Microwave Technology for Processing of Metals

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Overview & Agenda

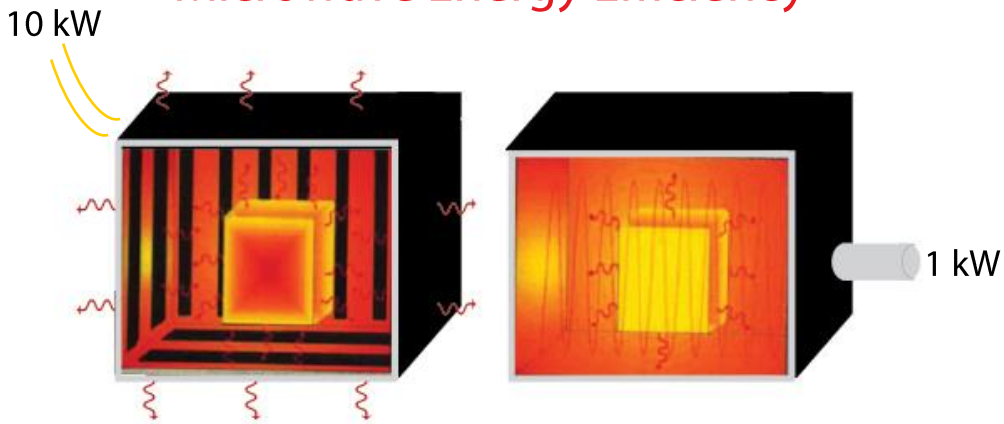
- Why (and why not) Microwave?
- The Truth about Microwave Heating
- Designing for Success – Process & Equipment
- Case Study Examples
- Summary

Microwave Heating - Primary Benefits

- Energy efficient - saves energy because only the product is heated
- Rapid processing - load heated directly

★ Cycle times and energy requirements drastically reduced ★

Microwave Energy Efficiency



Conventional Sintering
58 kW hr/ kg

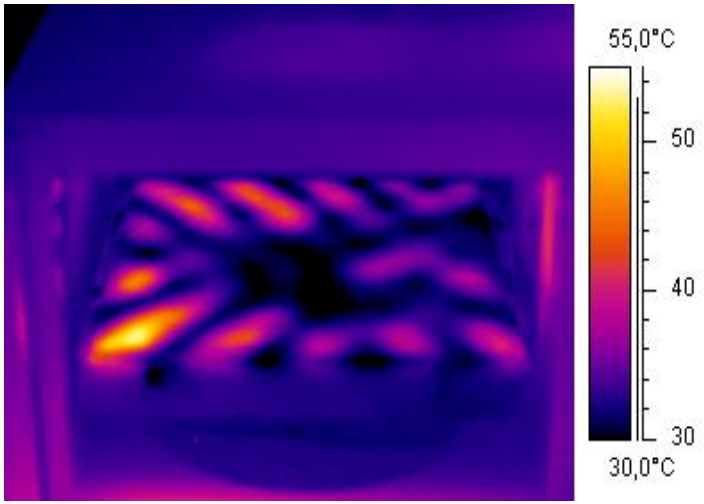
Microwave Sintering
4.3 kW hr/ kg

Microwave Heating – Secondary Benefits

- ✓ Flexibility – ability to process in different environments
- ✓ Material Purity – product contamination can be dramatically reduced
- ✓ Increased Volumetric Utilization – avoids limitations of thermal conductivity, shadowing, convective heat transfer
- ✓ Smaller Footprint – little or no cooling or insulation required
- ✓ Control over Moisture Content – coupling with water is very effective
- ✓ Volumetric Heating – Little or no gradient from the outside to interior

Microwave Heating Conceptions

- Microwaves heat from the inside out? Not Quite
- Energy distribution in microwave equipment is uniform? NO
- The load is the heating element? True
- Metallic materials do not heat in microwaves? True(ish)
- Cannot build continuous systems? False



The Challenge

- Microwaves at 915 and 2450 MHz have a very small depth of penetration in metallic materials.
- Therefore, metals cannot be directly heated by microwave energy in a controlled fashion.

The Solution

- Tungsten Carbide, Cobalt, various Cermets:
  - Readily couples with microwaves

- Other metals:
  - Indirect heating
  - Heating with susceptor beds

Microwave Benefit: Heating of small local volume adjacent to the object thus improving heat transfer.

Case Studies

Analyze issues, challenges and solutions for:

- Process modification
  - Susceptor Bed

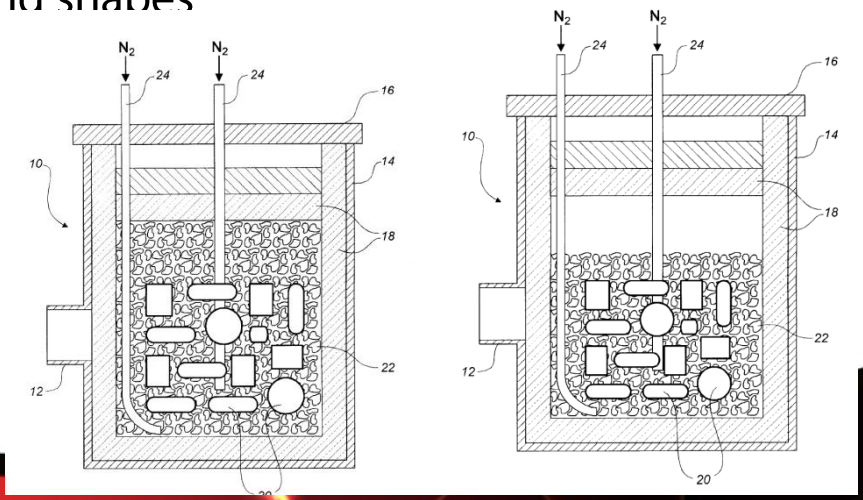
- Equipment Modification
  - Precise Waveguide Engineering

Process Modification

Use a susceptor bed to couple with microwaves and transfer the heat to the object.

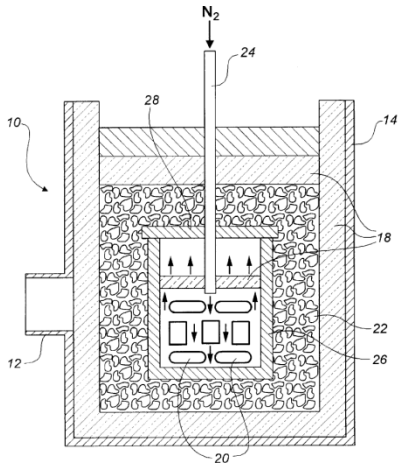
- ✓ **Developed a 'Powder Bed' process [USP 5808282]**
  - Placed load in a granular bed of microwave susceptible material
  - The bed heats the load .
  - The bed then acts as insulation as it collapses with the shrinking load
  - Accommodates multiple sizes and shapes

Works for many materials which do not couple

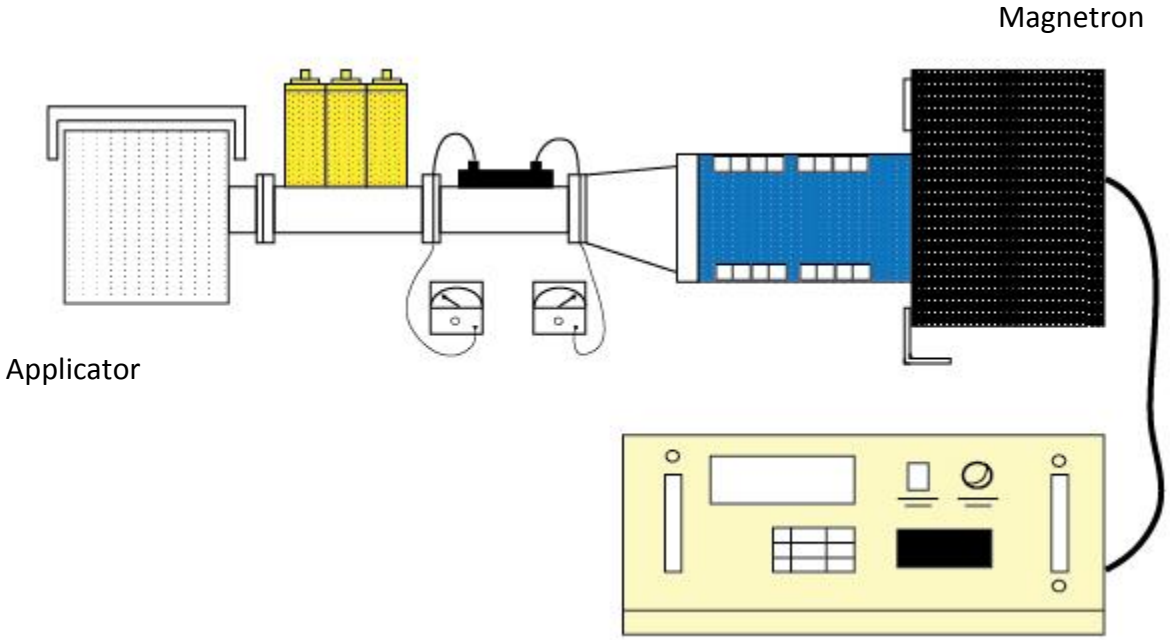


Properties of Powder Bed

- Should couple with microwaves at room temperature
- Free flowing so it can collapse with the samples as they shrink
- Tailored to provide the desired heating
- Should not react with the load
- Should permit gas flow for atmosphere control
- Should not sinter to itself

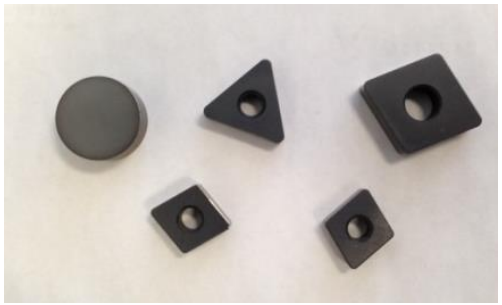


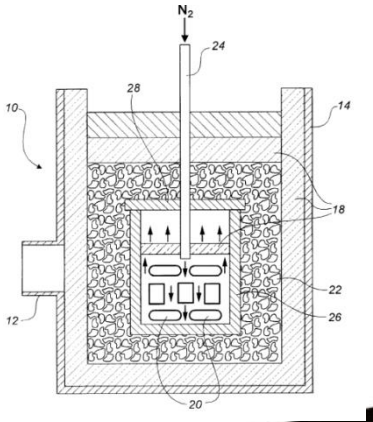
Schematic of Apparatus Assembly



Powder bed example: Hard-metal WC-Co

- WC/Co couple very nicely with microwave energy from room temperature.
- Important to maintain insulation cover
- Powder bed concept as a collapsing insulation very effective
- Ultrafine microstructures have been produced and reported



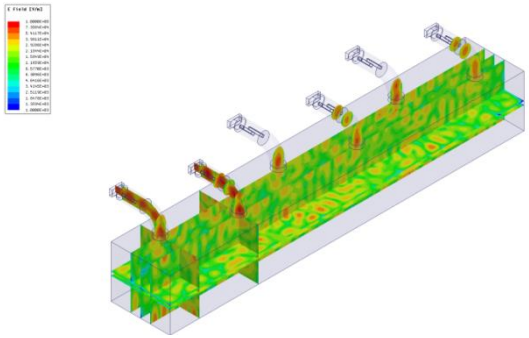


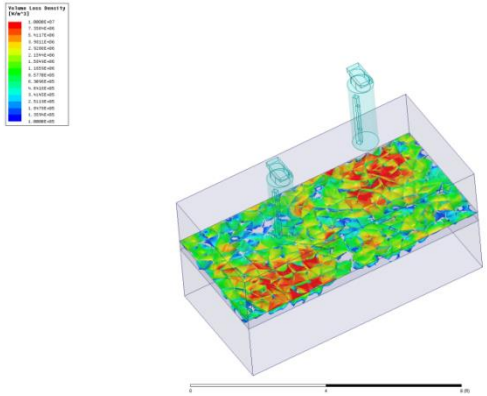
Processing of other Metals

- Metals such as Copper, Aluminum, Nickel and alloys melted, sintered and heat treated:
  - Powder bed generates the heat locally
  - Powder bed can be graded to provide heating and insulation
  - Rapid processing achieved since the heat is generated in close vicinity of the sample

Considerations for Equipment Modification

- ✓ Continuous system has to be choked well for safety
- ✓ Heating needs to be controlled across the width of the furnace
- ✓ 'Line of sight' effect where the microwave energy is introduced
- ✓ Process needs to be modified to utilize the properties of microwave energy.
- ✓ 'Samples in powder bed' concept utilized successfully





Courtesy of Ferrite Microwave Technologies

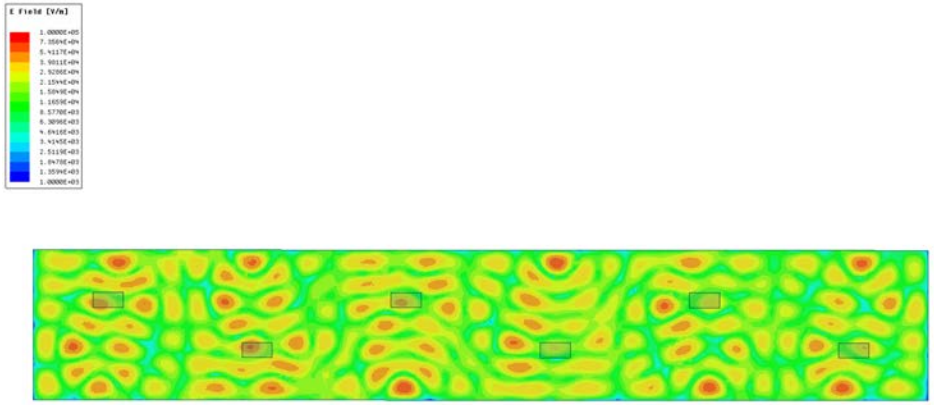
Microwave Powered Continuous Equipment

Courtesy of Ferrite Microwave Technologies

Field Distribution in a Tunnel Applicator

Plane view along the length

- Normal wave guide input in multiple locations along the length
- Simulation of the electric field distribution shows regions of 'hot spots' - up to 6 times more energy
- These could heat up more than the surrounding area and could sometimes cause thermal runaway
- Parts can be heated if the load arrangement in the furnace is modified to utilize high field strength regions



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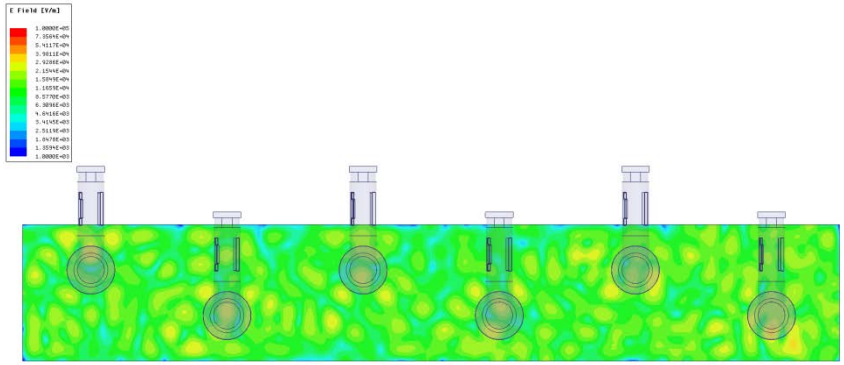
Field Distribution in a Tunnel Applicator

Plan view along the length

- With novel patented input design
- Electric field distribution more uniform
- Better distribution of energy, more uniform energy distribution



Courtesy of Ferrite Microwave Technologies

Summary

- Microwave processing technology and equipment can be beneficially utilized for processing metals on a commercial scale
- The applications have to utilize the concepts of local, rapid and perhaps indirect heating
- Careful design of equipment based on the material properties of the load is essential
- Once developed, the process and equipment can yield superior products
- Not possible to design and build a ‘standard’ furnace
- Beneficial to de-risk the development and reduce costs by jointly designing the equipment and testing, with the equipment supplier

Thank You!

Any Questions?

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