

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.



Presentation Outline:

> Who is RTI?

> Technical benefits of the HSC[™] process.

> Who are some of RTI's clients?

> How can the technology be acquired?



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.



» 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.

Who is RTI?



> Three of RTI's founders were founders of other successful ceramics companies.

» RTI technical staff has over 180 years of experience in technical ceramics.





Randall C. Ragan - Founder (1915-2009)







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.





<u>Randall C. Ragan – Founder (1915–2009)</u>
 > 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.

Who is RTI?



<u>Randall C. Ragan - Founder (1915-2009)</u>
 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

Who is RTI?



<u>Ken Wallace – Board Member</u> > 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.





<u> Ken Wallace – Board Member</u>

Mechanical engineer, process engineer, machine designer.

> Expert in automation and process control.

> Corporate Director.





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

Who is RTI?



William C. Belko – President & CEO > Awarded one patent for ZST™ LTCC technology.

- > Technical liaison with clients.
- > Corporate Director.





<u>C.L. (Bim) Wallace – Founder (1925–2019)</u> > Active in the ceramics industry since 1955.

- > Co-founder of Cladan Corp.
- Physicist
- > Master machinist





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

Who is RTI?



William R. Belko – Board Member > 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.





<u>William R. Belko – Board Member</u> > Awarded 14 patents in the field of electronic ceramics.

- Founded 3 other successful companies specializing in technology transfer.
- Corporate Director





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.



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





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





- 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.



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.



Spray dried or "prepared" powder greatly reduces labor and increases efficiency in tolling operation.

> Increased efficiency = lower cost



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



Technical benefits of HSC[™]



> 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).



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





Process is an improvement on traditional roll compaction.

> HSC[™] tapes can be stiff or flexible.

> HSC[™] tapes are never brittle.



- 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.

Technical benefits of HSC[™]



> HSC[™] tapes are completely isotropic.

> HSC[™] tapes fire FLAT.



- 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.



> Extreme thickness control.

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



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

> Thickness repeatability is maximized.





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





The particles are sheared against one another and find the "best fit" increasing green density.

> Improved sintering due to close particle packing.



Powder pressed SiC





HSC[™] SiC Tape




> This isotropic dispersion yields tapes with greatly reduced shrinkage variation.

Density typically >70% of theoretical and as high as 85% possible.

> Reduced sintering temperature.



- > 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.



> 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.



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.



Porosity can be induced when required.

> Fugitive pore formers are easily dispersed.





Sintered porosity can be >60%.

Degree of compaction and organic content can be controlled which allows porosity to be accurately predicted.



» 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.



> Tapes are isotropic right up to the edges reducing scrap.

> Trimmings can be re-processed into tape.

> Powder yield approaches 100%.



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



> The HSC[™] process utilizes proprietary aqueous binders.

Eliminates explosion hazards and EPA concerns.





> Easy water clean up of equipment.

> Reduced equipment down-time.

Solvent based binders available when needed.



- > 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)



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.





➤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.



<u>Smith International – SII MegaDiamond</u> > 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.



- 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.



Diamond Enhanced Inserts





PCD Cutting Inserts





Process is used in facilities in Provo, UT and in Italy.

SII awarded 10 new patents based on products made with HSC™ tape.



<u>Rogers Corporation – Thermal Management</u> <u>Solutions.</u>

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



> 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").



> 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.



> CTE matched thermal spreaders.

Flip Chip Lids.

> IGBT base plates.

> Other light weight high strength applications.



IGBT base plates





AlSiC flip chip lids





SiC infiltrated with Al metal, note metal "skin"





Semi-auto integrated system at 13" wide running at 6'/min







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







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.



> Mining filter plates.





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





Tolling Applications for HSC™:

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



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.



Tolling Applications for HSC™:

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





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.



HOW CAN THE TECHNOLOGY BE UTILIZED OR ACQUIRED?

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


> 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.



> 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.



» 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.



<u>The following is a typical scenario for</u> <u>technology transfer:</u>

- » 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.



Client ships powder to RTI.

» RTI produces small batches to determine process parameters, binder loading, and formulation.



- 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.



> 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.



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.



> Tapes are then produced on the semiautomatic HSC[™] system.

> Tapes are delivered to client, typically 50 – 100 sheets from optimized formulation.



» 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.



> Higher volumes reduce tape cost.

» Blanket orders with monthly draws reduce costs.

> Client evaluates the tapes made with the volume manufacturing process.



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



> 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.



> RTI develops ball park cost estimate for HSC™ production module.

Equipment is custom designed for size and level of automation.



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.



» RTI and client meet with machine builders and finalize design, machine cost, and lead-time.

> Client places order for machine module.



» RTI and client negotiate terms of license agreement.

» RTI and client sign license agreement – Milestone 4.



> RTI continues to toll manufacture for client while HSC[™] module is built.

> Typical lead-time is 4 months.



> 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.



> 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.



» RTI provides ongoing support with periodic visits to client facility.

> Machine warrantee is typically 2 years.

> Technology transfer complete - Milestone 5.



> 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.



www.ragantech.com

bbelko@ragantech.com

(978) 297–9805

204 Pleasant Street Winchendon, MA 01475



