VOLTAN™ Specialty Additives for Electronics
we are THE BETTER WAY.

An Introduction to ANGUS Chemical Company
Dedicated to Performance

"We develop and produce a unique portfolio of multifunctional chemistries that deliver value and performance across a broad range of applications and markets."

The world’s only company dedicated to nitroalkanes and their derivatives

Extensive track record of industry innovation and leadership

6 Regional Customer Application Centers to address the local needs of our customers

Strong focus on Responsible Care® and product stewardship
What We Do

ANGUS uses proprietary propane nitration technology to create a unique set of specialty chemistries.

Propane → Nitroalkanes (Nitromethane, Nitroethane) → Nitroalcohols → Amino alcohols (AMP™, TRIS AMINO™) → Aminoalcohol Derivatives (ZOLDINE™, ALKATERGE™)

MULTIFUNCTIONAL Performance and Value

PIGMENT DISPERSION
METAL CHELATING
FORMULATION STABILIZATION

PH BUFFERING
SURFACE WETTING
OXYGEN/RADICAL SCAVENGING

CROSSLINKING
ANTI-CORROSION
MOISTURE SCAVENGING

PH ADJUSTING

angus.com
Primary Markets We Serve

- Personal Care
- Metalworking Fluids
- Electronics
- Paints
- Ag
- Pharma
- Biotech
Our Commitment to Value

• Consistency/Reliability
• Tech support/Customer service
• Specific performance features (sustainability, animal-component free, etc.)
• Quality Management System

• Trustworthiness/Transparency
• Innovation/New technology
• Change notifications
• Product availability

Our Commitment to Growth

• Purchased ANGUS in February 2015
• Dedicated to growing ANGUS by:
  • Investing in research and development
  • Expanding our staff of experts
  • Increasing customer intimacy
Electronic Chemicals

DISCOVER A BETTER WAY™
VOLTAN™ Products

- The VOLTAN product line delivers high-purity solutions for use in semiconductor and display manufacturing industries
- VOLTAN chemistries provide high precision and tunable functionality for a variety of electronics processing demands
- VOLTAN products enable removal of unwanted debris during electronics manufacturing while preserving end product functionality

ANGUS CAPABILITIES

- Production of low-metals amino alcohols on developmental, pilot, and commercial scale
- Expertise in synthesis, handling, and application of amino alcohols
- World-class technical service and regulatory expertise, tailored to each market and region
- ISO 9001:2015 certified manufacturing facilities
## ANGUS VOLTAN™ Products

- **VOLTAN™ Products**: Cover a broad range of chemical properties with varied pKa, polarity and solvency characteristics to provide desirable process-specific attributes.

<table>
<thead>
<tr>
<th>Product</th>
<th>Chemistry</th>
<th>MW (calc.)</th>
<th>pKa</th>
<th>Freeze / Melting Point, °C</th>
<th>Log P(o/w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOLTAN™ 95</td>
<td>2-amino-2-methyl-1-propanol</td>
<td>89.1</td>
<td>9.8</td>
<td>-2</td>
<td>-0.63</td>
</tr>
<tr>
<td>VOLTAN™ T</td>
<td>2-amino-2-hydroxymethyl-1,3-propanediol</td>
<td>121.1</td>
<td>8.0</td>
<td>171-172</td>
<td>-2.31</td>
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<tr>
<td>VOLTAN™ DM</td>
<td>2-(dimethylamino)-2-methyl-1-propanol</td>
<td>117.0</td>
<td>10.2</td>
<td>-20</td>
<td>0.09</td>
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<tr>
<td>VOLTAN™ AE</td>
<td>2-amino-2-ethyl-1,3-propanediol</td>
<td>119.2</td>
<td>8.8</td>
<td>&lt; -24</td>
<td>-1.02</td>
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<tr>
<td>VOLTAN™ D</td>
<td>2-amino-1-butanol</td>
<td>89.1</td>
<td>9.5</td>
<td>-2</td>
<td>-0.45</td>
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<tr>
<td>VOLTAN™ AM</td>
<td>2-amino-2-methyl-1,3-propanediol</td>
<td>105.1</td>
<td>8.8</td>
<td>109-111</td>
<td>-1.75&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>VOLTAN™ E</td>
<td>3-amino-4-octanol</td>
<td>145</td>
<td>9.8</td>
<td>-3</td>
<td>1.3</td>
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*a* Typically supplied as concentrated aqueous solution  
*<sup>b</sup>*Calculated
# ANGUS VOLTANTM Products

## VOLTANTM Products: Wide range of Structure

<table>
<thead>
<tr>
<th>VOLTANTM 95</th>
<th>VOLTANTM T</th>
<th>VOLTANTM DM</th>
<th>VOLTANTM AE</th>
<th>VOLTANTM D</th>
<th>VOLTANTM AM</th>
<th>VOLTANTM E</th>
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<td><img src="image3" alt="Structure" /></td>
<td><img src="image4" alt="Structure" /></td>
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<td><img src="image6" alt="Structure" /></td>
<td><img src="image7" alt="Structure" /></td>
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</table>

## Other unique chemistries and potential structure

<table>
<thead>
<tr>
<th>2-amino-2-methylpropylamine</th>
<th>N-isopropylhydroxylamine</th>
<th>2-(dimethylamino)-2-methyl-1,3-propanediol *</th>
<th>2-(dimethylamino)-2-ethyl-1,3-propanediol *</th>
<th>2-(dimethylamino)-2-hydroxymethyl-1,3-propanediol *</th>
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</thead>
<tbody>
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<td><img src="image9" alt="Structure" /></td>
<td><img src="image10" alt="Structure" /></td>
<td><img src="image11" alt="Structure" /></td>
<td><img src="image12" alt="Structure" /></td>
</tr>
</tbody>
</table>
VOLTAN™ Products

- VOLTAN chemistries could be used in a variety of processes during electronics manufacture

<table>
<thead>
<tr>
<th>Semiconductor</th>
<th>Liquid crystal display</th>
<th>Printed circuit board</th>
<th>LIB Battery</th>
<th>Photovoltaic</th>
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</thead>
<tbody>
<tr>
<td>Ingot slicing</td>
<td>Etching</td>
<td>Stripping</td>
<td>Slurry dispersion</td>
<td>Ingot slicing</td>
</tr>
<tr>
<td>CMP</td>
<td>Etching</td>
<td>Stripping</td>
<td>Cleaning</td>
<td>Cleaning</td>
</tr>
<tr>
<td>PCMP cleaning</td>
<td>Etching</td>
<td>Cleaning</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
VOLTAN™ Products

VOLTAN™ 95 specialty amino alcohol: 2-amino-2-methyl -1-propanol (AMP). Multifunctional amino alcohol with high base strength and low molecular weight. Low metal version is also available.

Variety of Benefits for Electronic Process

- Helps remove debris from precious metals and materials while preserving component functionality
- Effective in cleaners, rinses, and strippers with lower copper corrosion
- Efficient neutralizer with high base strength and low molecular weight
- Acts as a co-dispersant for particulates (pCMP cleaners, etc.)
- Demonstrates low cobalt-leaching potential
- VOC-exempt by U.S. EPA
VOLTAN™ Products

VOLTAN™ E Specialty amino alcohol: 3-amino-4-octanol (3A4O). It is exceptionally mild to non-ferrous metals like copper and aluminum. Successfully used in ultrafine PCB cleaning applications.

- 3A4O is exceptionally good in both mildness to metals and less foaming in water based PCB cleaners to remove solder pastes and fluxes after soldering.
- ANGUS products AB, AMP and AEPD can be used in PCB cleaning or dry film stripping.
VOLTAN™ Products

**VOLTAN™ D** specialty amino alcohol: 2-amino-1-butanol (AB). High base strength amino alcohol which is less aggressive to metal. It is a multifunctional additive in etching and stripping formulations for LCD manufacturing processes.

- AB enables very good stripping performance coupled with good corrosion control for Cu, Mo, Al, ITO and IGZO patterns
- AB could be also used in cleaning formulations for pH development and buffering while being less aggressive to metals
VOLTAN™ Products

VOLTAN™ T specialty amino alcohol: 2-amino-2-hydroxymethyl-1,3-propanediol. Excellent buffering capability and mild to metals. One potential application area is in pCMP cleaning for semiconductor processing.

- ANGUS specialty amino alcohols (VOLTAN T, or VOLTAN 95) could enable excellent particle removal capability while minimizing metal corrosivity.
Summary

- **VOLTAN**™ Products: Cover a broad range of chemical properties with varied pKa, polarity and solvency characteristics for customizable functionality in formulating cleaning and stripping solutions used in semiconductor and electronic display manufacturing
  - ✔ Reliable supply of consistently high quality amino alcohols
  - ✔ Provide high precision and tunable functionality for a variety of electronics processing demands
  - ✔ Thoroughly clean semiconductor wafers after etching, chemical-mechanical planarization (CMP) and photoresist stripping
  - ✔ Effective in cleaners and strippers with lower copper corrosion for ultra-high-definition large screen flat panel displays
  - ✔ Enable removal of unwanted debris during electronics manufacturing while preserving end product functionality
Innovative Chemistry
- TMAH Replacement

DISCOVER A BETTER WAY™
Background Introduction

Tetramethylammonium Hydroxide
CAS NO: 75-59-2

Commercial TMAH product grade
- Grade: Electronic/Industrial grade
- Concentration: 5%, 25%, 50%
- Application: Widely used in semiconductor and panel manufacture process: CMP slurry, pCMP cleaning, photoresist, etching etc.

Toxicity is THE key issue of TMAH

- TMAH toxicity caused >15 accidents and dead in Taiwan
- Toxicity level is raised by most of the regions and associates
- Disposal cost goes up as toxicity to aquatic organisms

Accidents caused by TMAH in Taiwan

Low Toxicity Candidates from ANGUS

ANGUS Candidates Models - Low Toxicity Organic Hydroxides

Computational Toxicology Results

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>TMAH</th>
<th>ETMAH</th>
<th>CH</th>
<th>AH-212</th>
<th>Candidate 1</th>
<th>Candidate 2</th>
<th>Candidate 3</th>
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<tbody>
<tr>
<td>Oral LD50</td>
<td>Red</td>
<td>Red</td>
<td>Green</td>
<td></td>
<td>Yellow</td>
<td>Red</td>
<td>Yellow</td>
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<tr>
<td>Dermal LD50</td>
<td>Red</td>
<td>Red</td>
<td>Yellow</td>
<td></td>
<td>Yellow</td>
<td>Red</td>
<td>Yellow</td>
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<tr>
<td>Inhalation LC50</td>
<td>White</td>
<td>Yellow</td>
<td>Green</td>
<td></td>
<td>Yellow</td>
<td>Red</td>
<td>Red</td>
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<tr>
<td>Skin Irritation</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td></td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
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<tr>
<td>Eye Irritation</td>
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<td>Skin Sensitization</td>
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<td>Green</td>
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<td>Yellow</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
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<td>Mutagen</td>
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<td></td>
<td>Yellow</td>
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<td>Reprotoxicity</td>
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<td>Red</td>
<td>Green</td>
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<td>Acute Ecotox</td>
<td>Green</td>
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<td>Red</td>
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<td>Chronic Ecotox</td>
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<tr>
<td>Biodegradation</td>
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<td>Green</td>
<td></td>
<td>Red</td>
<td>Green</td>
<td>Green</td>
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</tbody>
</table>

- Risk: Red (High), Orange (Med), Yellow (Low), Green (Very Low)

CH: Choline Hydroxide
AH212: Bis(2-hydroxyethyl)dimethylammonium Hydroxide
Tris(2-hydroxyethyl)methylammonium Hydroxide
Low Toxicity Candidates from ANGUS

• Thermal Stability Study

- Samples were heated in a 60 °C oven and monitored for changes in color and pH

<table>
<thead>
<tr>
<th>Sample</th>
<th>% Solids</th>
<th>pH (1% solids)</th>
<th>Appearance</th>
<th>pH (with 100 parts water)</th>
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<tbody>
<tr>
<td>Candidate-1</td>
<td>39</td>
<td>12.8</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Candidate-2</td>
<td>44</td>
<td>12.8</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Candidate-3</td>
<td>40</td>
<td>12.7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TMAH</td>
<td>25</td>
<td>13.1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Choline Hydroxide</td>
<td>46</td>
<td>NA</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

0 = clear colorless liquid, 1 = clear slightly yellow liquid, 2 = clear yellow liquid, 3 = clear amber liquid, 4 = dark

❖ Candidate-1: Color stable, off-gassing upon heating
❖ Candidate-2: Low solubility, color/odor development
❖ Candidate-3: Best color/odor/pH stability