Chip Slapper Detonator Processing for Rapid Prototyping and Hydrodynamic Properties

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Next generation weapons require reliable, compact, energy-efficient initiation systems that will perform for the lifetime of the stockpile. Chip slapper detonators are now being evaluated for future use. There are limitations in the present technology and high costs associated with tooling for each configuration as we strive to produce reliable, low-energy slappers. The present manufacturing process uses thick-film, hybrid-circuit, photolithographic processing with solvent-based polymers. Two main problem areas exist:

1. for the multilayer metallization process—poor alignment tolerances and high tooling costs; and
2. for the flyer polymer process—solvent-based aging issues and inadequate hydrodynamic properties.

Project Goals

This three-year project has two goals: reduce the costs associated with creating chip slapper patterns by applying rapid prototyping techniques; and evaluate alternative detonator flyer materials by using LLNL's SolventLess vapor deposition followed by an *In-situ* Polymerization (SLIP) process.

Relevance to LLNL Mission

Efficient chip slapper fabrication can enable future initiation systems with improved safety and performance that would be relevant to both DOE and DoD missions at the Laboratory.

FY2007 Accomplishments and Results

Fabrication of the initial rapid prototyping plan included thick film PVD coatings, gold electroplating combined with photolithography, and femtosecond laser machining to define final geometries (Fig. 1). All coatings and laser definition were within manufacturing tolerances for a slapper device.

Software was written to "direct write" slapper arrays on a processed substrate (Figs. 2-3) with the femtosecond laser (Fig. 4) and is in its preliminary stage of implementation. Once the software for rapid prototyping is complete, it will include a feature that allows the user to arbitrarily change the slapper dimensions quickly (seconds) between runs. Full-scale slapper models are initially laser machined from paper to check dimensions, and repeatability is well within requirements.

The processed substrates must be coated with a protective film before laser-machining operations to avoid recoating and contamination of deposited films. It takes approximately 20 s to cut a simple slapper pattern on a substrate. A substrate full of finished slapper patterns can be machined in approximately 6 min.

The SLIP process consists of monomers in the vapor phase being mixed in a nozzle system and deposited onto a substrate (Fig. 5). Deposited films range in thickness from 6 µm to 100 µm. Substrates remain at room temperature or can be heated. Stoichiometric polyimide has been confirmed with a PMDA/ODA molar ratio of 0.83 for flat substrates. This is quite different from the molar ratio of 1.17 that produced stoichiometric films for ICF targets (Fig. 6). The process parameters for flat substrates are not the same as those for spherical substrates, which made it challenging to find the proper operating conditions since we started with the ratios for ICF applications.

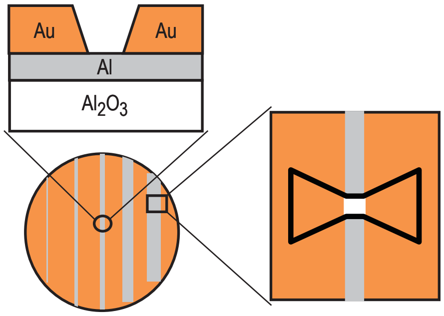

Figure 1. Schematic of thick-film deposition and patterning of Au over Al using femtosecond laser machining to define final geometries.

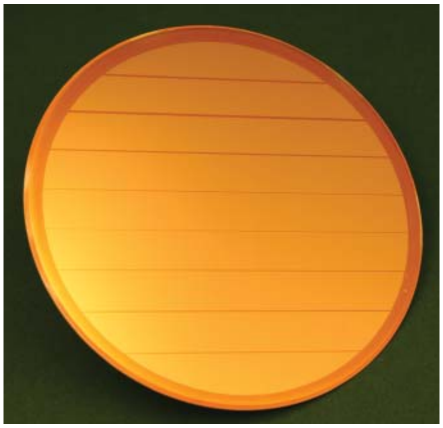

Figure 2. Processed substrate with various bridge widths defined.

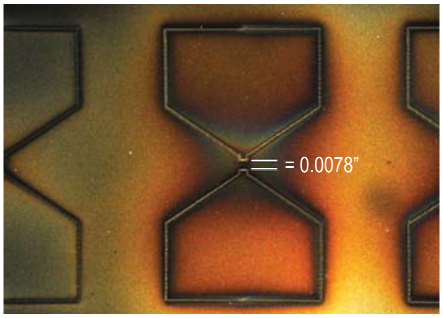

Figure 3. Prototype slappers laser-machined into Au on an alumina substrate.

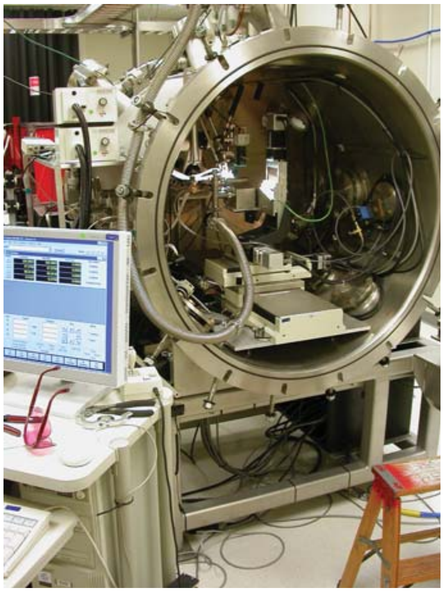

Figure 4. Femtosecond laser micromachining laboratory, which includes a 4-axis motion control system that enables rapid prototyping of slappers and slapper arrays.

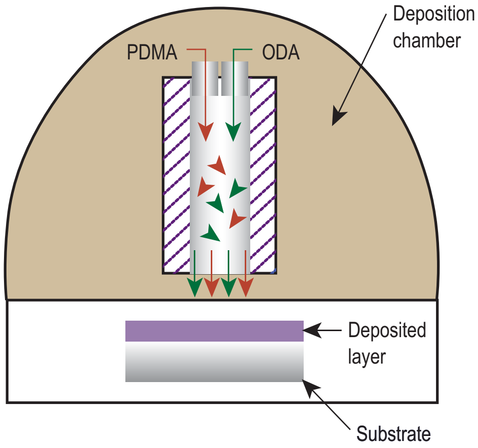

Figure 5. Solvent-less process for deposition of polyimide films.

Significant progress was made extending past work on exploding bridgewire models into a small slapper detonator initiation model. Early attempts looked at fairly sophisticated 2-D representations, but have been reduced to simple 1-D models for the sake of model robustness, and for verification with other modeling attempts and validation against experiments. The present model accepts an electrical stimulus (in the form of a charged external capacitor – a fireset) and predicts burst time, burst current, and flyer speed as functions of chip slapper materials, geometry, and excitation. Recent work focuses on the proper initiation response from the acceptor HE, building toward comparison with experiments planned for the first quarter of FY2008.

FY2008 Proposed Work

Next year we will test the rapid prototyping pattern and compare it to a standard part made by present manufacturing methods. The experimental data will be evaluated alongside the model. Efforts will also include implementing a robust 2-D slapper detonator initiation model and comparing it to the 1-D model for consistency. For the polyimide flyer material, we need to determine the temperature(s) that will produce the desired mechanical film properties, establish adhesion characteristics on multiple materials, and investigate adhesion promoters, if required.

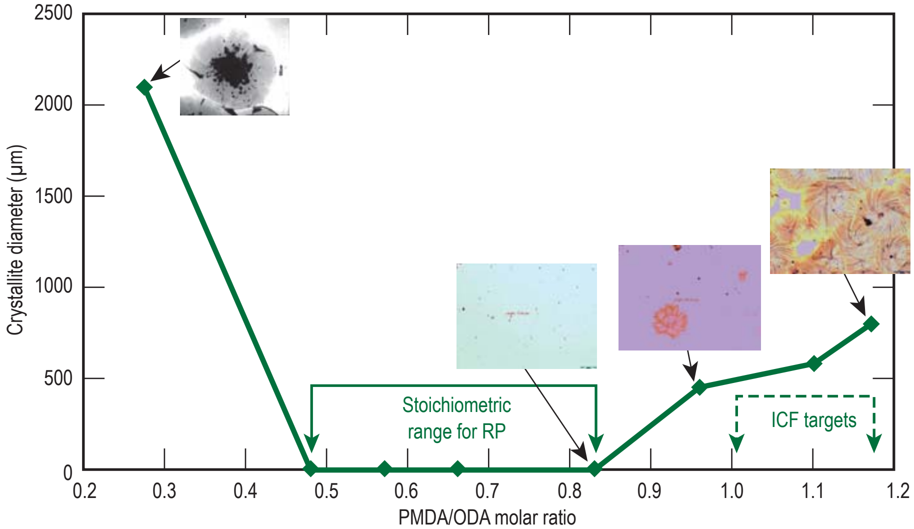

Figure 6. Stoichiometry per molar ratio as determined by crystallite formation.