



AXSUN
TECHNOLOGIES



Leadership
Teaming
Communication
Employee Support
Strategic Thinking
Organizational Climate

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

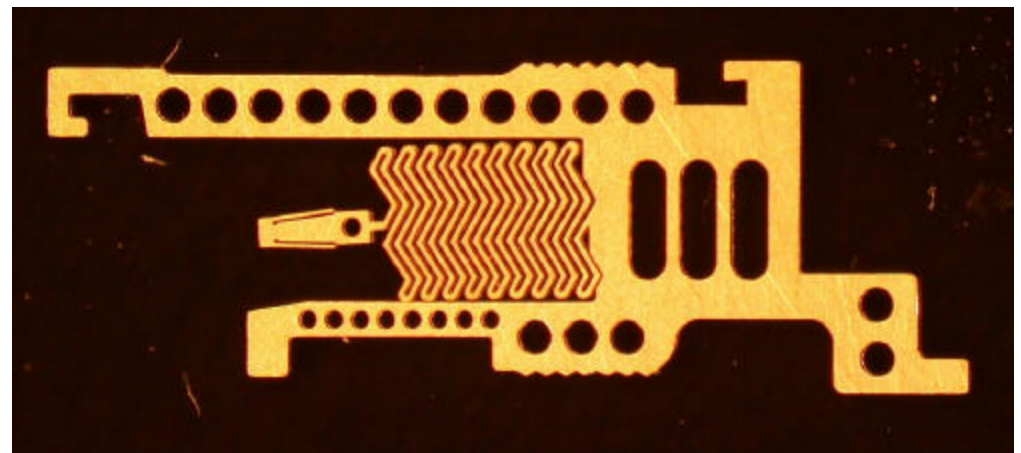
John Rasmussen, William Bonivert, John Krafcik

*NDIA 47th Annual Fuze Conference
April 10, 2003*

UNCLASSIFIED

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



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

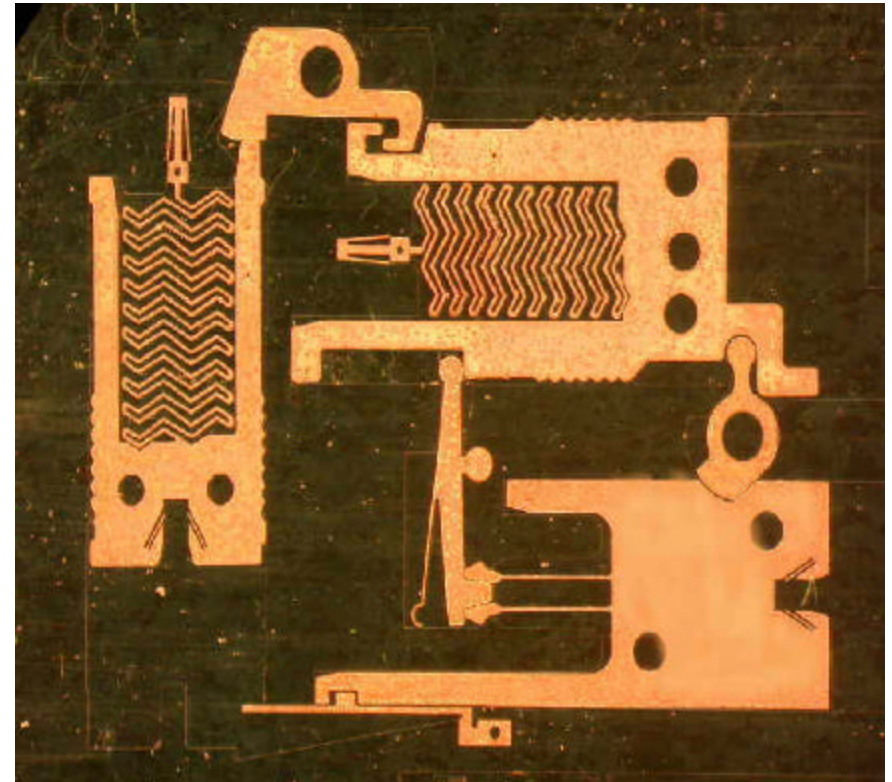
develops, manufactures, and assembles a new class of miniaturized mechanical and optical devices that enable cost-saving, performance-enhancing opto-electronic and mechanical products for communications, defense, life sciences, and industrial applications.



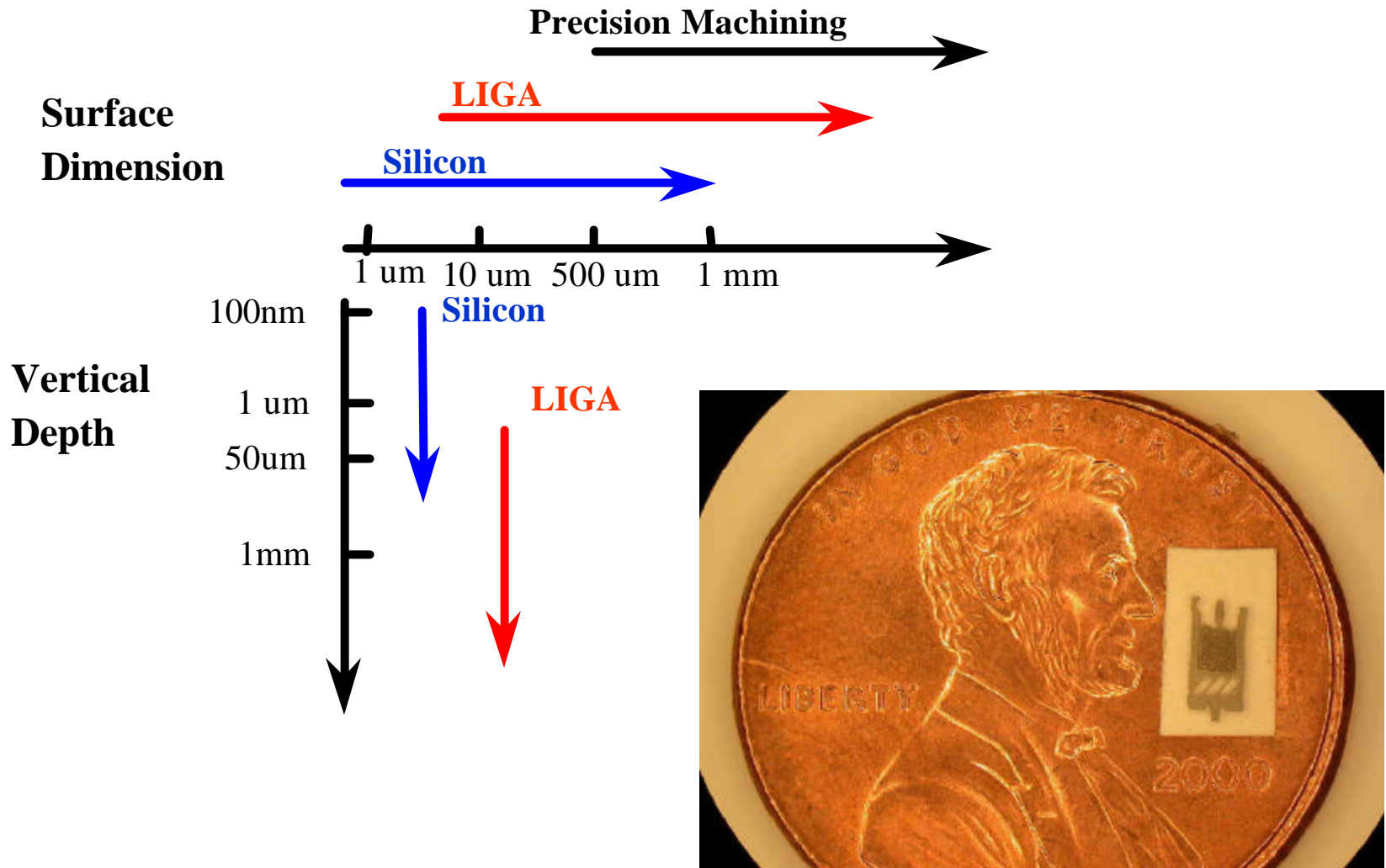
Livermore, CA

LIGA Is...

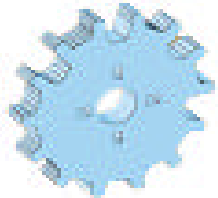
- An acronym for the German words for **lithography, electroforming, and molding**
 - Electroforming is a process for creating 3-dimensional metal parts by using a carefully controlled long-duration electroplating process
- A technology for fabricating highly precise micro components from metals and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



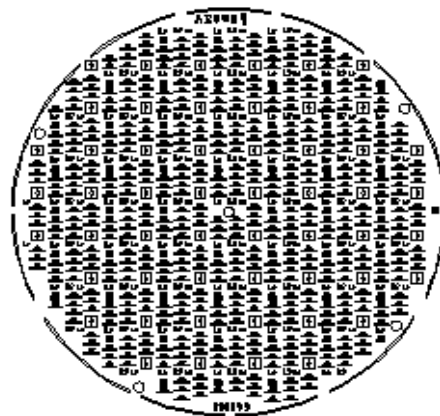
LIGA - - Biggest of the Small Devices



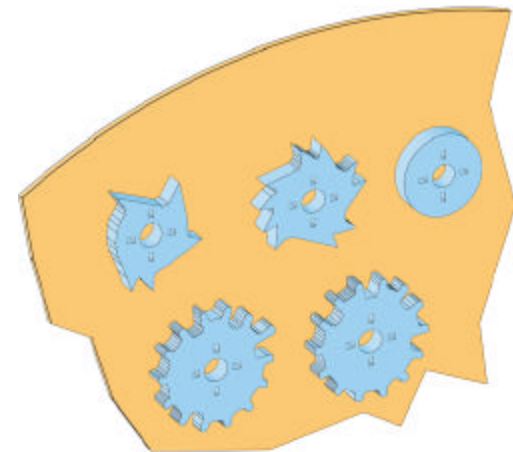
LIGA Technology Starts With...



**Individual
part designs
from CAD
files**



**Layout and mask
fabrication**



**Lithography (similar to
semiconductor fabrication
process)**

LIGA - -Process Overview

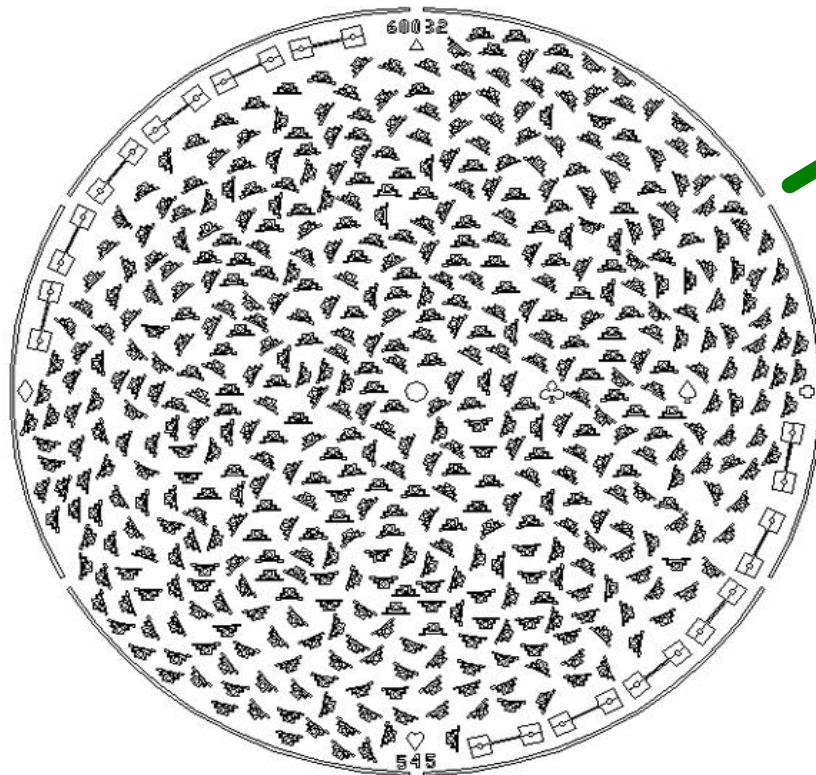


Photo Mask

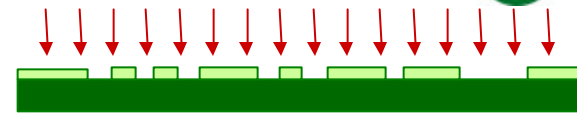
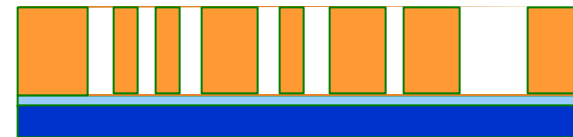
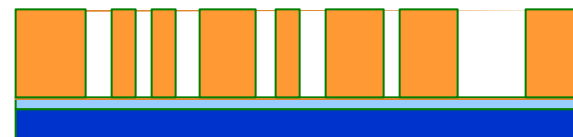


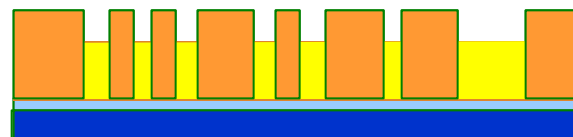
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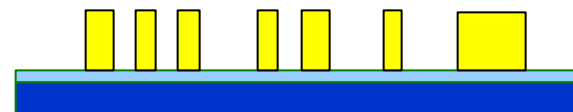
Photolithography



Development



Electroplating

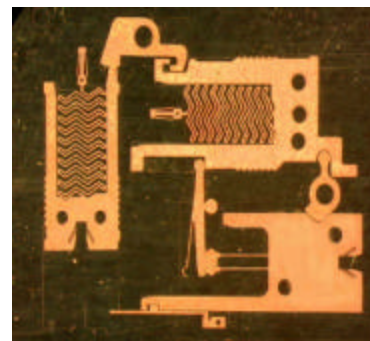
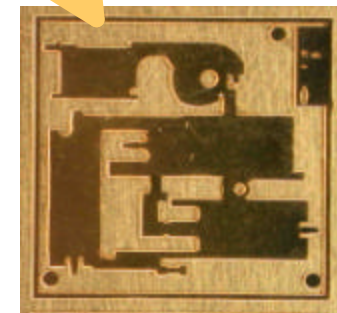
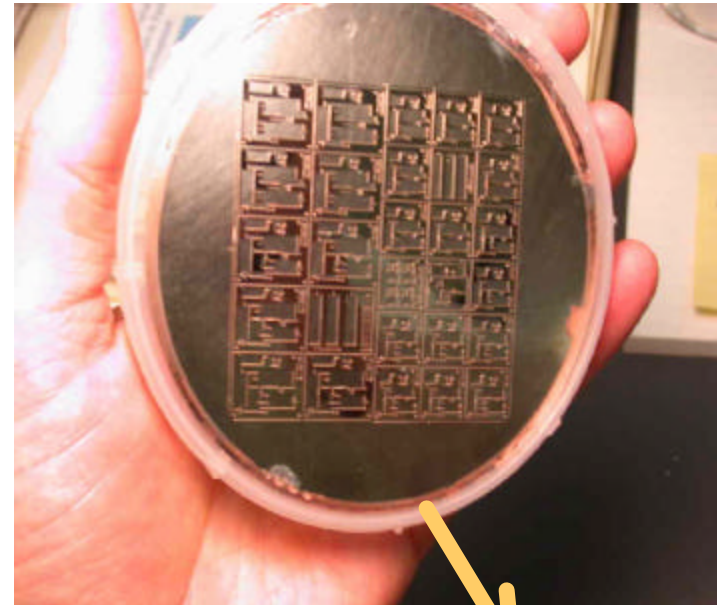


Resist Removal

Alternative Final Part Configurations

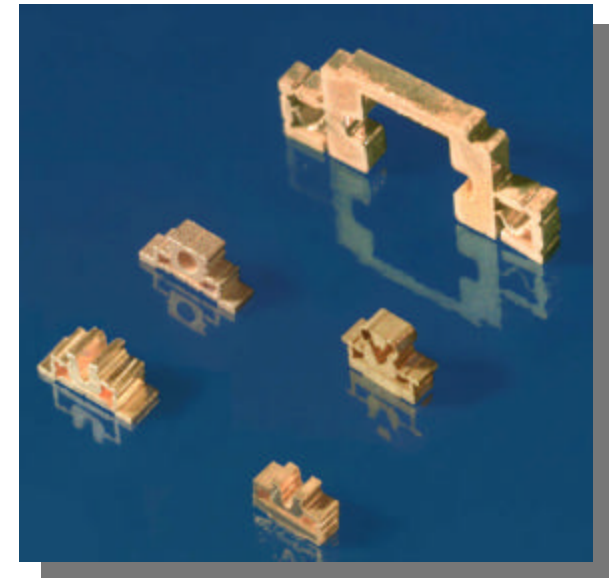
Final part options include:

- 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)

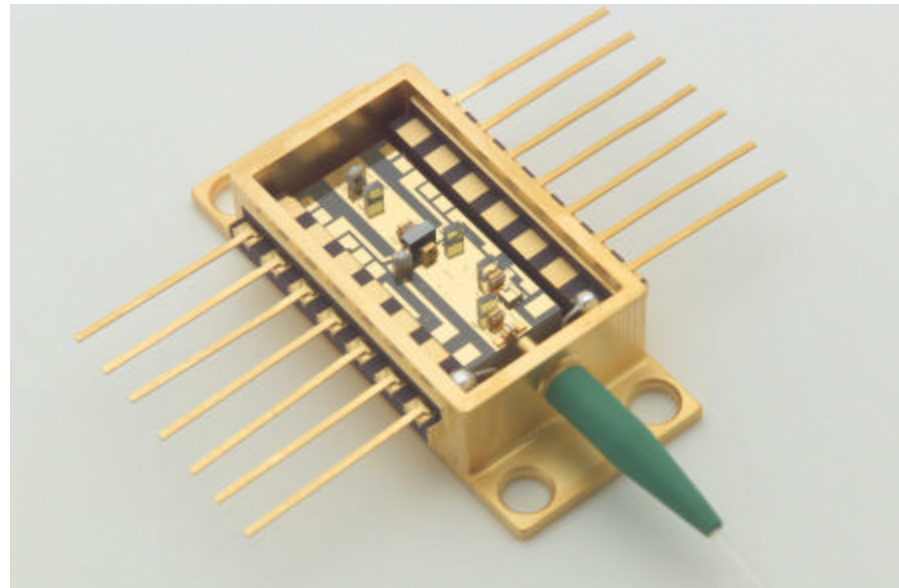
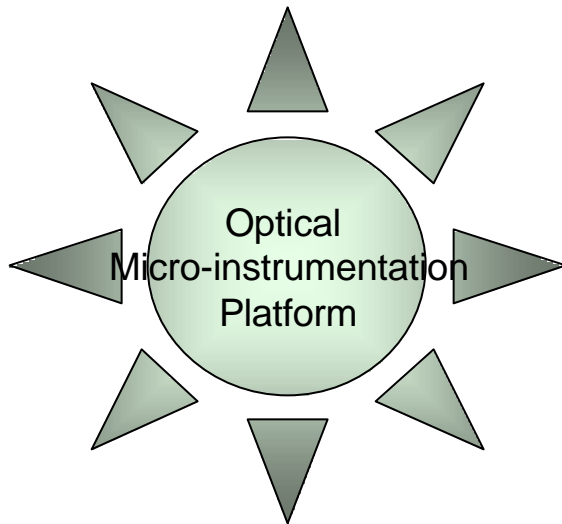


Why LIGA??

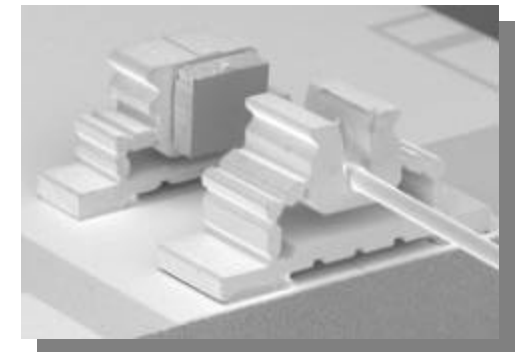
- **Rugged, high precision metal parts**
 - Withstand high pressures and temperatures
 - Transfer useful forces and torques
 - Resist chipping and stiction
- **Finished components without micro machining**
 - Superior feature definition and radius
 - Ultra-smooth sidewalls
- **Readily assembled to create 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



LIGA Enables Micro Instrumentation Modules



- 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-fabricated
lens and fiber
alignment structures**

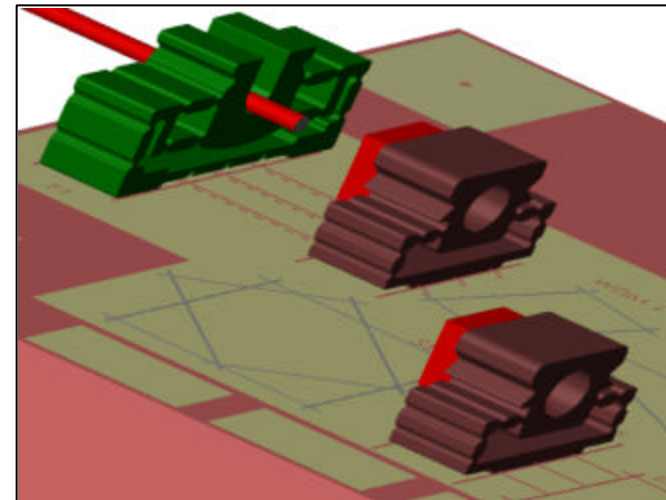
LIGA - - An Enabling Technology In Telecom Use Today



- **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

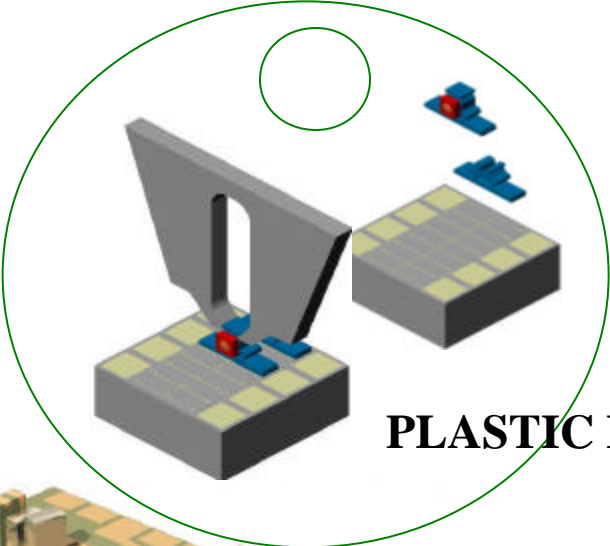
- **Obtains maximum performance from every device, enabling**
 - **Maximum prices for high performance modules, or**
 - **Use of lower cost, lower performance devices for greater profits**
- **Result - - higher performance at lower cost**



Integrating mechanical, optical, and electronic functions



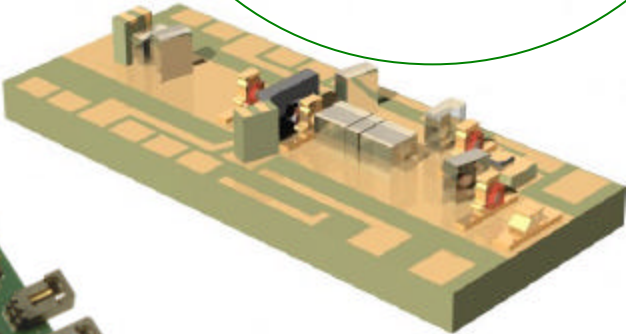
MICRO-OPTICAL TOOLBOX



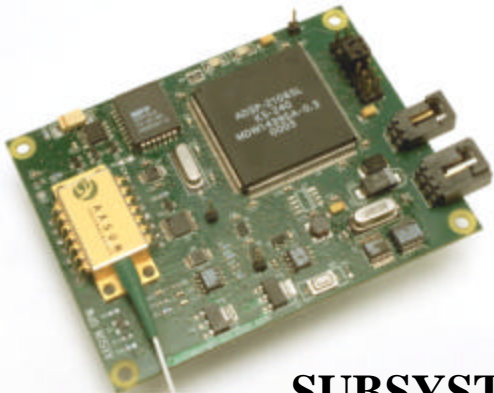
PLASTIC DEFORMATION

Processes

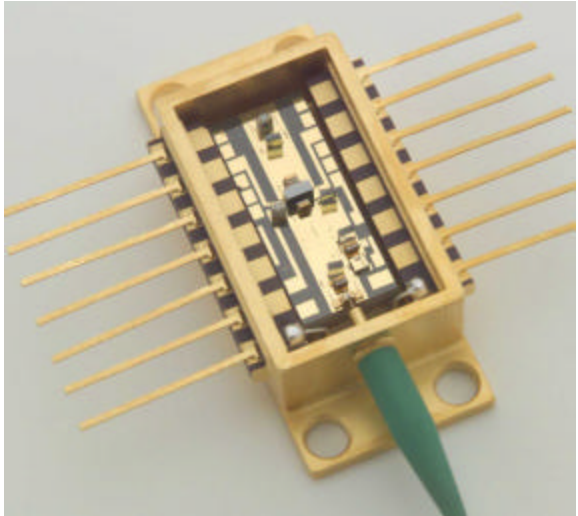
- Precision Pick & Place
- Micro-Joining
- Robotic Alignment
- Final Assembly



BENCH



SUBSYSTEM



MODULE

LIGA – Making BETTER Small Parts

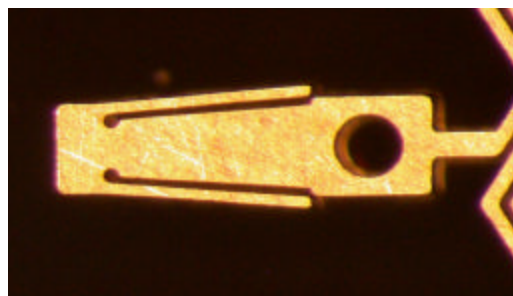
If You Make	(Sample Uses)	Switching to LIGA could result in
<ul style="list-style-type: none"> • High frequency antenna arrays 	Traveling Wave Tubes (TWTs for 80-180 GHZ communications)	<ul style="list-style-type: none"> • Arrays with required 2 micron features • (EDM achieved only 20 micron features)
<ul style="list-style-type: none"> • Micro probes • Grippers • Cutters • Motors 	Medical instruments: <ul style="list-style-type: none"> • Catheters • Endoscopes 	Rugged, sterile, chip-free, burr-free metal devices with smooth surfaces and precise features Smaller devices than other fabrication methods
<ul style="list-style-type: none"> • Micro-nozzle arrays • Micro-fluidic delivery systems 	Biomedical and bio-analytical devices for: <ul style="list-style-type: none"> • Drug delivery • DNA sequencing 	Finer, more uniform droplet size for improved drug inhalation More precise dosage control



LIGA – Making BETTER Small Parts



If You Make	(Sample Uses)	Switching to LIGA could result in
<ul style="list-style-type: none"> • Cams • Gears • Levers 	Wristwatches -- Proven high-volume production (100 million parts/year)	Burr-free parts with smooth, straight sidewalls for readily assembled, smoother operating mechanisms Benefit -- Longer mechanical life and substantially longer battery life
<ul style="list-style-type: none"> • Frames • Springs • Sliders • Latches 	Safe and Arm devices for gun-launched munitions <ul style="list-style-type: none"> • Replacing devices previously made with watchmaker's tools (EDM, stamping, etc.) 	Parts and operating mechanisms that can be <ul style="list-style-type: none"> • 75% smaller • Rugged (proven to withstand 65,000 g's) • Inexpensive • Reliable



(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



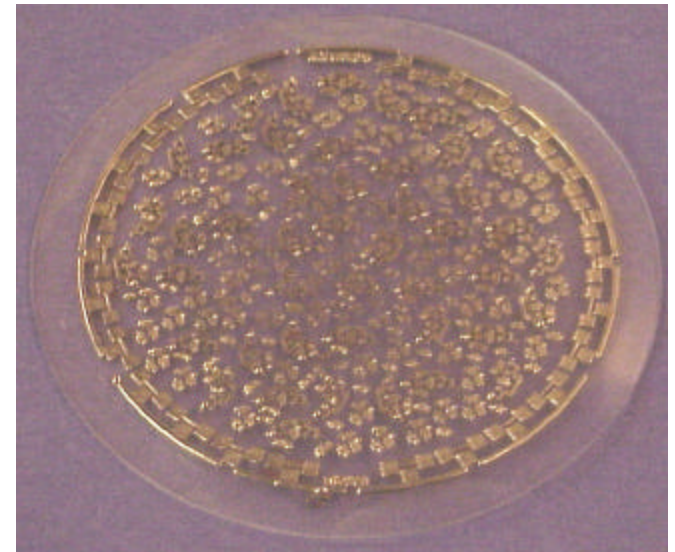
- Requirements for munitions command, control, and fuzing demand
 - Increasingly complex functions
 - Smaller size
 - Lower cost
 - Higher precision
 - Lighter weight
 - High reliability
 - Reduced hazard of unexploded ordnance left on the battlefield
- LIGA-based devices
 - Readily integrated with micro 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



Foundry Manufacturing Capabilities (Cont)



- 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 <math><1</math> micron; $R_a < 50</math> nm$
 - Lateral surfaces can be lapped and polished to mirror finish



Quality Assurance and Analytical Capabilities

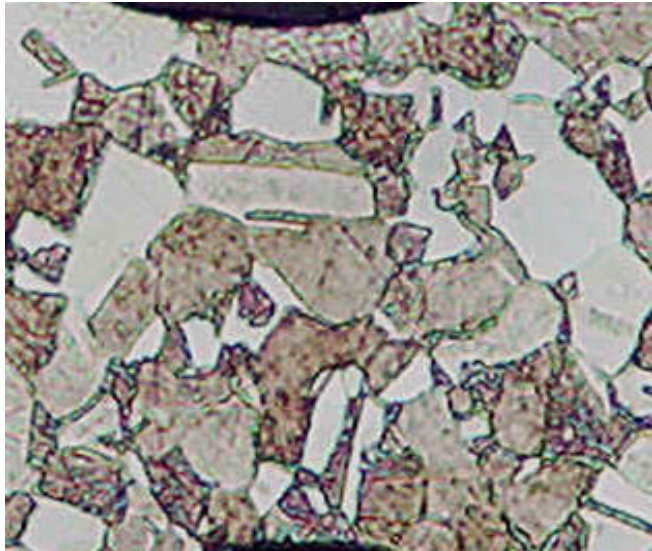
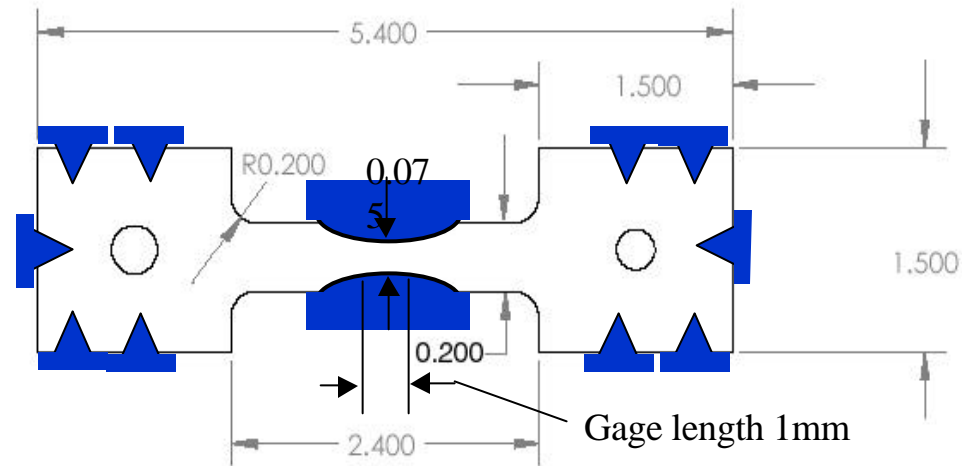


A good LIGA foundry will have

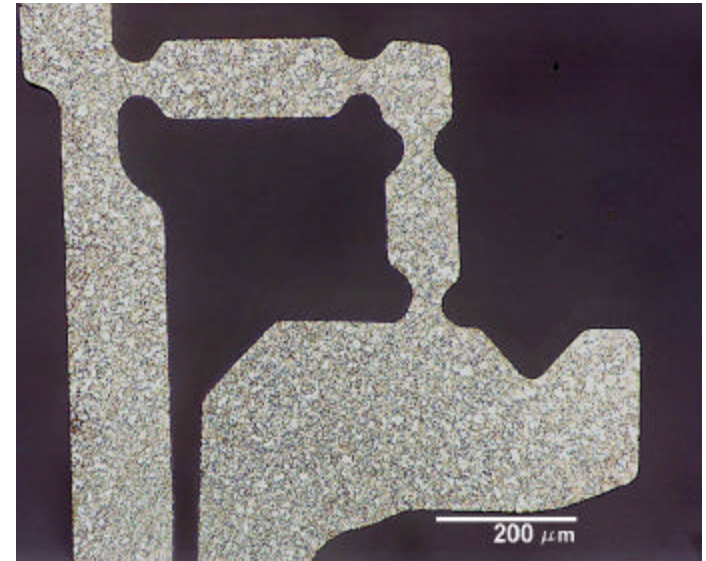
- ISO 9001:2000-based Quality System
- Statistical Process Control (SPC)
- Material Properties
 - Grain structure control
 - Material characteristics
- Metrology
 - Planarity and dimensional stability
 - Dimensions and tolerances, spring pitch variation, thickness, etc.
- Mechanical Properties
 - Yield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



LIGA Tensile Bar



LIGA
Grain Structure



- **What is LIGA?**
 - Technology for fabricating precise micro components from metals and plastics
- **Why LIGA?**
 - Rugged, precise 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
 - 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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