ADVANCED THIN FILM TECHNOLOGIES TOUR
• Provider of technically demanding RF/microwave, electromagnetic, power, and security solutions for defense, aerospace and commercial industries
• Founded in 1981; Listed on NASDAQ June 2011 with a new company vision
  – Today, one of the largest non-Prime provider of RF/Microwave and microelectronics
• 1,975 employees worldwide
• 3,000+ customers worldwide
• Revenue breakdown
  – ~75% Domestic / 25% International
  – ~60% Defense & Government / 40% Commercial
• 12 Trusted facilities worldwide (US, UK, Canada)

• Technology focused: Nearly 20% of our employees are engineers and skilled design professionals

• International manufacturing locations are API companies - not subcontractors; same equipment and processes as U.S.
RF/Microwave & Microelectronics – US Division:

30 Years Of Design and Manufacturing Experience

- **CMT (Commercial Microwave Technology)**
  - Rancho Cordova, CA
    - (Acquired November 2011)

- **Spectrum Microwave** (Acquired June 2011)
  - Columbia, MD
    - Acquired July 2002 (FSY)
  - Delmar, DE
    - Acquired February 2004 (Salisbury Engineering)
  - Melbourne, FL
    - Acquired October 2004 (Q-bit)
  - Philadelphia, PA
    - Acquired February 2005 (Amplifonix)
  - State College, PA
    - Acquired January 2007 (EMF Systems)
  - Marlborough, MA
    - Acquired September 2008 (SatCon)
    - Acquired December 2009 (Micro Networks)
  - Nashua, NH
    - Acquired June 2010 (Sage Laboratories)

- Additional API Facilities Utilized by the RF2M Group include Mexico & China
- Over 600 RF2M Employees
API Technologies 45,000 ft² facility to support the combined manufacturing and engineering operations of our Worcester and Marlborough facilities, located in the Marlborough, Massachusetts Technology Park. The facility is AS9100 registered and fully certified to MIL-PRF-38534 Class H and Class K standards.

API is a designer and manufacturer of RF/microwave and hybrid components, microwave, MMW, and microelectronic assemblies for defense, space systems, satellite, high-rel commercial, communications, avionics and ruggedized industrial applications.

API Benefits
- 30,000 square feet of Class 100,000 Clean Room
- Prototypes, Production and Qualification
- Reduce Size/Lower Weight
- Improve Performance and Reliability
- Full Temperature Testing
- Environmental Stress Screening
- MIL-PRF-38534 Class H / K
KEY SUPPLIER TO SATELLITE/SPACE PROGRAMS

Only 19 facilities worldwide have MIL-PRF-38534 Class K (Space) certification.

Two of them are ours.

MIL-PRF-38534
Class K

Deep Space
• Galileo
• Cassini
• USERS
• Mars Phoenix
• OCO
• LCROSS
• Mars Satellite Lab
• ISS Kibo EF

Scientific Missions
• SAOCOM
• Hershel Plank
• Grail
• EnMap
• AMS-02
• Lisa Pathfinder
• Meteosat
• Juno

Communications
• Sirius Radio
• DirectTV
• Olympus
• Optus 10
• Amazonas 3
• GPS-2F
• Thor 7
• MUOS
• Inmarsat
• Intelsat
• Hot Bird

Launch & Reentry
• Curiosity
• Taurus
• Minuteman
• HII
COMPLETE SOLUTION PROVIDER

Technologies
- Mixed Signal & Power
- RF, Microwave & MMW
- Optoelectronics
- Space
- Thin Film / SAW Wafer
- Power Conversion / Regulation

Markets
- Defense (MIL-PRF-38534 Class H)
- Space (MIL-PRF-38534 Class K)
- Avionics
- Hi-Rel Commercial
- Ruggedized Industrial
- Secure Communications

Capabilities
- Advanced Engineering
- High Density Manufacturing
- DC-50 GHz
- High Reliability
- Class K Certified Facility
- Thin Film / SAW Wafer Fab
THIN FILM & SAW FAB

Capabilities
- Laser Cutting
- Metal Deposition
- Photo Lithography
- Auto Step Reticle Stepper
- Precision Photo Resist
- Automated Developer Application
- Ion Etching
- Pack
- Auto Probe & Trim
- Auto Wafer Dicing
- Active or Passive Laser Trim
API Technologies provides a complete solution for thin film products. API has extensive experience with thin film design, manufacturing and quality. Our thin film capabilities include multiple substrate materials, conductor and resistor layers of various materials, plated through and filled interconnects, protective coatings and laser trimming, among others. API engages with our customers from design concept and layout assistance, prototype development and full production support.
API commonly uses several different materials for our thin film products, including alumina, beryllium oxide, aluminum nitride, fused silica quartz, titanates, ferrites and garnets. The materials are chosen for suitability for the application. Alumina is the most common substrate, but applications with high power dissipation tend to use BeO and AlN substrates for their thermal conductivity and high frequency applications would tend to use fused silica quartz for its low dielectric constant.
## TYPICAL PROPERTIES OF COMMON THIN FILM SUBSTRATES

<table>
<thead>
<tr>
<th>Properties</th>
<th>Units</th>
<th>99.6% Alumina</th>
<th>Beryllium Oxide</th>
<th>Aluminum Nitride</th>
<th>Fused Silica Quartz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular Structure</td>
<td>Al2O3</td>
<td>BeO</td>
<td>AlN</td>
<td></td>
<td>SiO2</td>
</tr>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td>3.87</td>
<td>2.85</td>
<td>3.28</td>
<td>2.2</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion (CTE)</td>
<td>10⁻⁶</td>
<td>7.0⁻³</td>
<td>9.0</td>
<td>4.6</td>
<td>0.55</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>Watts/m-K</td>
<td>26.9</td>
<td>270</td>
<td>170</td>
<td>1.3</td>
</tr>
<tr>
<td>Dielectric Constant</td>
<td></td>
<td>9.9</td>
<td>6.5</td>
<td>8.6</td>
<td>3.83</td>
</tr>
<tr>
<td>Dissipation Factor @ 1 MHz</td>
<td></td>
<td>0.0001</td>
<td>0.0004</td>
<td>0.001</td>
<td>0.000015</td>
</tr>
</tbody>
</table>
Metal schemes include Gold, Copper, Nickel, Titanium Tungsten, Nichrom and Tantalum Nitride lines/spaces to ± 0.000050".

Gold plated or metallized vias for improved ground plane connection or heat dissipation.

BeO, Alumina, Aluminum Nitride, Silicon and Ferrites are just some of the substrate materials available.

Selective 360° deposition allows for Gold to be deposited with a thickness of 100-400 micro inches.
# RESISTOR FILM PROPERTIES

<table>
<thead>
<tr>
<th>Material</th>
<th>Ohms/square range</th>
<th>Temperature Coefficient of Resistance (ppm/°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel Chromium (NiCr)</td>
<td>50 to 350</td>
<td>±50, ±25</td>
</tr>
<tr>
<td>Tantalum Nitride (TaN)</td>
<td>10 to 100</td>
<td>-75 to -120</td>
</tr>
</tbody>
</table>
Vias

API Technologies offer plated through vias, gold filled vias and copper filled vias. These vias allow for excellent electrical and thermal paths to the ground plane, which will provide better performance for the intended application.

Filled vias provide better electrical and thermal conductivity for RF/Microwave than plated through holes, and are preferable for high power applications. Filled vias and plated through holes both provide electrical connections to the ground plane and interconnects for thin film substrates with patterns on both sides of the substrate.
COPPER FILLED VIAS

• Copper filled vias provide a cost efficient solution to rising costs as the price of gold has risen more than 300% over the last decade.

• Copper technology offers increased thermal and electrical conductivity over gold.

• Copper filled vias are the preferred technology available for commercial packaging, hybrid manufacturers, and microelectronics providers in need of a high reliability and high conductivity substrate.
FILLED VIAS vs. PLATED THROUGH HOLES

- Filled vias provide higher conductivity and better thermal conductivity for RF/Microwave than plated through holes, and are preferable for high power applications.

- Filled vias and plated through holes both provide electrical connections to the ground plane in thin film substrates (also on PWBs/PCBs and thick film). Also, it provides interconnects for thin film substrates with patterns on both sides of the substrates.
Polyimide can be customized to meet a variety of shapes and dimensions, thereby providing versatility and flexibility with your design requests.

Adding a second layer of Polyimide helps protect the delicate bridge from structural damage during the assembly process.

Another example of adding value through innovation is found while utilizing Polyimide for bridges and dams. The advantage of poly bridges over traditional air bridges is that non-conductive polyimide adds a level of support preventing the bridge from collapsing onto the circuit below. We have taken that process one step further by adding a second layer of polyimide on top of the bridge, complementing the foundation of structural integrity added to the bridge process by the base Polyimide layer.

Polyimide, which when added traditionally allows for repeatable coupler lines and spaces as small as 0.0006".
With over 4 decades of sputtering experience, we are the premier choice for thin film metallization solutions.

- Titanium Tungsten
- Nickel
- Platinum
- Chromium
- Palladium
- Gold
- Copper
- Aluminum
- Silver
ADVANCED THIN FILM TECHNOLOGIES

Sputtering Equipment
- KDF954
- KDF943
- MRC954
- Load lock systems
- 12” x 12” pallette size

Process
- Multiple sputtering systems with multiple targets
- Improved lead times with reduced target changes
- Alkaline cleaning with DI water rinse
- 12” x 10” sweet spot
Photolithography and Etching

- Positive Resist
- Wet etching available for Au, TiW, Ta, NiCr, Ni, Cu, Ti, SiO2
- Minimum Geometrical Etching
  - Conductors: 0.6 mils (0.1 tolerance)
  - Resistors: 0.2 mils (0.04)
Design Guide

*Thin Film Metallized Substrates*

This useful layout guide, with its accompanying metals and their functions outline, should help serve as a resource for both the CAD specialists, as well as the engineer involved in the design of the substrate or PC board. Helpful resistor values along with material types and their range of functions is included and is another example of why API Technologies leads the industry in both innovation AND customer service.

### Sample Resistor Layout Guide

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value Inches (µm)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistor Style</td>
<td>Type-1</td>
<td>Resistor inboard of conductor</td>
</tr>
<tr>
<td>Min. Resistor Dim.</td>
<td>0.002 x 0.002 (50 x 50)</td>
<td></td>
</tr>
<tr>
<td>Min. Probe Pad Dim.</td>
<td>0.003 x 0.003 (75 x 75)</td>
<td>Perpendicular to current flow</td>
</tr>
<tr>
<td>Conductor/Resistor Overlap</td>
<td>0.0005 (12.5) per side min. 0.002 (50) per end</td>
<td>Parallel to current flow</td>
</tr>
</tbody>
</table>

### Metals and their Functions

<table>
<thead>
<tr>
<th>Material Function</th>
<th>Material Type</th>
<th>Range of Functions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>Tantalum-Nitride (TaNi)</td>
<td>10 - 150 Ω/square (Min)</td>
<td>Best for non-hermetic environment</td>
</tr>
<tr>
<td></td>
<td>Nickel-Chromium (NiCr)</td>
<td>20 - 350 Ω/square (Min)</td>
<td>Low TCR</td>
</tr>
<tr>
<td></td>
<td>Chromium-Silicon (CrSi)</td>
<td>500 - 1500 Ω/square</td>
<td>Small package hi-value resistors</td>
</tr>
<tr>
<td>Adhesion</td>
<td>Titanium - Tungsten (TiW)</td>
<td>250 - 750 Angstroms</td>
<td>Ideal for high temperatures</td>
</tr>
<tr>
<td></td>
<td>Chromium (Cr)</td>
<td>250 - 750 Angstroms</td>
<td>Low temperature limitation</td>
</tr>
<tr>
<td>Barriers</td>
<td>Nickel (Ni) - Sputtered</td>
<td>750 - 20000 Angstroms</td>
<td>Standard barrier</td>
</tr>
<tr>
<td></td>
<td>Nickel (Ni) - Plated</td>
<td>40 - 100µ in. (1 - 2.5µm)</td>
<td>High conductivity barrier</td>
</tr>
<tr>
<td>Conductors</td>
<td>Copper (Cu)</td>
<td>30 - 500µ in.</td>
<td>High power/solderable</td>
</tr>
<tr>
<td></td>
<td>Gold (Au)</td>
<td>10 - 200µ in. (0.25 - 5 µm)</td>
<td>Tight tolerance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fine line features available</td>
</tr>
</tbody>
</table>
API offers a wide variety of thin film chip resistors as standard products. There are multiple options available that provide options for substrate material, resistor material, temperature coefficient of resistance, resistor value and tolerance and size.
THIN FILM CHIP RESISTORS

Core Competencies
• Silicon or alumina substrate
• Resistor tolerance 0.1%
• Back side contact options
• Pre-soldered options
• Tantalum Nitride or Nickel Chrome resistor materials
• Passivation as required

Processing Steps
• 100% sputter thin film
• Conductor and resistor photolithography and etch
• Stabilization
• YAG laser trim
• Passivation as required
• 100% Visual inspection

Chip Resistor Sizes
• Single Tap .020 x .020 Series
• Single Tap .020 x .040 Series
• Single Tap .030 x .030 Series
• Center Tap .030 x .030 Series
• Multi Tap .030 x .030 Series
• Single Tap .040 x .040 Series
• Single Tap .050 x .050 Series
• Single Tap .050 x .100 Series
Values and Tolerances Schematic

API Technologies knows that critical attention to artwork dimensions and tolerances is of paramount importance during a design packet transfer. To assist with this critical step in the design process, we provide an illustration as seen here, which includes suggested values and tolerances that should be followed in order to facilitate a complete and comprehensive design packet.
QUALITY AND RELIABILITY – Marlborough Facility

- **AS9100:2009 Certified - DNV**

- **MIL-PRF-38534 Certified and Qualified - DLA Land and Maritime**
  - MIL-PRF-38534, Class K and H Certified Hybrid Microcircuits
  - MIL-PRF-38534, QML-38534 Qualified Processes and Materials
  - MIL-PRF-38534, Thin Film Chip Resistor & Substrate Fab
  - MIL-STD-883 Test Methods - DLA Lab Suitability

- **Other Specifications Guidelines**
  - J-STD-001
  - IPC-A-610

- **Quality Assurance Programs**
  - Calibration Recall System for Test and Measurement Equipment
  - ESD Program
  - Failure Analysis and Corrective Action System
  - AS9100 and MIL-PRF-38534 Internal Audit Program
  - Operator Training and Recertification Program
MIL-PRF-38534
HYBRID MICROCIRCUIT CERTIFICATION
FOR
CLASSES K and H
IS HEREBY AWARDED TO

SPECTRUM MICROWAVE
400 Nickerson Road
Marlborough, MA 01752

THIS CERTIFICATION IS VALID UNTIL TERMINATED BY WRITTEN NOTIFICATION FROM DLA LAND AND MARITIME. REFERENCE DLA LAND AND MARITIME LETTER VQ(VQH-12-024940) FOR DETAILS PERTAINING TO THIS CERTIFICATION.

SAMUEL E. MERRITT
Director, Operations Support Directorate
DLA Land and Maritime
DNV BUSINESS ASSURANCE
MANAGEMENT SYSTEM CERTIFICATE

Certificate No. 137259-2013-AQ-USA-ANAB

This is to certify that

API Technologies Corp.- Spectrum Microwave

at

400 Nickerson Road, Suite #1, Marlborough, MA 01752 USA

has been found to conform to the Management System Standard:
API’s Thin Film products all have the highest quality screenings which will provide assurances of performance and reliability for any application.

- MIL-PRF-38534
- Class H and K
- AS9100
- In-House Thin Film Fabrication Line
DESIGN & DEVELOPMENT PROCESS

1. Specification Development
2. Simulation & Design
3. Prototyping
4. Testing
5. Manufacturing
6. Logistics
Custom Thin Film Substrates & Thin Film Chip Resistors

Points of Contact

Paul Possemato
Microelectronics Business Development Manager
Paul.Possemato@apitech.com

Michael Schweyer
Product Line Manager
Michael.Schweyer@apitech.com

Mark Sullivan
Engineering Manager
Mark.Sullivan@apitech.com