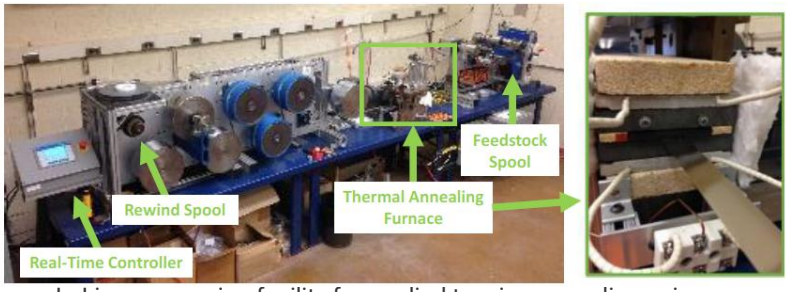
TECHBRIEF

NETL Ref. No: 18N-29

Microwave Annealing Systems for Alloy Processing



In-Line processing facility for applied tension annealing using a conventional furnace set-up.

Opportunity

Producing soft magnetic alloys with tightly controlled properties requires heat treatments that can tune microstructures without introducing large thermal gradients or slow furnace cycles. Engineers at the U.S. Department of Energy's National Energy Technology Laboratory (NETL) and Pennsylvania State University (Penn State) designed a single-mode microwave processing system that creates spatially distinct regions of pure magnetic and pure electric fields inside the same chamber. Amorphous alloy segments are automatically positioned in one of these field regions, where microwave energy couples directly into the material to generate internal heating between 400 and 700°C. Because the chamber geometry separates electric and magnetic field maxima, operators can select annealing conditions that influence permeability, microstructural evolution or stress relief with high spatial precision. Automated loading and unloading supports continuous, in-line treatment of short alloy sections, enabling consistent production of tape-wound cores and other magnetic components. This approach provides a controllable alternative to conventional furnace annealing while allowing real time adjustment of stress, temperature and processing speed. This technology is available for licensing and/or further collaborative research from NETL in partnership with Penn State.

Problems Addressed

- Traditional thermal annealing methods involve large heating zones and slow processing, which severely limit spatial control over material properties and reduce production speed.
- Existing in-line annealing techniques, such as strain annealing furnaces, lack the fine spatial resolution needed to easily produce localized variations in properties like permeability.

Potential Commercial Application

- Manufacturing of Soft Magnetic Components: high-throughput, in-line production of improved soft magnetic components like inductors, transformers, motors and sensors.
- Manufacturing of Electromagnetic Shielding Materials: efficient, in-line production of electromagnetic interference (EMI) and general electromagnetic shielding materials

Competitive Advantages

- Enhanced Spatial Control: Microwave and radio frequency (RF) annealing provide fine spatial control over heating, enabling localized treatment of amorphous and nanocrystalline alloy ribbons.
- Increased Processing Speed: The rapid heating and cooling cycles of microwave and RF annealing significantly reduce processing time compared to traditional thermal annealing methods.

Intellectual Property Status

A U.S. patent (US12349262) was issued on July 1, 2025, and expires on January 16, 2042.

Publications

P. Ohodnicki, et al. In-line microwave processing of alloys. (2025). United States Patent and Trademark Office. U.S. Patent No.: 12,349,262.

Licensing
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