Stoichiometric Laser-Induced Breakdown Spectroscopy for Simple and Cost-Effective Laser Material Fabrication: A Case Study of Polycrystalline Yttrium Aluminum Garnet Ceramics

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The fabrication of laser grade ceramics must be improved to achieve better reproducibility of high quality yields, requiring a control of the bulk stoichiometry beyond that of current analytical techniques. This work evaluated Laser-Induced Breakdown Spectroscopy (LIBS) for measuring the aluminum to yttrium ratio in Y3Al5O12 (YAG) laser ceramics. The student developed a novel plasma code using Matlab software to model LIBS plasmas, and utilizing this model, elucidated the effects of variation in plasma temperature (T), electron density (Ne), and sample composition on the chemical composition of the plasma. A theoretical optimization of experimental parameters was then achieved for the first time via a Monte Carlo approach (T=1eV, Ne=10^23 m^-3). Further experimentation at these optimized parameters are expected to produce plasmas that are both robust to experimental fluctuation and highly sensitive to sample stoichiometry, approaching the 0.1mol% threshold for ceramic YAG fabrication. This study (1) advances LIBS for improving YAG fabrication for the $2.2 billion solid-state laser industry (2) validates the general notion that optical emission spectroscopy (OES) can be used to improve the production processes of advanced materials and (3) presents dramatic cost savings potential in the optimization of experimental OES protocols and promises foreseeable benefits to analytical chemistry and materials science at large.

Awards Won:

Second Award of $2,000