High Aspect Ratio Metal MEMS (LIGA) Technologies for Rugged, Low-Cost Firetrain and Control Components

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LIGA: Enabling technology for miniaturized fuze components

• What is LIGA?
• Why LIGA?
• (Metal) MEMS S&A Development Program
• LIGA Foundry Capabilities
• Getting Started is Easy
AXSUN Technologies - Corporate Overview

Corporate Overview
- Founded in 1999
- Locations
  - Billerica, MA
  - Livermore, CA
- Employees -- > 100
- Company and management background
  - Telecommunications
  - LIGA precision mechanical components
  - Optical and electrical components
- VC funded

AXSUN Technologies develops, manufactures, and assembles a new class of miniaturized mechanical and optical devices that enable cost-saving, performance-enhancing opto-electronic and mechanical products for communications, defense, life sciences, and industrial applications.
LIGA Is…

- An acronym for the German words for **lithography**, **electroforming**, and **molding**
  - Electroforming is a process for creating 3-dimensional metal parts by using a carefully controlled long-duration electroplating process
- A technology for fabricating highly precise micro components from metals and plastics
- Being commercialized around the world
  - AXSUN is the commercial leader in the U.S.
LIGA - Biggest of the Small Devices

Precision Machining

Surface Dimension

LIGA

Silicon

Vertical Depth

100nm

1 um

50um

1mm

1 um 10 um 500 um 1 mm
LIGA Technology Starts With…

- Individual part designs from CAD files
- Layout and mask fabrication
- Lithography (similar to semiconductor fabrication process)
LIGA - Process Overview

- Photo Mask
- Photolithography
- Development
- Electroplating
- Resist Removal
Alternative Final Part Configurations

Final part options include:

• Leave metal structure itself, including base plate, intact to serve as final product,
  – Or use it as a mold insert for injection molding, hot embossing, or thermoforming high precision plastic parts, or

• The metal structure, including base plate, may be diced into 3-D parts, or

• Finished metal parts can be removed from the base plate (loose parts)
Why LIGA??

• Rugged, high precision metal parts
  – Withstand high pressures and temperatures
  – Transfer useful forces and torques
  – Resist chipping and stiction
• Finished components without micro machining
  – Superior feature definition and radius
  – Ultra-smooth sidewalls
• Readily assembled to create mechanisms
  – Conventional parts feeding; pick and place
• Attach by soldering, welding, brazing, or adhesives
• Superior mechanism performance - - longer mechanical life and reduced power demand
  – Enabled by greater precision, lack of burrs, and smoother, straighter sidewalls
AXSUN: founded to develop a new class of optical capabilities, an *Optical Micro Instrumentation Platform*

- The key feature: order of magnitude reduction in size of components needed to manipulate optical capabilities
- **A key enabling technology - LIGA**
- The **benefits** – Micro instrumentation modules that are
  - Lower cost
  - More precise
  - Easier to integrate with electronic systems
LIGA - - An Enabling Technology
In Telecom Use Today

• High precision metal structures for mounting and aligning micro optical devices

• Why LIGA?
  – Enables both active and passive device alignment
  – Deformable for precise multi-axis alignments to 0.1 micron
  – Rugged - - retains alignment over life of the product
  – Precise surfaces for easy, accurate mounting
  – Increasingly used in customer-proven, Telcordia qualified modules

Benefit - - improved competitiveness
  – Obtains maximum performance from every device, enabling
    • Maximum prices for high performance modules, or
    • Use of lower cost, lower performance devices for greater profits
  • Result - - higher performance at lower cost
Integrating mechanical, optical, and electronic functions

**Processes**
- Precision Pick & Place
- Micro-Joining
- Robotic Alignment
- Final Assembly

**MICRO-OPTICAL TOOLBOX**

**PLASTIC DEFORMATION**

**BENCH**

**SUBSYSTEM**

**MODULE**
# LIGA – Making BETTER Small Parts

<table>
<thead>
<tr>
<th>If You Make</th>
<th>(Sample Uses)</th>
<th>Switching to LIGA could result in</th>
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| • High frequency antenna arrays | Traveling Wave Tubes (TWTs for 80-180 GHZ communications | • Arrays with required 2 micron features  
                                          • (EDM achieved only 20 micron features)                                         |
| • Micro probes                  | Medical instruments:                                    | Rugged, sterile, chip-free, burr-free metal devices with smooth surfaces and precise features  
                           • Catheters                                                   | Smaller devices than other fabrication methods                                      |
| • Grippers                      |                                                          |                                                                                                   |
| • Cutters                       |                                                          |                                                                                                   |
| • Motors                        |                                                          |                                                                                                   |
| • Micro-nozzle arrays           | Biomedical and bio-analytical devices for:              | Finer, more uniform droplet size for improved drug inhalation  
                           • Drug delivery                                                | More precise dosage control                                               |
| • Micro-fluidic delivery systems|                                                          |                                                                                                   |

Switching to LIGA could result in:

- Arrays with required 2 micron features
- (EDM achieved only 20 micron features)
- Rugged, sterile, chip-free, burr-free metal devices with smooth surfaces and precise features
- Smaller devices than other fabrication methods
- Finer, more uniform droplet size for improved drug inhalation
- More precise dosage control
LIGA – Making BETTER Small Parts

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<td>• Cams • Gears • Levers</td>
<td>Wristwatches -- Proven high-volume production (100 million parts/year)</td>
<td>Burr-free parts with smooth, straight sidewalls for readily assembled, smoother operating mechanisms Benefit -- Longer mechanical life and substantially longer battery life</td>
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<td>• Frames • Springs • Sliders • Latches</td>
<td>Safe and Arm devices for gun-launched munitions • Replacing devices previously made with watchmaker’s tools (EDM, stamping, etc.)</td>
<td>Parts and operating mechanisms that can be • 75% smaller • Rugged (proven to withstand 65,000 g’s) • Inexpensive • Reliable</td>
</tr>
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(Metal) MEMS S&A Development Program

- **Customer:** PM Individual Weapons
- **Program Sponsor:** JSSAP (OICW System Enhancements STO)
  - Joel Goldman, Chief; Camilo Sanchez, STO Manager
- **Task A:** Explore advanced fabrication processes for improved, more economical production
- **Task B:** Fabricate and deliver LIGA parts and assemblies
- **Objectives:**
  - Rugged alternative to present (“watchworks”) S&A
    - 50% less cost and 75% smaller
  - Demonstrate advanced fabrication processes with potential to meet cost and size objectives
- **Key milestones:**
  - Contract start: Sept 2002
  - First hardware delivery: Complete
  - Advanced process development: Underway
Fuzing: Beyond Today’s Devices

• Requirements for munitions command, control, and fuzing demand
  – Increasingly complex functions
  – Smaller size
  – Lower cost
  – Higher precision
  – Lighter weight
  – High reliability
  – Reduced hazard of unexploded ordnance left on the battlefield

• LIGA-based devices
  – Readily integrated with micro optics and microelectronics
  – Enable multi-function modules that meet above demands
Foundry Manufacturing Capabilities

• Virtually any shape that can be drawn in two dimensions and which has vertical sidewalls (thickness)
• Individual part size
  – Max. lateral -- must fit within 3.4 inch diameter circle (parts typically oriented on their sides)
• Thickness -- 100 microns, min. to several mm max.
• Parts per wafer
  – From 1 to over 2500
• Materials
  – Metals -- Ni, Ni-Fe, Ni-Co, Au, Cu, Ag
    • Custom material properties (yield strength, grain size, and stiffness) if required
    • Solderable and optically black surfaces available
  – Plastics -- PMMA (acrylic; Plexiglas); Teflon
    • PMMA surfaces can be metallized, if required
• Feature sizes
  – Min. feature sizes, line widths, and spaces: 20 microns
    • Smaller features possible, depending on surrounding geometry
• Aspect ratios (ratio of feature height to width)
  – Standard maximum 70:1
  – Higher ratios possible
• Sidewall straightness/perpendicularity
  – ~1 micron per mm (~1 degree)
  – Slight tapers possible for mold draft
• Surface texture
  – Vertical (sidewall) surfaces defined within <1 micron; Ra <50 nm
  – Lateral surfaces can be lapped and polished to mirror finish
Quality Assurance and Analytical Capabilities

A good LIGA foundry will have

- ISO 9001:2000-based Quality System
- Statistical Process Control (SPC)
- Material Properties
  - Grain structure control
  - Material characteristics
- Metrology
  - Planarity and dimensional stability
  - Dimensions and tolerances, spring pitch variation, thickness, etc.
- Mechanical Properties
  - Yield strength
  - Spring constants
Materials Testing For Process Control

LIGA Tensile Bar

Gage length 1mm

LIGA Grain Structure
Summary

• **What is LIGA?**
  – Technology for fabricating precise micro components from metals and plastics

• **Why LIGA?**
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    • Resist chipping and stiction
  – Finished components without micro machining
    • Superior feature definition and radius
    • Ultra-smooth sidewalls
  – Readily assembled to create mechanisms
  – Attach by soldering, welding, brazing, or adhesives
  – Easily integrated with electronics and optics

LIGA Manufacturing - - Enabling Technology for Next Generation Products
Getting Started is Easy…

• Send specifications and CAD design files for producibility analysis and quotation
  – Contact Mr. Bill Bonivert bbonivert@axsun.com
  – Ph: 925-373-3174 x 101

• AXSUN fabricates mask and sample parts
  – Try many designs on one wafer
  – Initial parts in as little as 6 weeks

• Evaluate samples

• Ramp up production
  – Sample mask can be initial production tool
    • Next parts in as little as 3 weeks

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