considerations, the maximum melt depths as a function of energy density, pulse duration and substrate temperature were obtained and compared with the exact solutions. The maximum surface temperatures, solidification velocities and melt lifetimes were also determined by this analytical method and compared with the detailed calculations. A good agreement between the analytical relations and the detailed numerical calculations provides an excellent guide to researchers in this field.

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