An Introduction to Ragan Technologies, Inc.

High Shear Compaction – HSC™

An advanced efficient process for producing tapes from ceramic, metal, glass, or plastic powders with improved performance.

Ragan Technologies, Inc.

Presentation Outline:

- Who is RTI?
- Technical benefits of the HSC™ process.
- Who are some of RTI's clients?
- How can the technology be acquired?

Ragan Technologies, Inc.

WHO IS RTI?

- RTI is a private corporation based in San Diego, California. RTI was a spin off of Wallace Technical Ceramics.

- RTI has been offering turn-key technology development services since 1994.

Ragan Technologies, Inc.

- RTI specializes in tape or sheet forming technology.
- RTI maintains a development lab in Winchendon, MA.
- Tape development – toll manufacturing – lab functions as second source for our licensees.

Ragan Technologies, Inc.

- Three of RTI's founders were founders of other successful ceramics companies.
- RTI technical staff has over 180 years of experience in technical ceramics.

Ragan Technologies, Inc.

Randall C. Ragan – Founder (1915–2009)

Who is RTI?

Ragan Technologies, Inc.

Randall C. Ragan – Founder (1915-2009)

- Past V.P. North American Philips.
- Co-founder of Mepcopal, a successful passive component company.
- Received the original patent on roll compaction technology – Gladding McBean.
- Devoted his entire life to ceramics process development.

Ragan Technologies, Inc.

Randall C. Ragan – Founder (1915-2009)

- Received the 1991 Samuel Geijsbeek award for developments of singular significance from the American Ceramics Society.

- During a sabbatical period, Randy invented the HSC™ process, the foundation technology of RTI.

Ragan Technologies, Inc.

Randall C. Ragan – Founder (1915-2009)

- In 1993 Randy was elevated to Emeritus status at the American Ceramic Society.
- Randy has been awarded many patents for solid-state fuses and thick film resistor materials.
- Considered the Father of thick-film resistors

Ragan Technologies, Inc.

Ken Wallace – Board Member

- Active in the ceramics industry since 1974.
- Co-founder of Wallace Technical Ceramics, from which RTI was spun off.
- Co-founder of Cladan Corporation, specializing in multilayer ceramic processing equipment design and construction.

Ragan Technologies, Inc.

Ken Wallace – Board Member

- Mechanical engineer, process engineer, machine designer.
- Expert in automation and process control.
- Corporate Director.

Ragan Technologies, Inc.

William C. Belko – President & CEO

- General Manager of the Development Lab in Winchendon, MA.
- Involved in the development of HSC™ process from its inception.
- Employed in the ceramics industry since 1984, joined WTC in 1987.

Ragan Technologies, Inc.

<u>William C. Belko – President & CEO</u>

- Awarded one patent for ZST™ LTCC technology.
- Technical liaison with clients.
- Corporate Director.

Ragan Technologies, Inc.

C.L. (Bim) Wallace – Founder (1925–2019)

- Active in the ceramics industry since 1955.
- Co-founder of Cladan Corp.
- Physicist
- Master machinist

Ragan Technologies, Inc.

C.L. (Bim) Wallace – Founder (1925–2019)

- Expert in material and process development.
- Awarded 8 patents for multi-layer ceramic manufacturing technology, solar cells, and integrated switches.
- Corporate Director

Ragan Technologies, Inc.

<u>William R. Belko – Board Member</u>

- Active in the ceramics industry since 1958.
- V.P. of Research and Development at Vitramon, Inc. (1970's)
- Founded a successful MLCC manufacturing company which was sold to AVX.

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William R. Belko – Board Member

- Awarded 14 patents in the field of electronic ceramics.
- Founded 3 other successful companies specializing in technology transfer.
- Corporate Director

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TECHNICAL BENEFITS OF HSC™

- HSC™ is more than just an efficient high volume tape manufacturing process.
- HSC™ provides engineering degrees of freedom that are not possible with traditional forming methods.

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- HSC™ offers many technical benefits when compared to tape casting, roll compaction, slip casting, or powder pressing.

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- HSC™ is a robust, *scalable* process which permits small batch development, toll manufacturing, and low cost – high volume production.

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- Because the need to formulate slurries is eliminated, small test batches can be quickly and easily produced in our lab, usually many in one day.

- Powders and binder are mixed and dispersed using high shear forces.

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- Batches as small as 1 or 2 grams are possible.
- Typical batches without spray dried powders are about 2kg.
- Several batches can be processed in a day.

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- Spray dried or “prepared” powder greatly reduces labor and increases efficiency in tolling operation.

- Increased efficiency = lower cost

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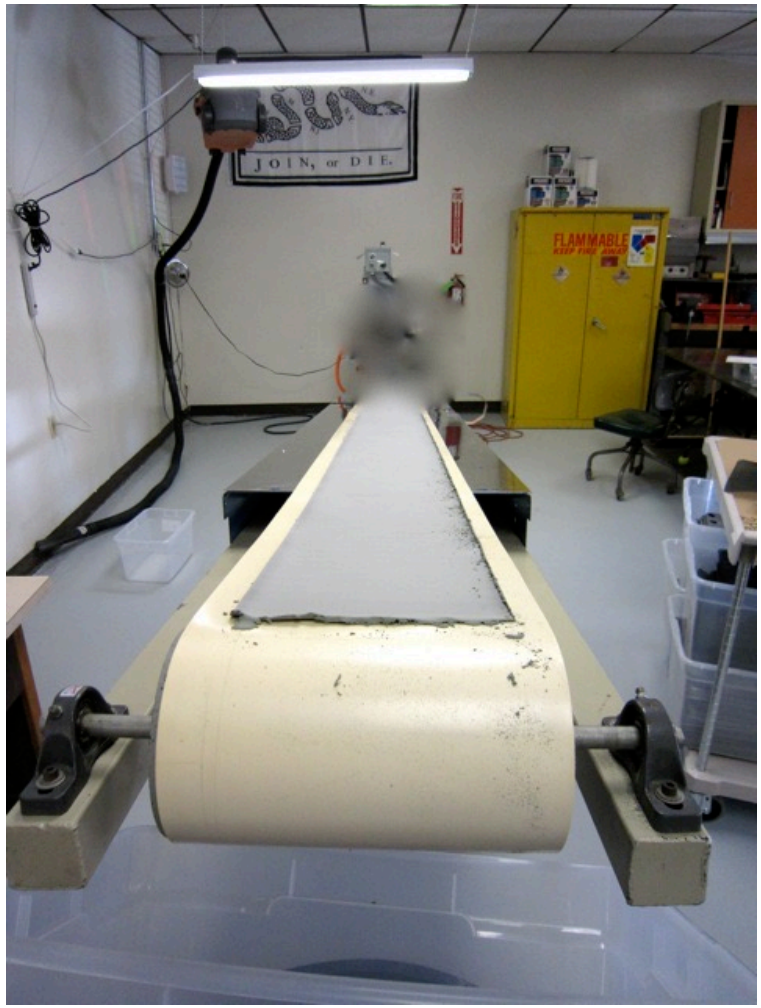
- RTI tolling service can process up to about 50Kg per week.
- Semi-automatic machines in various configurations available in lab.



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- HSC™ is an efficient continuous production process.
- Typical rate of 5 feet per minute full width and full thickness.
- Capacity of over 3600 square feet per shift with 2 operators typical (18” wide).

Technical benefits of HSC™

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- Tape width is not limited by process.
- Rolls can be up to 25 feet wide.
- All contact surfaces are WC.

Technical benefits of HSC™

Ragan Technologies, Inc.

- Process is an improvement on traditional roll compaction.
- HSC™ tapes can be stiff or flexible.
- HSC™ tapes are never brittle.

Ragan Technologies, Inc.

- The material is maintained at a very high viscosity and subjected to very high shear forces.
- The particles cannot settle preventing non-uniform particle size distribution through Z-axis typical with cast tapes.

Ragan Technologies, Inc.

- HSC™ tapes are completely isotropic.

- HSC™ tapes fire FLAT.

Ragan Technologies, Inc.

- Single layer tapes can be any thickness from about 0.004” to over 0.5”. (0.1 - >12mm)
- Full thickness tapes eliminate the need to stack and laminate multiple sheets typical with tape casting.
- Sheets can be roll laminated to produce sheets several inches thick.

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- Extreme thickness control.
- Tolerance of +/- 0.0005” (0.01mm) typical
- 10 micron total variation across 10” wide tape reported.
- Set it and forget it!

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- Unlike tape casting or multi sheet lamination, the thickness is determined in the final calendaring step.

- Thickness repeatability is maximized.

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- Closed loop feedback with real-time thickness control is easily accomplished on an automatic system.

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- The particles are sheared against one another and find the “best fit” increasing green density.
- Improved sintering due to close particle packing.

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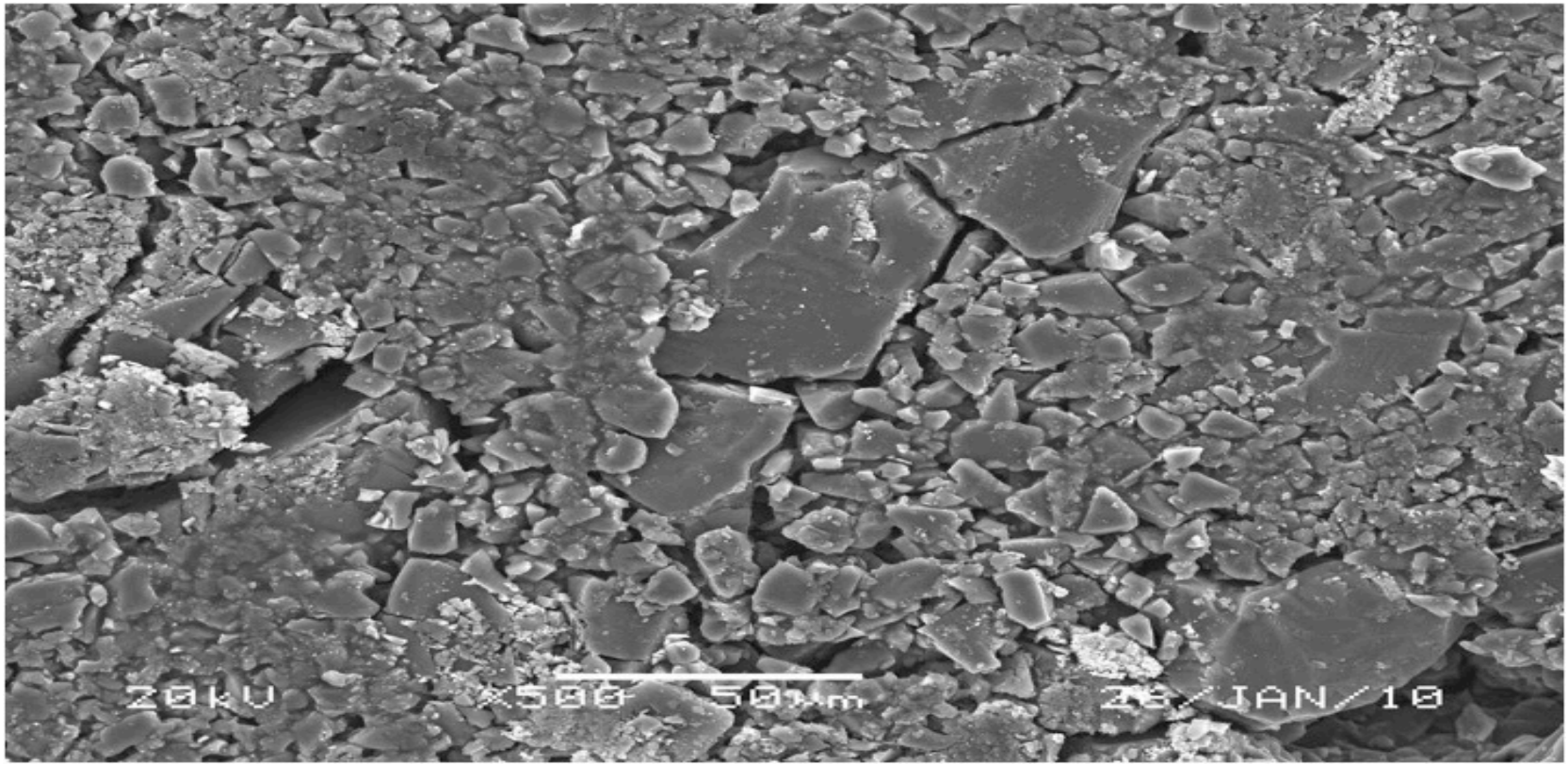
Powder pressed SiC



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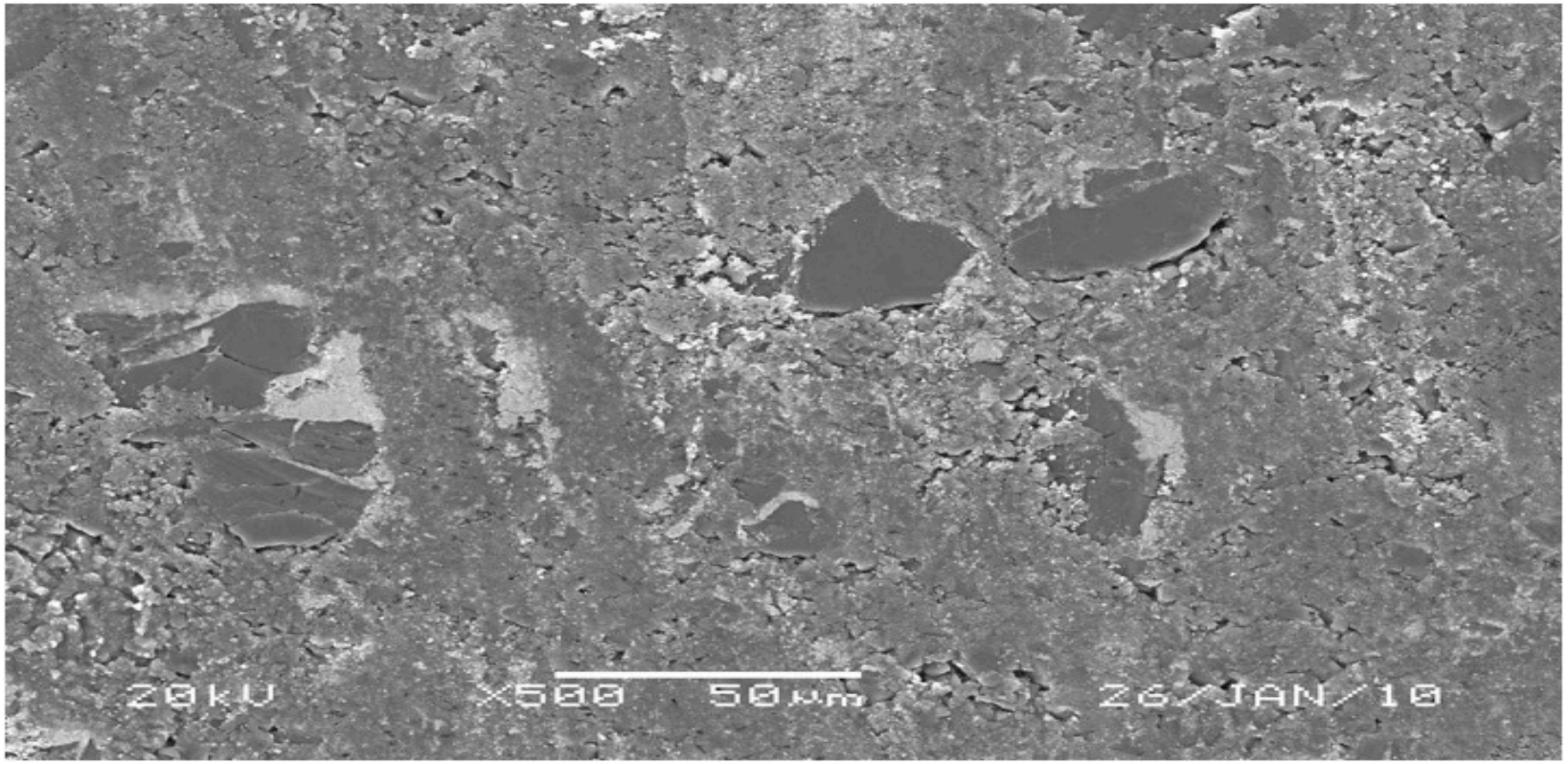
HSC™ SiC Tape



Technical benefits of HSC™

Ragan Technologies, Inc.

- This isotropic dispersion yields tapes with greatly reduced shrinkage variation.
- Density typically >70% of theoretical and as high as 85% possible.
- Reduced sintering temperature.

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- Very uniform green density reduces fired shrinkage variation. (+/- 0.1% typical)
- Tapes tend to have lower binder concentration than typical cast tapes.
- Pliable HSC tapes never have hidden defects typical with powder pressed parts.

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- 6 to 11 wt% binder solids typical.
- High specific gravity powders can be as low as 3 wt%.
- Very high surface area powder require increased binder loading.

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- Green density can be tightly *controlled*.
- Degree of compaction can be controlled which allows the density to be predicted.
- This is not possible with traditional forming methods.

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- Porosity can be induced when required.
- Fugitive pore formers are easily dispersed.

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- Sintered porosity can be >60%.
- Degree of compaction and organic content can be controlled which allows porosity to be accurately predicted.

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- Both sides of the tape can be smooth, unlike cast tapes where one side is dull.
- Surfaces of the tape can be embossed.
- Tapes can be easily post-formed to create complex shapes.

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- Tapes are isotropic right up to the edges reducing scrap.
- Trimmings can be re-processed into tape.
- Powder yield approaches 100%.

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- Tapes laminate at lower temperatures and pressures.
- Typical lamination cycle: 65° C at 2500psi for 10 minutes.
- Tapes can be hot roll laminated.

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- The HSC™ process utilizes proprietary aqueous binders.
- Eliminates explosion hazards and EPA concerns.

Technical benefits of HSC™

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- Easy water clean up of equipment.
- Reduced equipment down-time.
- Solvent based binders available when needed.

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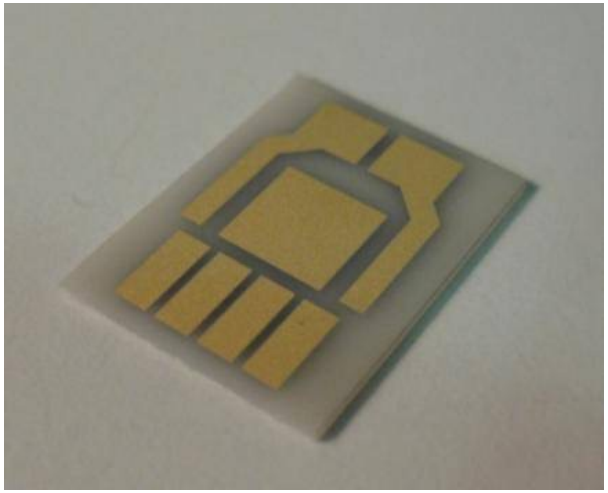
- Wide range of difficult materials to process can be easily formed into tapes.
  - Tungsten metal powder (very high specific gravity).
  - Non-oxide ceramics (organic binders)
  - Very coarse powders are easily formed into tapes.
  - Corn starch, carbon black, graphite (high bulk density materials).
  - Boron nitride (very lubricious)

Ragan Technologies, Inc.

WHO ARE SOME OF RTI'S CLIENTS?

Motorola – Albuquerque

- Acquired a license for HSC™ in 1992.
- Utilized process to produce cellular phone filter circuit substrate.



Ragan Technologies, Inc.

- The enabling feature of HSC™ in their process was extreme thickness control and uniform shrinkage.
- Control of the physical dimensions was key to controlling the frequency of the filter circuits.
- HSC™ eliminated tedious thickness QC operation increasing yields.

Who are some of RTI's clients?

Ragan Technologies, Inc.

Smith International – SII MegaDiamond

- Acquired a license to use HSC™ in 1996.
- Use HSC™ to produce tapes from diamond particles.
- These tapes are used to produce PCD cutting tools and oil well drill bit teeth.

Who are some of RTI's clients?

Ragan Technologies, Inc.

- The flexible tapes allowed MegaDiamond to produce drill bit teeth with complex shapes, improving drilling performance.
- The ability to increase particle contact allows their cutting tools made with HSC™ to have improved wear resistance.

Who are some of RTI's clients?

Ragan Technologies, Inc.

Diamond Enhanced Inserts

Who are some of RTI's clients?

Ragan Technologies, Inc.

PCD Cutting Inserts

Who are some of RTI's clients?

Ragan Technologies, Inc.

- Process is used in facilities in Provo, UT and in Italy.
- SII awarded 10 new patents based on products made with HSC™ tape.

Who are some of RTI's clients?

Ragan Technologies, Inc.

Rogers Corporation – Thermal Management Solutions.

- Acquired a license in 2010 for AlSiC metal matrix composite pre-form tapes.

Who are some of RTI's clients?

Ragan Technologies, Inc.

- HSC™ is used to produce tapes with controlled porosity.
- Tapes are burned-out, and then infiltrated with liquid Al metal.
- HSC enables Rogers to make high aspect ratio parts (12”x16”x0.10”).

Who are some of RTI’s clients?

Ragan Technologies, Inc.

- HSC™ process enables Rogers to control the skin thickness of the MMC very accurately.
- Control of porosity enables control of the CTE of the MMC.
- These features are not possible with any other forming process.

Who are some of RTI's clients?

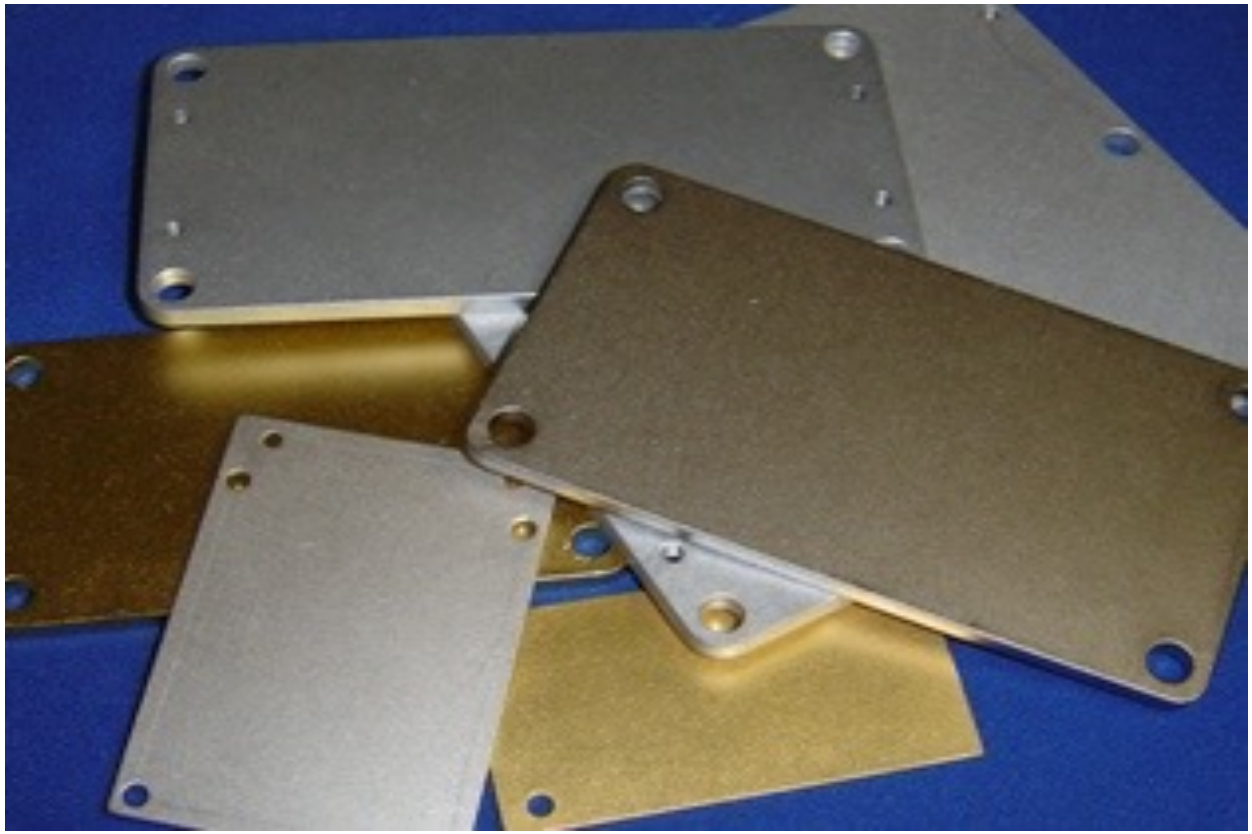
Ragan Technologies, Inc.

- CTE matched thermal spreaders.
- Flip Chip Lids.
- IGBT base plates.
- Other light weight high strength applications.

Who are some of RTI's clients?

Ragan Technologies, Inc.

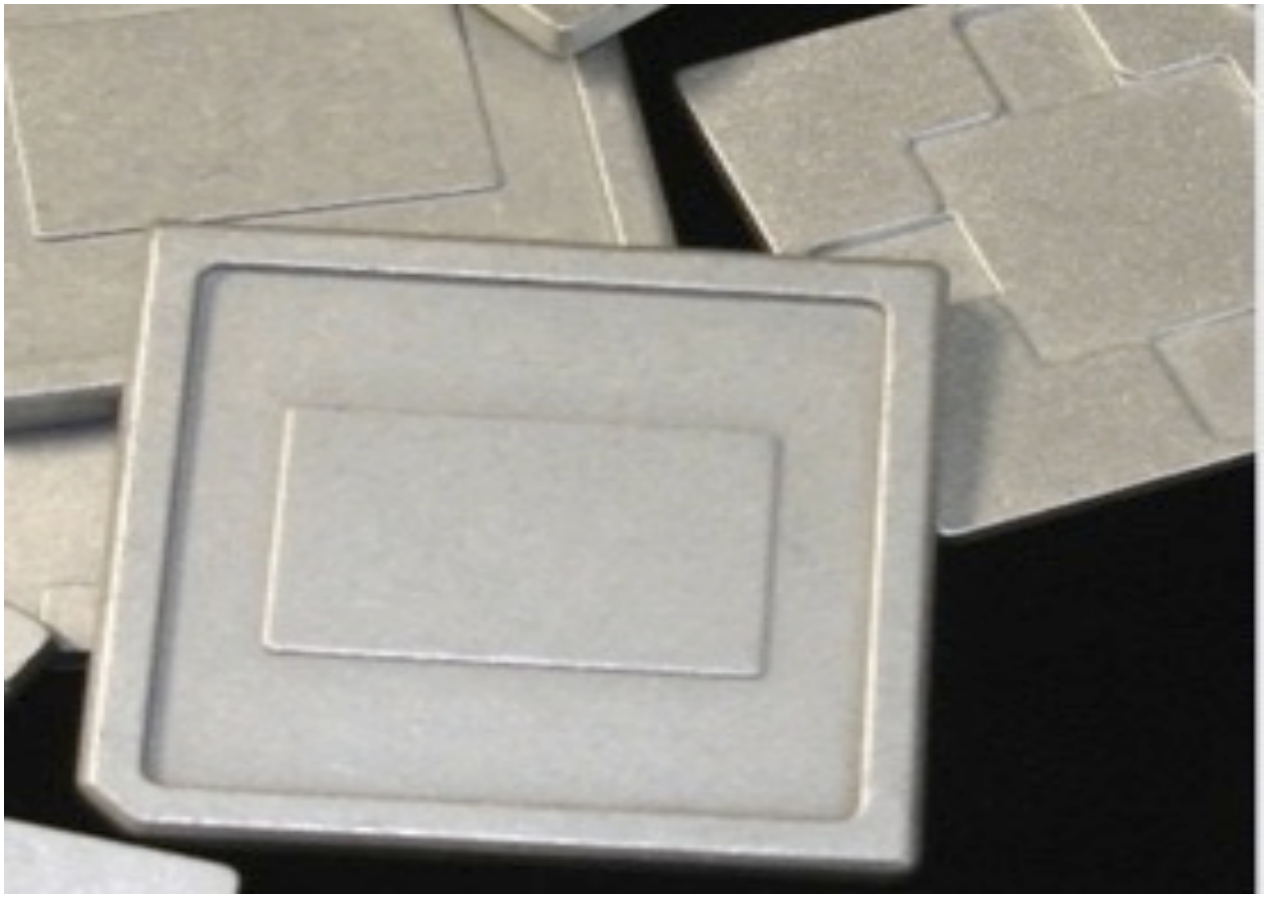
IGBT base plates



Who are some of RTI's clients?

Ragan Technologies, Inc.

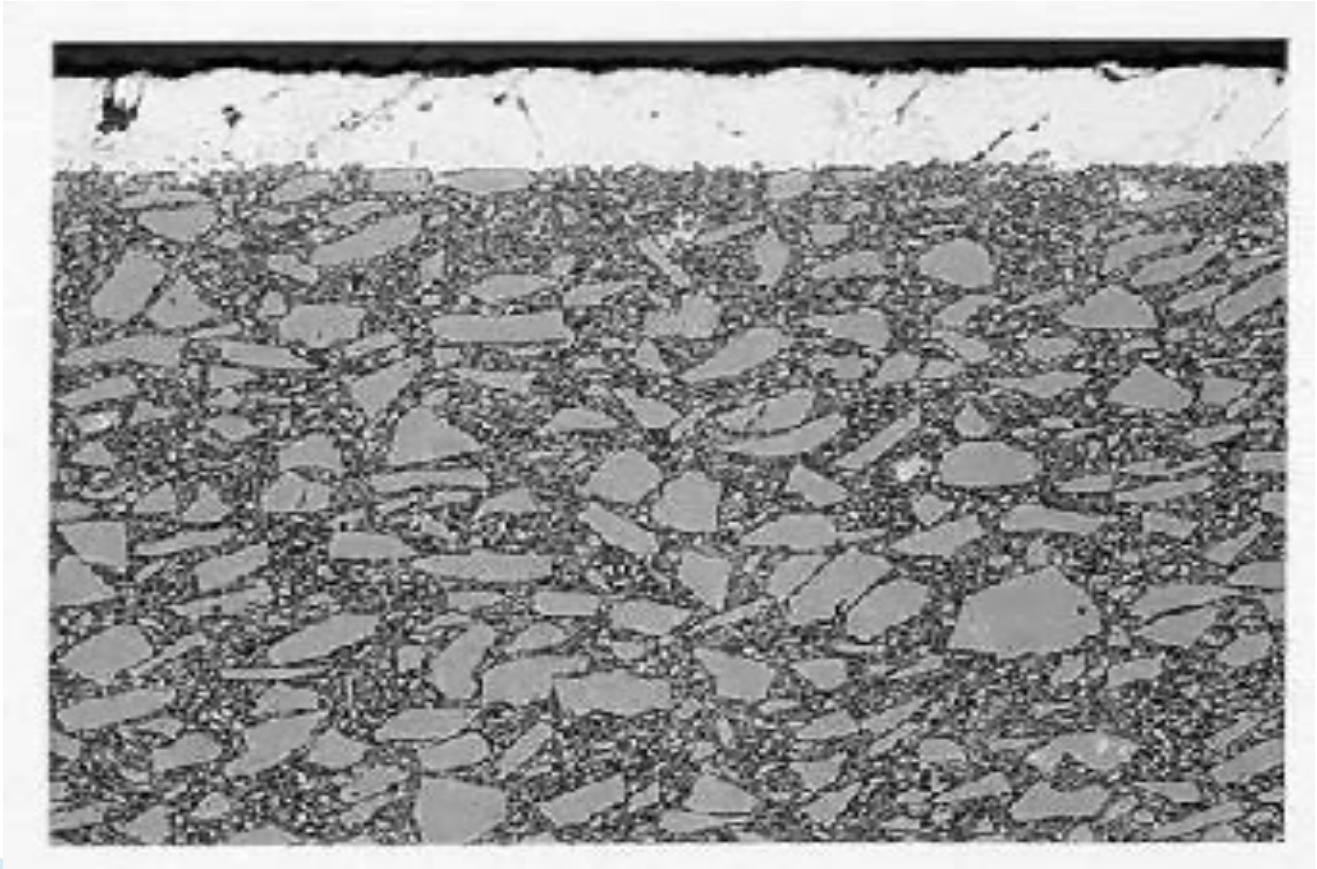
AlSiC flip chip lids



Who are some of RTI's clients?

Ragan Technologies, Inc.

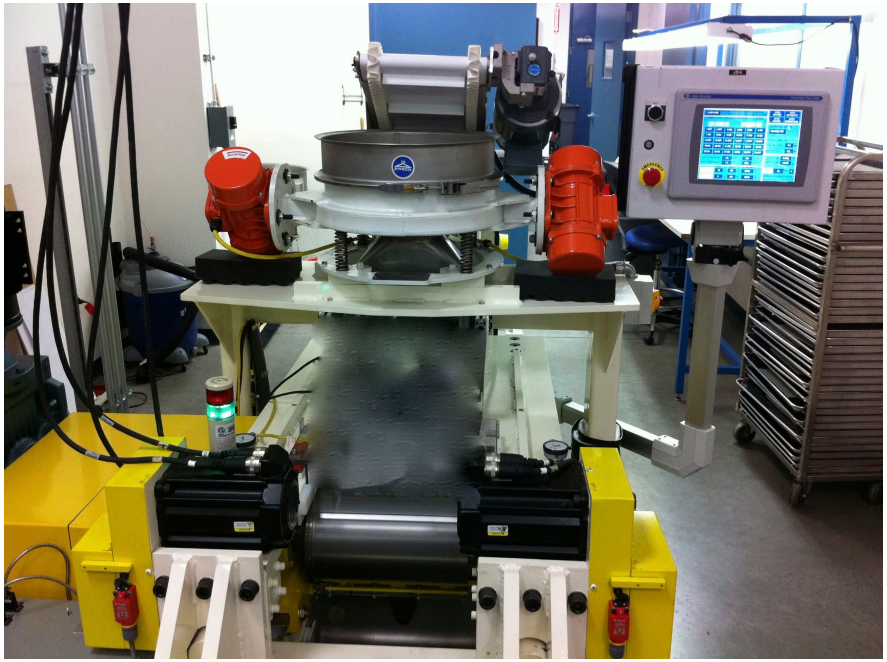
SiC infiltrated with Al metal,
note metal “skin”



Who are some of RTI’s clients?

Ragan Technologies, Inc.

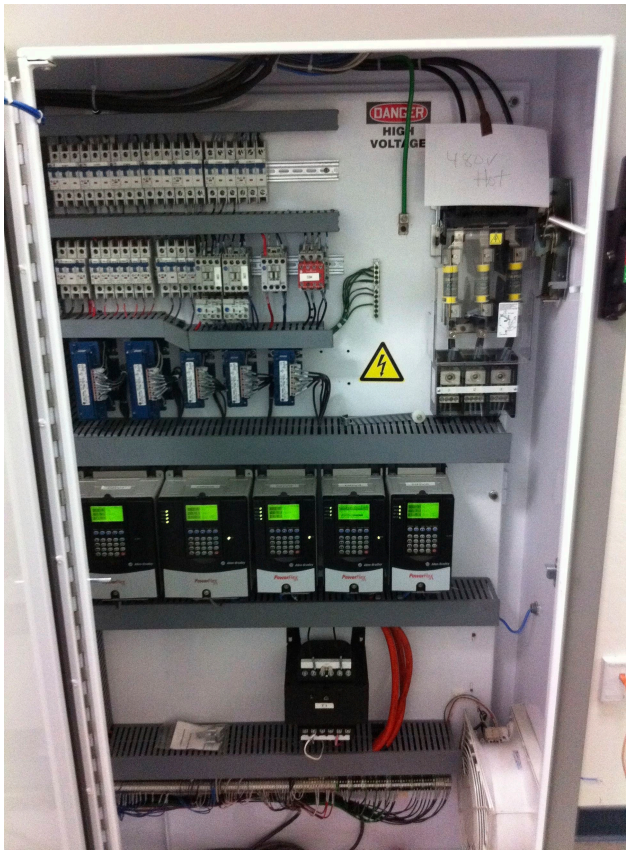
Semi-auto integrated system at
13” wide running at 6’/min



Who are some of RTI’s clients?

Ragan Technologies, Inc.

Module produced 3500 sq. ft. per day single shift at 0.180" thick.



Who are some of RTI's clients?

Ragan Technologies, Inc.

Refractron Technologies, Corp.

- Acquired a license in 2012 for porous ceramic filter plates for mining application.

- Replaced powder pressing process to make 30” x 60” sheets at 1” thick.

Who are some of RTI’s clients?

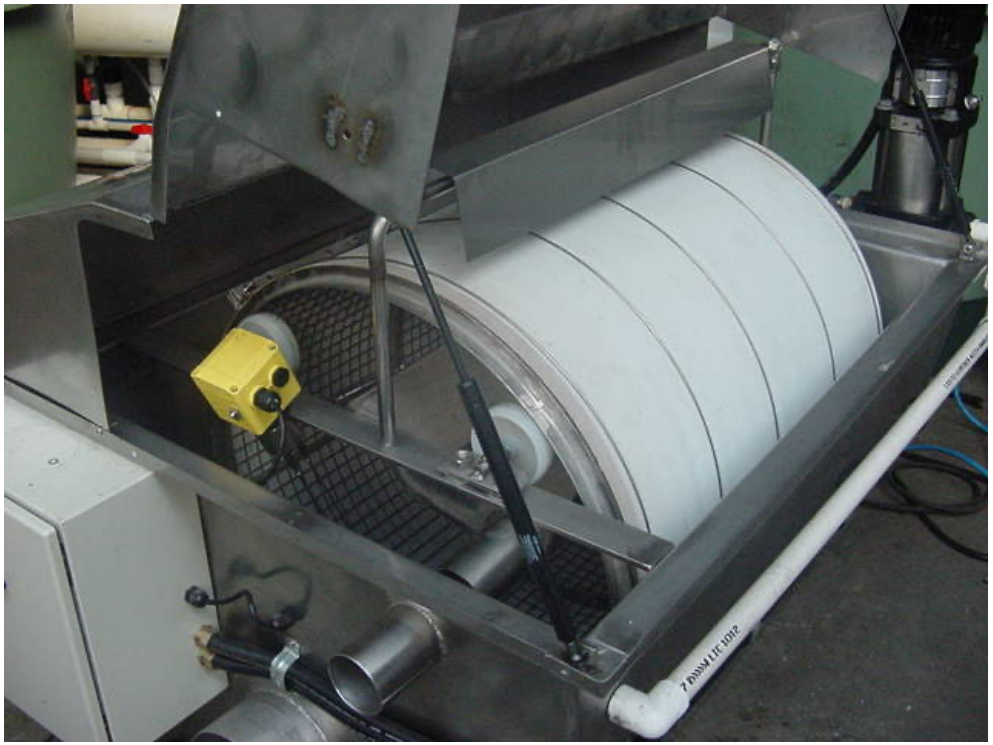
Ragan Technologies, Inc.

- Mining filter plates.

Who are some of RTI's clients?

Ragan Technologies, Inc.

- Flexible tapes enabled curved drum filter segments to be produced efficiently.



Who are some of RTI's clients?

Ragan Technologies, Inc.

Tolling Applications for HSC™:

- Ceramic capacitor dielectric – improved voltage strength.
- Increased green density.
- Reduced defects.
- Thickness control.
- Flat fire.

Who are some of RTI's clients?

Ragan Technologies, Inc.

Tolling Applications for HSC™:

- Body armor – form thick tapes single layer.
- Lighter tiles due to internal defect elimination.
- Metal matrix composite heat spreaders.
- Very dense powders easily formed into tapes.

Who are some of RTI's clients?

Ragan Technologies, Inc.

Tolling Applications for HSC™:

- Ceramic substrates – uniform density.
- Fire flat.
- Thickness control.
- Reduced shrinkage variation.

Who are some of RTI's clients?

Ragan Technologies, Inc.

Tolling Applications for HSC™:

- Fugitive tapes – sublimate upon heating, make hollow cavities.
- Solid oxide fuel cell anode and electrolyte.
- Braze alloy tape for turbine repair.
- Ferrite tapes for chip inductors.
- LED phosphors.
- Porous tapes for diesel exhaust filters.

Who are some of RTI's clients?

Ragan Technologies, Inc.

HOW CAN THE TECHNOLOGY BE UTILIZED OR ACQUIRED?

- Because the HSC™ technology is difficult to police it is kept as a trade secret.

Ragan Technologies, Inc.

- There are numerous options available:
- Turn-key technology transfer installation includes custom designed HSC™ equipment, process specifications, operator training, machine warrantee and ongoing support.
- Client only commits new capital when milestones events are achieved.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- Licenses are issued by field of use.
- If a license is not desired, RTI can toll manufacture tapes.
- No trade secret information is disclosed, no license fee or royalties are paid.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- RTI provides cost based on square feet or per sheet.
- Blanket orders with periodic releases reduce tape cost.
- In house lab scale equipment capable of processing about 15kg of powder per day with prepared powder.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

The following is a typical scenario for technology transfer:

- RTI meets with client to discuss technical requirements.
- Client provides a tape specification listing all critical parameters desired.
- Initial evaluation samples are provided for a nominal laboratory fee.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- Client ships powder to RTI.
- RTI produces small batches to determine process parameters, binder loading, and formulation.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- These samples are made on a lab scale, manual system that disperses the binder and forms the tapes.
- RTI delivers sample tapes, typically 10-50 sheets.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- Turn around is usually 1 week.
- Client performs evaluation of tapes.
- RTI and client meet telephonically to discuss results.
- Client determines that there is cost or technical benefit – Milestone 1.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- For high volume applications the powder and binder are spray dried.
- Drying runs are made at three binder concentrations.
- RTI evaluates the various mixes and determines the optimum binder concentration with spray drying.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- Tapes are then produced on the semi-automatic HSC™ system.
- Tapes are delivered to client, typically 50 – 100 sheets from optimized formulation.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- RTI determines cost for producing tapes and provides a quote for tape tolling.
- Tape cost estimates are based on volume due to the inherent efficiency of the process.

How can the technology be utilized or acquired?

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- Higher volumes reduce tape cost.
- Blanket orders with monthly draws reduce costs.
- Client evaluates the tapes made with the volume manufacturing process.

How can the technology be utilized or acquired?

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- Client determines if technical or cost advantage is still viable based on their results and the cost estimate – Milestone 2.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- RTI toll manufactures tapes for the client.
- Client processes tapes in parallel with current process to verify HSC™ tapes in production.
- Client qualifies tapes in production – Milestone 3.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- RTI develops ball park cost estimate for HSC™ production module.
- Equipment is custom designed for size and level of automation.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- Small scale laboratory version – manual
- Medium scale, semi automatic module – load hopper, handle pre-form billets, hand feed calendar mill, unload finished tapes.
- Fully automatic module – add powder to hopper, remove finished tapes.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- RTI and client meet with machine builders and finalize design, machine cost, and lead-time.
- Client places order for machine module.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- RTI and client negotiate terms of license agreement.
- RTI and client sign license agreement – Milestone 4.

How can the technology be utilized or acquired?

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- RTI continues to toll manufacture for client while HSC™ module is built.
- Typical lead-time is 4 months.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- Upon completion, machine is run at the machine builders facility. This allows for debugging of the machine, modifications to be made, and to prove out the system at production rates.

- Machine operation is verified by client.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- Machine is delivered to client.
- RTI assists in machine set-up at clients facility.
- RTI provides written process specifications and training of engineers and operators.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- RTI provides ongoing support with periodic visits to client facility.
- Machine warrantee is typically 2 years.
- Technology transfer complete – Milestone 5.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

- RTI shares in a small portion of the benefit derived from the HSC™ process in the form of royalty payments.
- Fully paid license can be negotiated.

How can the technology be utilized or acquired?

Ragan Technologies, Inc.

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