

# Industrial Heating

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## Progress in Microwave Heating

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*The application of microwaves in heat treating is coming of age with communication between users, equipment manufacturers, and research institutions being critical to successful implementation.*

Microwave heating is a familiar method for cooking, drying, sterilizing, and can be used to speed up chemical reactions. Microwave technology can also be applied in the metals industry. Equipment and ancillary products have become available as industries search for the advantages that microwaves have to offer. These advantages include:

- fast processing
- energy cost reduction
- clean processing
- space savings
- property improvements

The last 20 years have seen a steady growth in the use of microwaves for industrial heating. There are literally thousands of processes that can use microwaves cost effectively, but many are yet to be implemented. Designing cost effective microwave equipment with appropriate capability requires a clear understanding of the needs, knowledge of microwave and materials interactions, and intelligent engineering.

Today there is a service that accelerates and smoothes the path to commercialization for microwave heating processes by helping businesses make the connections between their processing needs and practical microwave heating solutions. The Microwave Testing Center at Ceralink Inc. (Troy, NY, [www.ceralink.com](http://www.ceralink.com)) is a hub for proof of concept, cost-benefit analysis, and equipment design services, providing critical information to equipment manufacturers when there is a need for scale-up. The focus is on commercialization through the integration of end users, equipment manufacturers, and research institutions. Communication between parties is critical to successful implementation of microwave technology.

One example of the end user driving the development of microwave systems is Dana Corporation (Toledo, OH, [www.dana.com](http://www.dana.com)) and their AtmoPlas™ microwave atmospheric plasma technology. Dana employs a commercially available microwave and has designed a method for generating a plasma, which can be used to join or heat treat metals. A major advantage to the technology is that it can be applied at atmospheric pressure. Dana's success has led to twenty patent applications. Their first patent was awarded in June 2005 for plasma assisted joining of metal components.



Fig. 1. An example of microwave diffused chrome used to prevent corrosion



Fig. 2. Microwave setup with 50 pound melt capability.

Dana's microwave group has grown to twenty people, to explore and commercialize this new technology. They are in the design phase, with plans to build a large, high power microwave system for larger loads. It is likely that Dana will use AtmoPlas™ internally for joining and carburizing, but there is also a major push to license the technology to equipment suppliers and other end users. At this stage, Dana has signed joint development agreements with two European companies to develop and manufacture microwave nitriding (Rubig GmbH, [www.rubig.com](http://www.rubig.com)) and carburizing equipment (ALD Vacuum Technologies, [www.ald-vt.com](http://www.ald-vt.com)). Other potential applications for microwave plasma technology include hardening, sintering, annealing, and coating.

Another microwave approach to many of these applications may grow out of the diffusion technology developed at Y-12 (Oak Ridge, TN, [y12.doe.gov](http://y12.doe.gov)) and licensed to Tesla USA (Chattanooga, TN, <http://teslausainc.com>). The microwave diffusion process is also carried out at atmospheric pressure in a system similar to the commercial system at Dana Corp. The technology is currently being used to chromize steel for corrosion resistance. The microwave diffusion process is cleaner and faster than the conventional packed bed method. In the traditional method, the powder bed becomes hard and sticks to the parts. In the microwave process, the powder is loose, making it easy to remove parts. Recent advances have shown that the parts can be diffused without submersion in the powder. This suggests that diffusion occurs through a vapor phase. Further investigations are warranted to determine if this method can be modified for carburizing and nitriding. Microwave systems similar to those used by Dana and Tesla are available from Communications and Power System (CPI, Beverly, MA, [www.autowave.tv](http://www.autowave.tv))

After a shaky start, Tesla USA has finally positioned themselves to move forward by adding the staff necessary to deploy the microwave diffusion chrome process on a commercial scale. They have demonstrated superior properties at a lower cost for at least one product. Their plan is to provide diffusion coatings, starting with low tech products (Fig 1), and with experience, as the technology is proven, to move up towards high tech parts such as turbines. Eventually, they will undoubtedly look to license the technology to larger customers.

In another example, a DOE project with a Fortune 500 company has led to a novel method for separating metals from polymers. The scale up stage requires specialized equipment that can apply microwaves in a high pressure autoclave. After analyzing the process needs Ceralink first looked for "off the shelf" solutions, but it was clear that the most efficient approach was to team an autoclave manufacturer and a microwave manufacturer. The system designs have been finalized and the microwave autoclave will be built early in 2006. Two other projects that will benefit from microwave autoclave capabilities are in process.

Microwave autoclaves are a fairly new concept, with few choices available commercially. Milestone (Shelton, CT, [www.milestonesci.com](http://www.milestonesci.com)) is offering the Ultraclave (still in development) for chemical processing. Michigan Technological University (Houghton, MI, [www.imp.mtu.edu](http://www.imp.mtu.edu)) built a laboratory microwave autoclave and offers to build and sell these units. Also, Microwave Materials Technology (Oak Ridge TN,) sells a low pressure microwave autoclave to the chemical industry.

Another technology that originated at Y-12 is a microwave process with a susceptor crucible to melt and form large uranium spheres. A similar concept was shown by Reid (<http://home.c2i.net/metaphor/mvpage.html>) for melting metal in a kitchen microwave. Ceralink adapted this process for scale-up and made it more affordable by using 915 MHz power instead of 2.45 GHz, the conventional kitchen microwave frequency. In addition, the furnace (Fig. 2) could be tapped. In this study, it was determined that the energy consumption per unit mass decreased for larger load sizes. This effect was also shown for sintering of ceramics ([http://www.ceralink.com/publications/ComparisonOfEnergy\\_April03.PDF](http://www.ceralink.com/publications/ComparisonOfEnergy_April03.PDF)). The process becomes more efficient with scale-up, which should be taken into consideration when performing a cost benefit analysis.

One established technology that is now experiencing a push-pull relationship is the patented Microwave Assist Technology (CerMAT™). Ceralink has an exclusive license for this technology in North America to make it more accessible. Microwave Assist Technology kilns are already available rated to 1100 °C (Fig. 4) and 1700 °C (Fig. 5). For example, an electric kiln rated to 1100 °C (2012 °F) was retrofit for a feasibility firing study of an ultra low weight, refractory brick. This technology was chosen due to the heating characteristics of the brick and the need for uniform shrinkage. Based on the proof of concept, the client chose Harrop Industries (Columbus, OH, [www.harropusa.com](http://www.harropusa.com)) as the furnace manufacturer for the scale-up system. This team will design and build a CerMAT™ elevator kiln for the application.

Finally, Carbolite, a UK kiln manufacturer is wrapping up a deal for an exclusive license for Microwave Assist Technology in Europe and is expected to introduce microwave assist laboratory kilns next year.

## In Conclusion

For those interested in microwave heating processes there are several upcoming conferences: The International Microwave Power Institute (IMPI) Annual Symposium will be held in Boston, MA, August 8-12, 2006 ([www.impi.org](http://www.impi.org)) and Dana Corporation's First Industrial Microwave Processing Technologies Symposium and Exhibition in San Antonio, TX, Nov 5-7, 2006. IH

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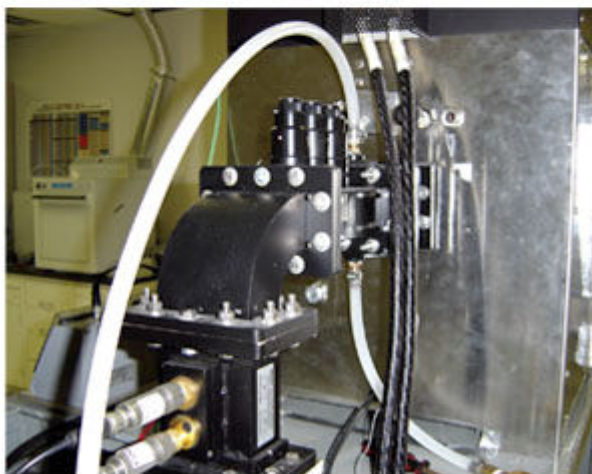


Fig. 3. A binder burnout furnace retrofitted to accept microwaves for the ultra low weight, refractory brick. Cycle time was reduced from one week to approximately 3-4 hours. The magnetron is shown in the back of the kiln. Fig. 4. Microwaves enter this 1700 °C CerMAT™ furnace through a waveguide configuration.