A COMSOL Model of Damage Evolution Due to High Energy Laser Irradiation of Partially Absorptive Materials

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Abstract

In this paper we present a transient numerical model of the heat transfer and thermochemical damage evolution in an IR translucent material using COMSOL Multiphysics. The model is evaluated using literature supplied and experimentally determined material properties for carbon black laden PMMA (polymethyl-methacrylate). This variant of PMMA was chosen because it is homogeneous, isotropic, and the decomposition from solid to gas is relatively straightforward to characterize. The incident high energy laser beam is modeled as a Gaussian heat flux. The beam parameters used for this study were selected to mimic that of a Nd:YAG high energy laser with a wavelength of 1070nm, an output power of 110W, and a spot size with a 5.5mm beam diameter. At this wavelength, NIRS/FTIR experiments have measured that PMMA absorbs approximately half of the incident laser energy. PMMA was also experimentally observed to vaporize from 310°C to 475°C via differential scanning calorimetry. The temperature range and endothermic phase change from solid to gas is incorporated in the COMSOL model. Rather than use an adaptive mesh, material removal (or drilling) was captured using temperature and phase dependent material properties. The model captures vaporization material removal by appropriately varying the thermal conductivity and density of the PMMA at the vaporization temperature. The model results are compared to experiments on carbon-laden PMMA.