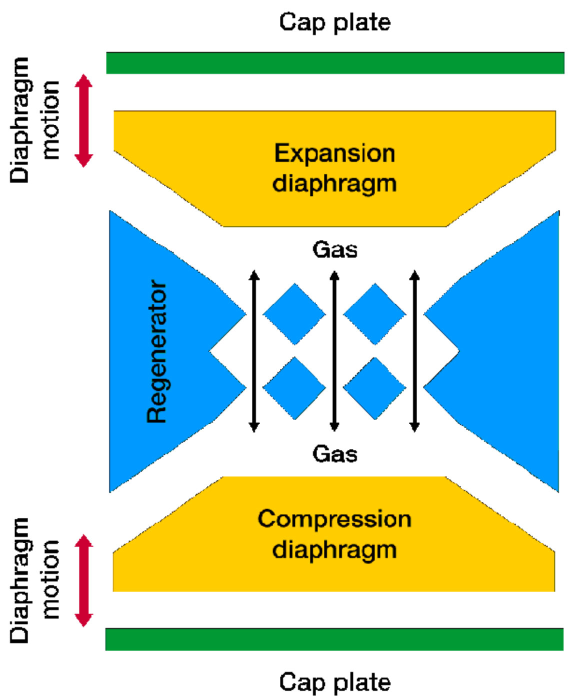
# MEMS Device Being Developed for Active Cooling and Temperature Control

High-capacity cooling options remain limited for many small-scale applications such as microelectronic components, miniature sensors, and microsystems. A microelectromechanical system (MEMS) is currently under development at the NASA Glenn Research Center to meet this need. It uses a thermodynamic cycle to provide cooling or heating directly to a thermally loaded surface. The device can be used strictly in the cooling mode, or it can be switched between cooling and heating modes in milliseconds for precise temperature control. Fabrication and assembly are accomplished by wet etching and wafer bonding techniques routinely used in the semiconductor processing industry. Benefits of the MEMS cooler include scalability to fractions of a millimeter, modularity for increased capacity and staging to low temperatures, simple interfaces and limited failure modes, and minimal induced vibration.




*Cross-sectional view of one cell of the MEMS Stirling cooler.*

The MEMS cooler has potential applications across a broad range of industries: biomedical, computer, automotive, and aerospace. The basic capabilities it provides can be categorized into four key areas:

1. Extended environmental temperature range in harsh environments
2. Lower operating temperatures for electronics and other components
3. Precision spatial and temporal thermal control for temperature-sensitive devices

4. The enabling of microsystem devices that require active cooling and/or temperature control

Stirling cycle coolers have been used for decades to produce cooling temperatures down to the cryogenic range for a variety of applications. Historically, these machines have been made using pistons, mechanical linkages, and other standard engine components along with traditional materials and fabrication methods. More recently, the need for smaller-scale coolers has pushed the limits of these traditional components and assembly techniques. However, available coolers are still too large for many applications including certain electronic components, sensors, and MEMS devices.

Rapidly expanding capabilities of semiconductor processing in general, and microsystems packaging in particular, present a new opportunity to extend Stirling cycle cooling to the MEMS domain. The comparatively high capacity and efficiency possible with a MEMS Stirling cooler provides a level of active cooling that is currently impossible at the micro scale with current state-of-the-art techniques. The MEMS cooler technology builds on decades of research on Stirling cycle machines performed at Glenn, while capitalizing on Glenn's emerging microsystems capabilities.

The MEMS cooler device is composed of numerous Stirling-cycle cells arranged in parallel and/or in series. The expansion and compression diaphragms, which are the only moving parts in the device, are deflected toward and away from the regenerator region in phase-shifted sinusoidal fashion to produce the Stirling cycle. Expansion of the working gas directly beneath the expansion diaphragm in each cycle creates a cold end for extracting heat, while compression at the other end creates a hot region for dissipating heat. Heat is transferred to and from the working gas as it is forced through the regenerator region by the moving diaphragms.

The slanted geometries of the diaphragm and regenerator surfaces are characteristic of the wet etching process used to create the structure and advantageously increase the swept volume in the expansion and compression regions. A thin-film temperature sensor deposited on the surface of the cap plate provides control feedback. This sensor, along with the ability to switch hot and cold ends by altering the cycle with control software, permits the device to be used for precise thermal control as well as cooling.

Preliminary analysis of the MEMS cooler has been completed and indicates a theoretical performance that is an order-of-magnitude improvement over existing state-of-the-art techniques for cooling small-scale components. Detailed analysis and design optimization is planned for the MEMS cooler followed by fabrication of a prototype device for performance testing. All research on the MEMS cooler has been conducted at the NASA Glenn Research Center, and a patent application has been prepared for this technology.

# Bibliography

1. Moran, Matthew E.: Multidisciplinary Analysis of a Microsystem Device for Thermal Control. Prepared for the 11th Thermal & Fluids Analysis Workshop,

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