March 2018
CMC Associate Member Monthly Meeting

- Conference Information
  - RSVP to Joint session April 25 1-4:30pm
- Analyst Update
  - Session I: 8am PST Tim Dyer: Ceramics Update
  - Session II: 6pm PST Kuang-Han Ke Quartz & Silicon Materials Update
- Joint Session Updates

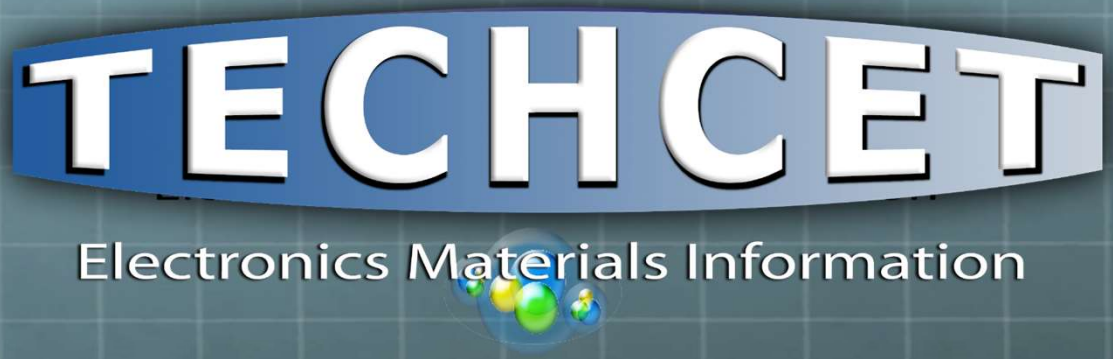
Fabs and Associate Members

2018 Outlook

- Membership renewals Ongoing (report section)
  - Continue to grow CMC Fab and Associate Membership
  - Associate Membership to Equipment Manufacturers
- Monthly Meetings with Analysts, see table
- PCN Joint Session Planning
- **April 25th 1-4:30 CMC Joint Session with Fabs**
- April 26th -27th CMC Conference and Not-so-usual-Roundtable Session
- Fall Seminar planning starting May 2018. Location in Asia TBD

Tim Dyer

- **Tim Dyer** – Sr. Market Analyst of TECHCET —
  - covers consumable equipment components and technologies.
  - 20+ years of materials engineering, product development, and senior technical leadership experience.
    - Elcon, Enovix, Morgan Advanced Ceramics, Cymer, Novellus/Speedfam, Heraeus, and Applied Materials.
    - Over 40 patents
  - B.S. in materials science and a M.S. in mechanical engineering from the University of California, Davis, and over 40 patents.



Critical Materials: Ceramic Materials and Silicon Carbide
Q1 2018 QUARTERLY UPDATE

Timothy Dyer

March / 2018

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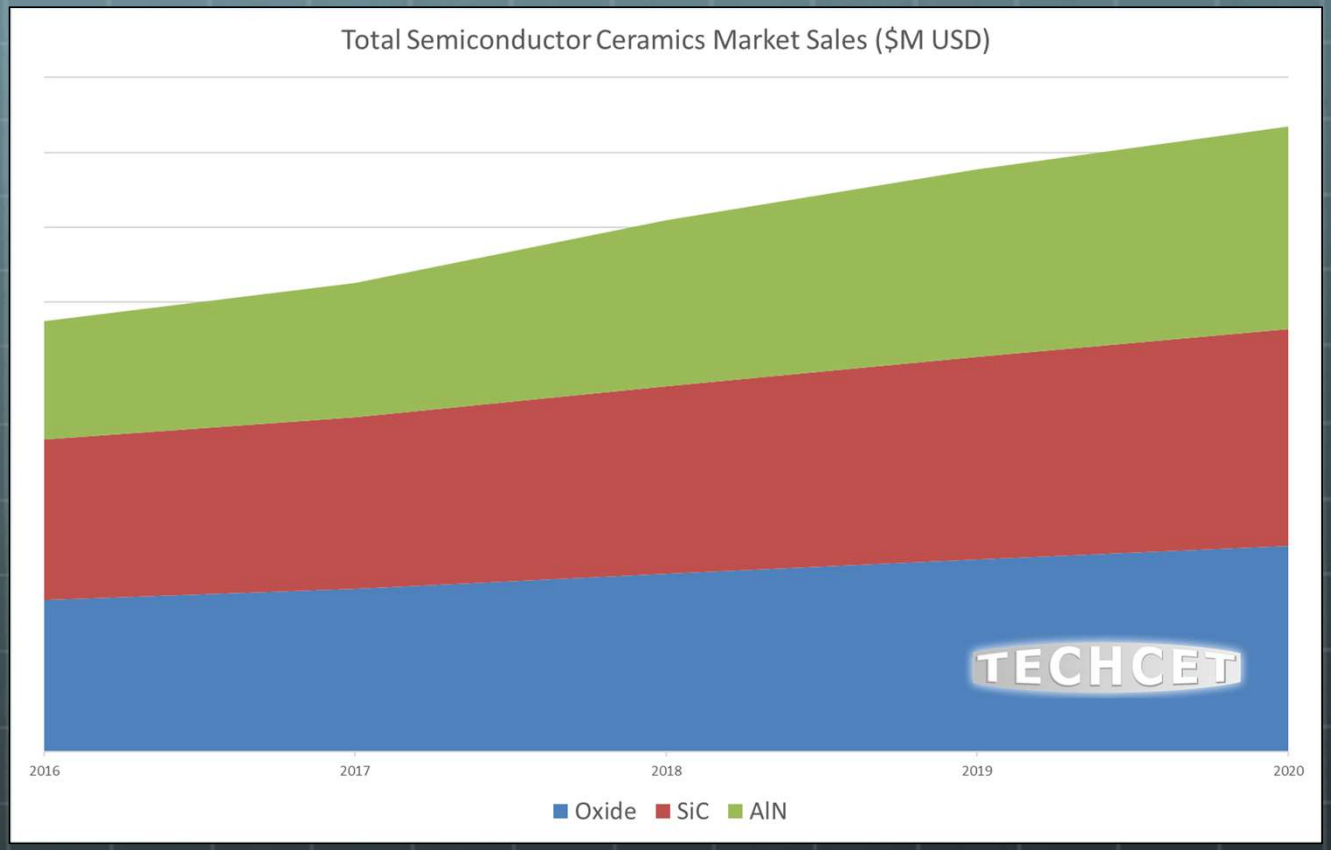
Most Common Semiconductor Ceramics

- High Purity (99.8%+) Alumina
  - High voltage insulators, PVD components, Excimer lasers, Oxide Etch components (often coated with Yttria), sapphire windows, domes, and PECVD internal reactor components (Silane, HDPCD, WCVD, ILD, TiN, Cu)
- Aluminum Nitride
  - Heater pedestals for CVD, electrostatic chucks, heater cover plates, high thermal conductivity etch and CVD components, temperature sensors
- CVD and Bulk SiC
  - Etch focus rings, long life substitute for quartz in thermal processing, etch heater pedestals, metal etch chamber liners, faceplates for etch reactors

Ceramics Supply Chain

- Raw Ceramic Materials
  - Chemical powders made by the multiple tons (small fraction are processed into semiconductor ceramics).
  - Made by processing and mining companies that serve multiple markets world wide.
- Ceramic Suppliers
  - Use raw materials to create ceramic components.
  - Process, Press, sinter, CVD, grinding, near net shape, fabrication, characterization.
- Component Markets
  - OEM –Applied Materials, LAM, KLA, TEL, Veeco, Cymer, etc.
    - Process performance focused
  - Fabs –Samsung, Cypress, Intel, Global Foundries, etc.
    - Process cost and performance focused

Semiconductor Ceramics Revenue



Market Assessment / Analysis

- Overall 2018 ceramic market is growing strongly (>7%) for Alumina, AlN and SiC materials
- Raw Alumina suppliers are adding long needed capacity to produce high purity materials to make semiconductor components
- Raw AlN remains dominated by Tokuyama, however new sources out of Taiwan and the USA are reducing material shortages.
- AlN component market is still dominated by NTK, however >5 new suppliers in the USA, South Korea, Japan, and Taiwan have come into the market to create a more completive environment.
- CVD SiC is now a critical capability for the modern OEM Equipment etch market. SiC producers are aligning with CVD coaters. Excess CVD chamber capacity is rapidly diminishing

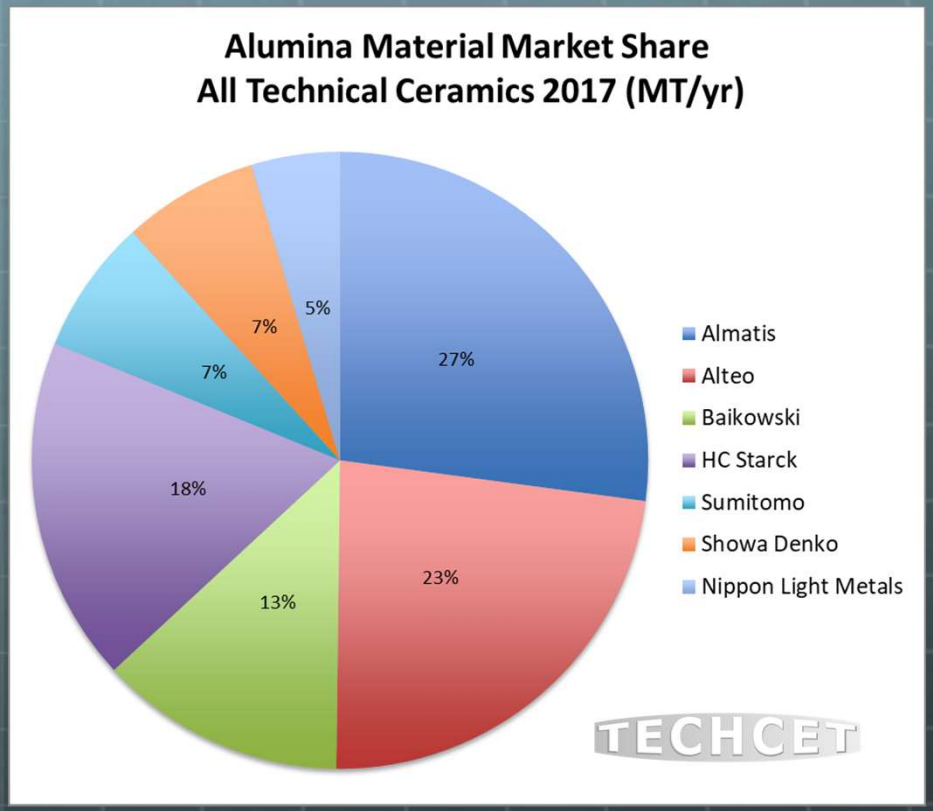
Quarterly Status

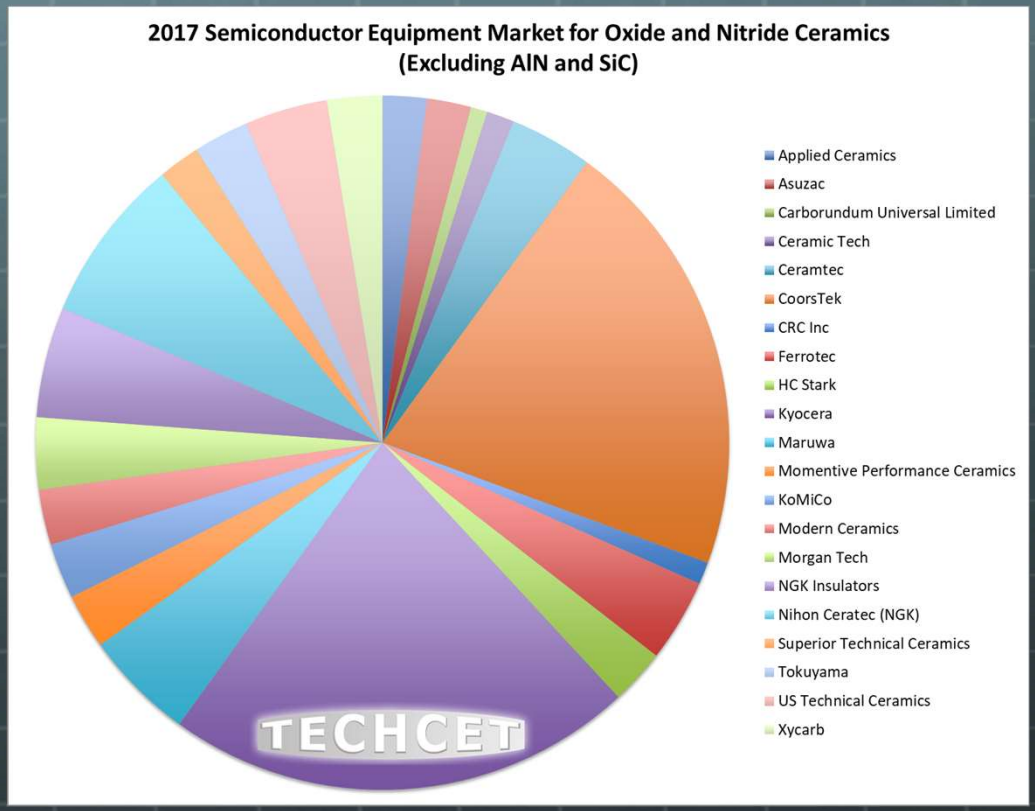
March 2018

2018 Alumina Update

- Raw material prices are increasing this year from the major suppliers (5%).
- Almatis has successfully adapted to new feedstock for semiconductor alumina following a major plant closure. They have also added significant capacity in the USA.
- Almatis recently demonstrated making 99.99% alumina products to compete with Baikowski (Semiconductor alumina and sapphire market)
- Nippon Light Metals is making slow progress into the US Semiconductor market
- Alumina continues to be the mainstay ceramic material for OEM and Fab components
- Higher quality, vertically integrated, ceramic suppliers are busy, therefore extending lead times for components > 10 weeks
  - Kyocera, Coorstek, STC, Morgan, USTC, Nihon Ceratec are all increasing lead times

Alumina Powders and Components

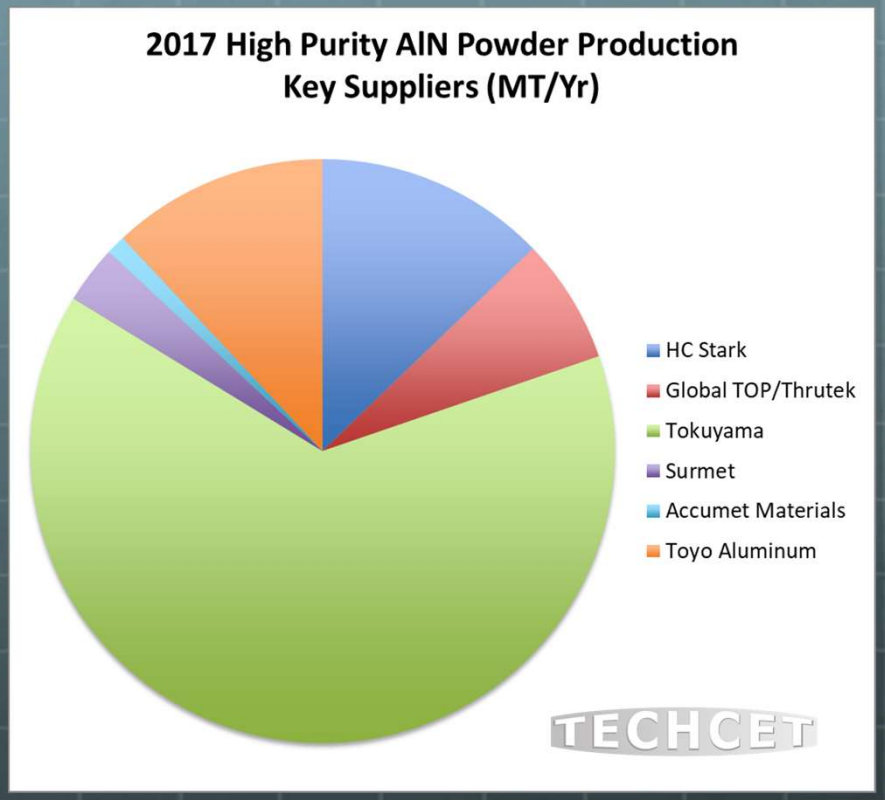


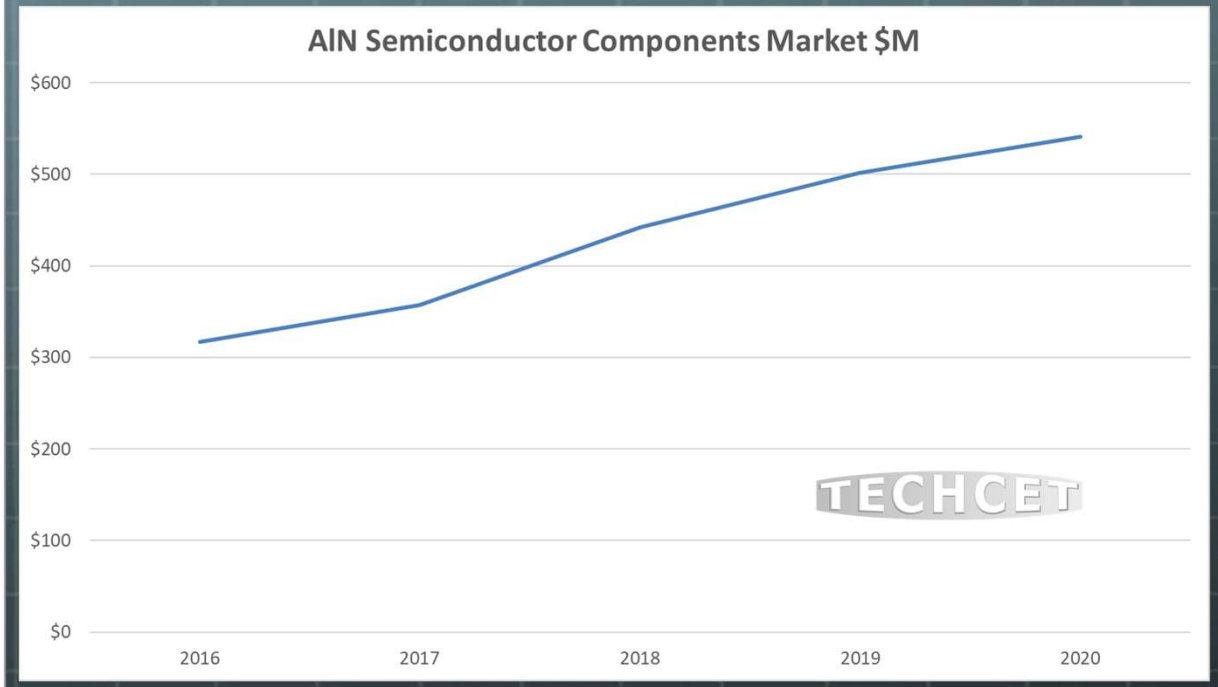


Aluminum Nitride Update

- AlN Heater and ESC Market is exploding with new supplier activity
  - More sources of AlN powder and ceramic blanks entering the market
  - 9 Key Patents protecting the heater and ESC market from third parties have expired over the last 2 years (AMAT, NTK, TEL, Mattson)
- Tokuyama has expanded ALN manufacturing capacity by 20% in early 2018
- In late 2017 G-Top/Thrutek introduced their AlN materials from Taiwan to the semiconductor market and they have significant capacity.
- CRC Inc continues making great progress entering the ALN heater and ESC market with key OEM discussions.
- New suppliers Watlow, Technetics, and Boboo are gaining ground in the ESC and Heater market (new and refurbished selling to Fabs).
- NTK is still the main player in AlN heaters working mostly through OEMs, not fabs.

AlN Market

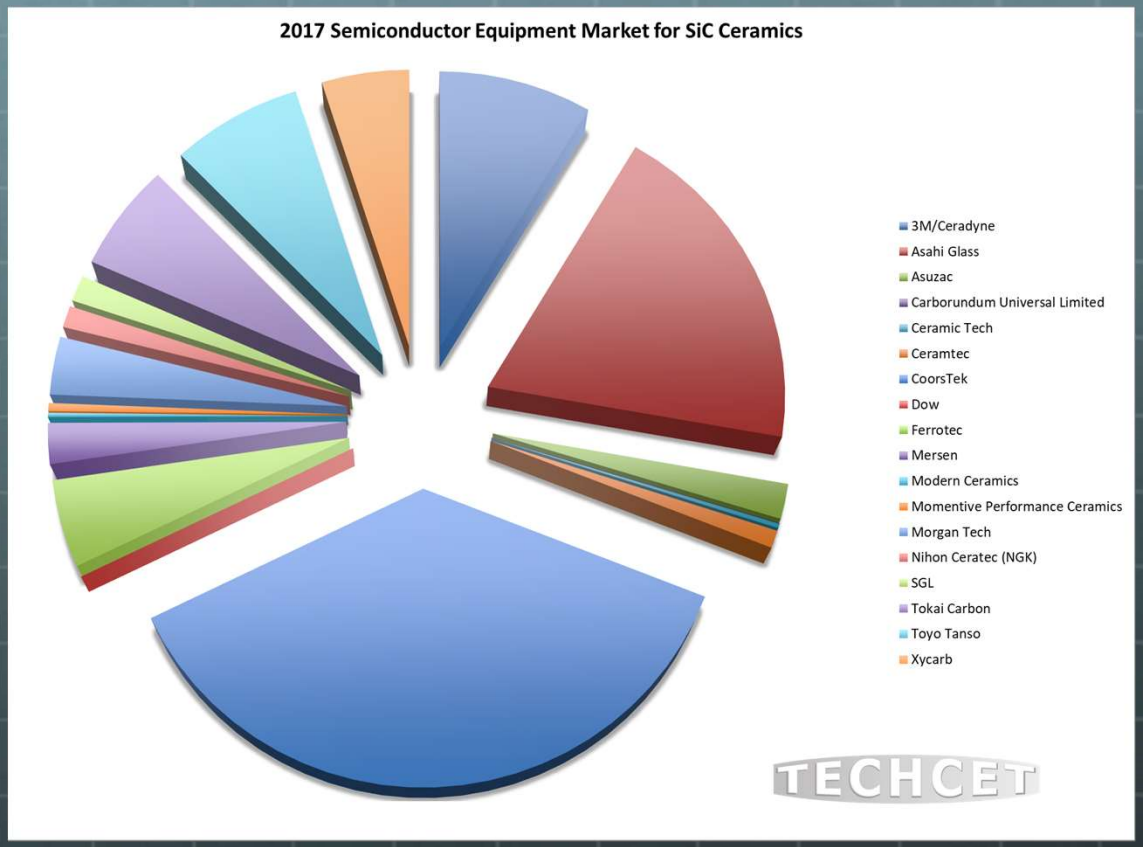


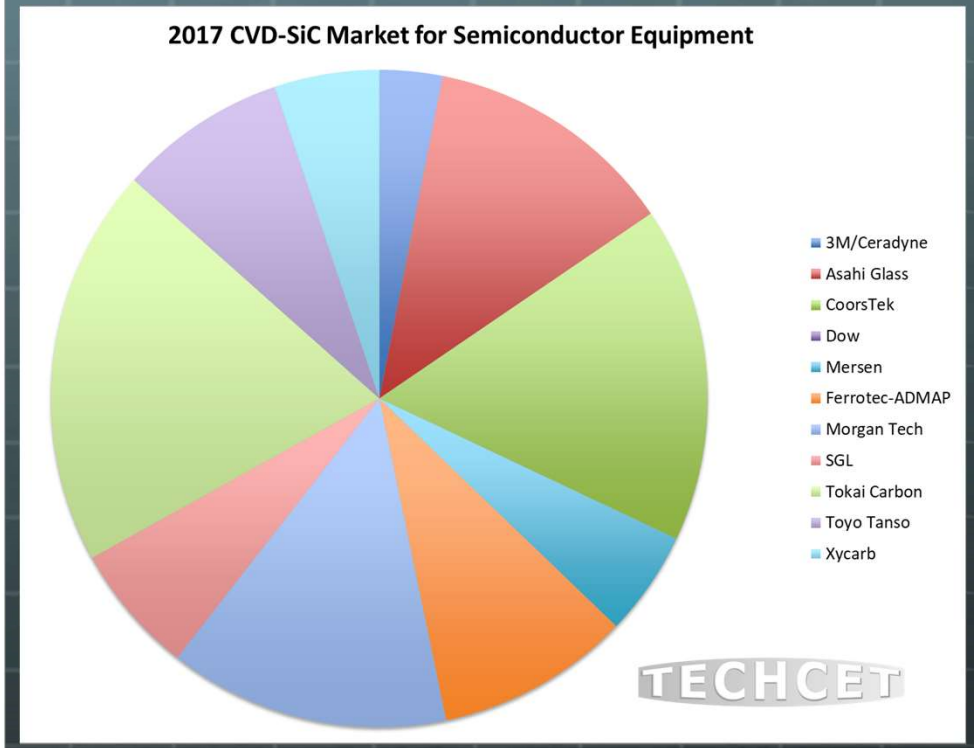


SiC and CVD SiC

- CVD SiC is becoming a requirement for OEM chamber components in etch and Si deposition due to increasing purity requirements.
  - SiC has superior high temperature resistance to chlorine containing gasses
  - Bulk SiC is not available at >99.9% Purity
  - CVD SiC has >99.999% Purity
  - CVD SiC can be grown onto graphite or SiC substrates
- CoorsTek remains the market leader in SiC components for semiconductor equipment, closely followed by Asahi Glass.
- CVD Reactor capacity for growing SiC is becoming sparse worldwide. Adding additional capacity requires great capital expense and EHS compliance for installation.
- SiC continues to make inroads on thermal quartz applications at fabs.
- Relatively new suppliers such as Mersen and Ferrotec have entered the CVD SiC market, adding some more diversity to the supply chain.

SiC Market Updates





Summary Slide Q1-2018

- Alumina market is mature and growing
  - Strong demand for components is resulting in increased lead times from major vertically integrated suppliers
  - Alumina remains a more mature ceramic with an equal split of OEM and direct fab sales
  - In 2017 Almatis added significant manufacturing capacity to make semiconductor grade alumina
- AlN market is OEM facing and reliant on a few suppliers
  - Recently expiring patents have resulted in many new component suppliers entering the market
  - Late 2017 Tokuyama and GTOP-Thrutek added significant capacity for making AlN powders
  - Most sales to OEMs at this time for high value assemblies
  - New ESC and Heater suppliers are coming on line to work directly with Fabs (Boboo, Techncetics, Watlow, CRC)
- Silicon Carbide is a specialty material
  - Older technology in being used by fabs to replace silica, while newer CVD capabilities being driven by OEMs for new performance requirements
  - CVD SiC is necessary for newer high performance applications
  - Lack of global CVD Reactor capacity may hurt short term market growth; resulting extended lead times

Thank You!

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CMC Associate Member/FAB F2F and Conference Update

- CMC Associate and CMC FAB F2F
  - Joint Session April 25, 1-4:30pm
    - At NXP
    - **Need to RSVP to get security badges**
    - Networking Reception to Follow
    - Contact Meena for hotel reservations for block room rate: msher@techcet.com

- CMC Conference at Hilton Hotel, Chandler, AZ
  - April 26-27
  - April 26th – not so usual round table
- http://cmcfabs.org/cmc-events/

PCN / Joint Session
April 25th 1pm PST, NXP, Chandler

- **Outcome Goals:**
  - **Educate entire supply-chain members of issues, challenges and potential solutions to PCN problems**
  - **Highlight next steps that may lead to solutions or clarity of understanding**
- 2 Presentations from CMC Associate Members on PCN Challenges / Case Study
- 1 Presentation from CMC Fabs Member on PCN Challenges
- Discussion
- Actions to be Taken
- **Let us know your plans to attend for NXP security entry to the plant**

Agenda-Joint Session Wed April 25 1-4:30 PST

1:00	Joint Session
1:15	Intro
1:30	End User Presentation – invited: Mark Denney, Intel (tenta
2:00	Sub-tier Supplier Presentation – invited: Kevin Mclaughlin,
2:30	Direct Supplier Presentation – invited: Fred McNeil(?)
3:00	15 min Break
3:15	Instructions on discussion
	Round Table Discussions
4:15	Output from each round table
5:00	Wrap Up / End
5:00	shuttle pick up
5:30	Reception back at Hotel

Timetable for Joint Session

PCN Challenges – Joint Session Meeting – April 25th, at NXP 2pm

1pm start:

- End User Presentation – suggested/invited: Mark Denney, Intel
- Supplier Presentations – invited: Kevin McLaughlin, SACHEM
  And Fred McNeil. Matheson Gases

3:15 Instructions on discussion

3:30 Break

3:45 Round Table Discussions

a. List of issues for ea. of supplier and end user
b. Identify common concerns / overlap
c. Answer set of questions – we will need to work on this
d. Brainstorm list of possible actions / next steps

4:15 Each Table reports their findings while facilitator lists and groups information on Poster sheets hung on easels or on the wall

5:00 Facilitator Summarizes findings and highlights next steps.

5:30 Beer-o'clock – go back to Hilton for reception

CMC Conference 2018 Agenda (update)

	KEYNOTE: David Bloss, VP/Director, Intel	Patterning Challenges and Fab Materials for Future ICs
	Session I: Global Issues	
Thurs.- April 26 Session I & II 8:15 to 5pm + 5:30-7:30 NSU RT	Lita Shon-Roy, President, TECHCET	Critical Materials Market Forecast & Roadmap
	James Votaw, Partner, Keller & Heckman	Regulatory Challenges for Novel Engineered Materials
	Keith Long, Director, USGS	Global Tantalum Supply Chain: Trends and Future Challenges
	Scott Jones, Sr. Partner, KPMG	Global Financial Impact on the Semiconductor Industry
	Other speakers TBA	
	Session II. Materials Issues Today	
	Risto Puhakka, President, VLSI Research	OEM Markets and Materials Trends
	Ken Unfried, Sr. Technologist, Linde	Neon and Xenon Recycling
	Texas Instruments (speaker TBA)	Reduce/Reuse of Wet Chemicals
	Michelle Garza, Sr. Technologist, Fujimi	Fast is the Only Speed: Quick turnaround slurry ramp process
	Dennis Brestovansky, Director, Praxair	Ion Implant Critical Materials
	Samsung (speaker TBA)	Topic TBA
	Other speakers TBA	
Fri. – April 27 8:15 to 12:30pm Session III	**Session III. Emerging Materials Challenges**	
	Glen Wilke, VP, ASM	ALD Materials Integration Challenges
	Dave Thompson, Director, Applied Materials	Ruthenium Integration
	Sanjeev Aggarwal, VP Technology, Everspin Technologies	Magnetic Materials for IC Manufacturing
	Nick Blasco, Director, Air Liquide	Ru precursors, & Co precursors issues
	Jonas Sundqvist and Terry Francis, Sr. Technology Analysts, TECHCET	ALD / CVD / PVD Metal Materials Markets
	Other Speakers TBA	

2018 Meeting Calendar w/ Analysts

YEAR	MONTH	DAY	Meeting Type	Subject/Analyst	Analyst
2018	January	17	CMC ASSOCIATES	Silicon Wafers	Mike
2018	February	14	CMC ASSOCIATES	Wet Chem	Yu
2018	March	21	CMC ASSOCIATES	Ceramics	Tim
2018	April	25,26,27	CMC Meeting & Conference	Gases/Metals	Various
2018	May	16	CMC ASSOCIATES	Photoresist	Ed
2018	June	20	CMC ASSOCIATES	CMP	Diane
2018	July	25	CMC ASSOCIATES	Precursors	Jonas
2018	August	15	CMC ASSOCIATES	Silicon Wafers	Mike
2018	September	19	CMC ASSOCIATES	Metals	Terry
2018	October	?	CMC Seminar & meeting		Various
2018	November	7	CMC ASSOCIATES	Wet Chem	Yu
2018	December	5	CMC ASSOCIATES	Gases	Bruce

Thank-you!

- Next Meeting is
  - **Face to Face in Chandler April 25th**

Kuang Han Ke

- Sr. Technology Analyst of TECHCET — covers quartz material and technologies
- 25+ year experience
  - AMAT- etch chambers, Ministry of Economic Affairs in Taiwan, etc…..
  - taught semiconductor equipment courses at Yuan-Zi University for 8 years
  - M.S. in Aeronautics and Astronautics from Stanford University and a B.S. in Aerospace Engineering & Mechanics from the University of Minnesota, Twin Cities
  - over 10 patents

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Electronics Materials Information

Techcet Critical Materials:
ANALYST UPDATE

Kuang-Han Ke, Quartz & Silicon Materials Update

March 22-23, 2018

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Quartz SiO_2

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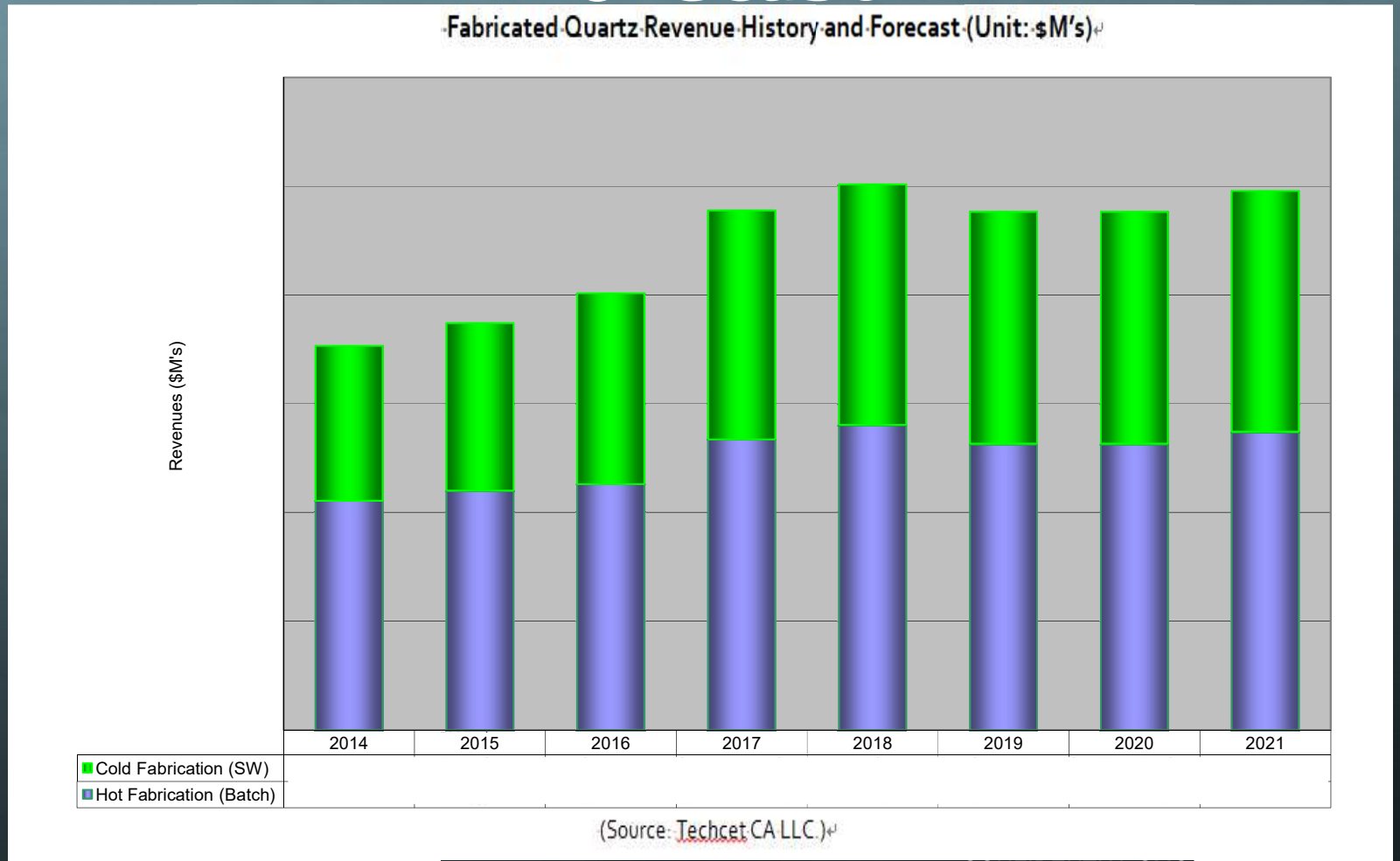
Forecasts

- 2017 has been a very good year due to vibrant semiconductor market.
  - For 2017, moving at good double-digit growth in Asia, and
  - Some portion of the market moving at 30+% in China, at the onset of big push for new fab build up there.
- Revised upwards from Nov.: Based Material Revenues totaled increased by 23% to $322 M in 2017. Raised forecast due to very good Q4 numbers.
- Revised upwards from Nov.: In 2017, WW market for fabricated parts was expected to reach $956M, up 19%. Raised forecast due to very good Q4 numbers.

Forecasts

- Even though the demand for semiconductor quartz components was largely supported by local suppliers, 2017 was also especially highly influenced by new furnace equipment sales, etch equipment OEM sales and parts pulls.
- 2017 was a good year for equipment sales. 2017 sales was up 31%. Strong growth in China & Taiwan in H1, and N. America & N. Korea in H2.
- The buying was more than historical normal, so new OEM equipment buy in 2017 strongly influenced the purchasing decision overall. The new OEM equipment buys % increased from 1/3 to 50% in 2017.

Forecast



Plant Disruptions / Closures / Discontinued Operations

- None.

Mergers and Acquisitions

- No merger or acquisition in 2017. Focus on expansion plans.

Production Change

- Tosoh's Specialty Group is expanding operations including R&D Center. Tosoh Quartz aims to reduce costs and will develop new materials.
- Ferretec already increased production floor, and orders from 4 OEMs exceed the planned increased production floor capacity.
  2 New factory expansion in progress.
- Wonik QnC Corporation invests facilities for USD$15 MIL., ~ Sept. 30.
- Feilihua finished Qianjiang plant phase II expansion, into production.
- Beijing Kaide confirmed ~ US$ 1MIL in plant improvement.

Market Landscape and Regional Characteristics

- In 2017, the following factors are in play affecting the quartz market
- Overall breakneck pace in semiconductor market, especially in Asia, and particularly in China.
- >20 new fabs starting in China in the next 3 years will pull OEM equipment demand.
- Matured 8" equipment becomes lacking in global second-hand market, due to purchase from the new fabs.
- Overall new equipment OEM purchase growth has been pulling the capacity away from normal fab demand. (@20-31% increase on average).
- 12" Diffusion Quartz Tube demand will come online slower due to long-time craftsman talent development lag.

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China Special Landscape

- Some fabricators request raw quartz base material suppliers to meet quartz demand ~20-50% in China in 2017.
- Due to hot quartz market in 2017 and former local industry practice, very few percentage (<2%) of base materials use mixture of sands from different sources. We understand： mostly used for 6”-8” usage, the less critical processes.
- In 2017, even though there was strong attempt to have new fabricators in China, most of the existing major fabricators globally seem to be getting the business; hence, possibly affected the lead time in 2017.
- China will have new fabricators, and have existing large fabricators opening new capacity there. As new base material suppliers get qualified, more capacity will help balance situation.
- Looking forward to 2018, capacity expansion plans in China seems able to meet future demand.

Analyst Outlook & Summary

- 2017 was a breakneck year for quartz. Machining parts can be ramped up while diffusion parts are slower to ramp up.
- Growth of Quartz Fabrication market in 2017 was 19% overall, while portion of the market faced 20-50% growth, similar to 1995-97 period.
- 5-year CAGR of Quartz Base Materials Market: 2017 @ 23%, 2018 @ 7.3%,
- 2019-2021 @ 1% (shift regionally).
- Hot growth Areas: China, OEM buys.
- Future Challenges for Quartz suppliers: Diffusion parts craftsman development training time.

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Electronics Materials Information

Techcet Critical Materials:

ANALYST UPDATE

Kuang-Han Ke, Quartz & Silicon Materials Update

March 22-23, 2018

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Thank You!

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