Industry Developments:

Piezoelectric Cooling

The first Piezoelectric effects were discovered in the late nineteenth century, when it was found that deforming certain materials, e.g. crystals and ceramics, would generate a voltage. Soon after, the reverse effects were seen: applying electrical current to certain materials caused them to deform. This became known as the inverse or converse piezoelectric effect, where the application of an electric field creates mechanical deformation.

Although the first experimental demonstrations of piezoelectric phenomena were published in the early 1880s [1-2], its application for airflow generation started much later [3] and more recent Piezo-related studies have been performed for the electronics cooling market [4-7]. The inverse effect of the Piezoelectric phenomena, where stress is generated as a response to an applied electric field, is the basis for development of a new generation of Piezofans.

Piezoelectric-based cooling methods that employ this inverse effect may play an increasingly important role in smaller and mobile electronics. As mobile packages get smaller and denser, cooling airflow is needed, but adding conventional fans or blowers is impractical. Piezoelectric cooling's small profile offers advantages over circular fans, particularly for cooling low power components in tight spaces. This includes both Piezo fans and jets. [8]

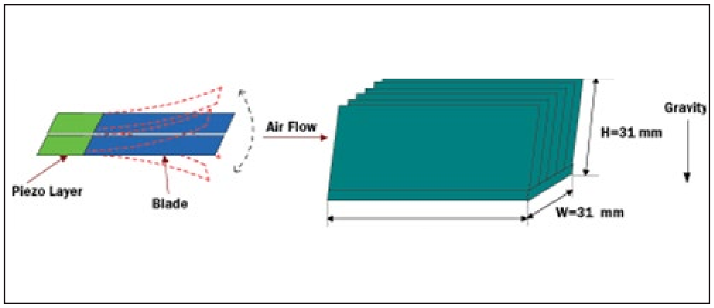

Figure 1. Alternating Current Applied to a Piezo Layer Causes Blades to Vibrate Resulting in Cooling Air Flow [1]

Figure 1 shows an application where the inverse Piezo effect is used to generate airflow. A metal or plastic blade is bonded to a piezoelectric material in a cantilever fashion. When an electric field is applied to the Piezo layer, the randomly oriented ions inside the layer immediately come into alignment. The result is a deformation of the Piezo layer and motion of the blade. Positive and negative electrical voltages affect the material differently. As a positive voltage is applied, the ceramic can expand, causing the blade to move in one direction. A negative electrical voltage can cause the ceramic material to contract and move the blade back in the opposite direction. Under an alternating current, the blade vibrates back and forth with the same frequency as the AC. This vibration generates airflow, which can be used to cool neighboring nearby electronic components.

Piezofans

Piezofans are low power, small, relatively low noise, solid-state devices that recently emerged as viable thermal management solutions for a variety of portable electronics applications, including laptop computers and cellular phones. Piezofans utilize piezoceramic patches bonded onto thin, low frequency flexible blades to drive the fan at its resonance frequency. The resonating low frequency blade creates a streaming airflow directed at electronics components. A group at Purdue reports up to a 100% enhancement over natural convection heat transfer. [4]

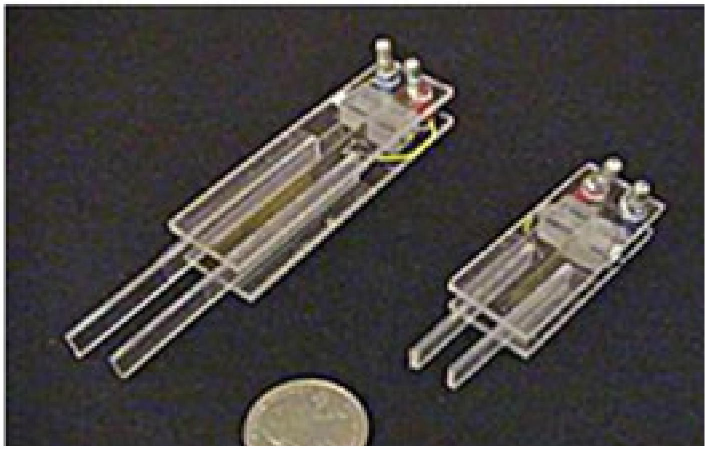

Figure 2. Low-Profile Piezofans Have No Motors and Run With Little Noise [9]

Piezofans consume just 1/150 of the electricity of circular fans. The solid state devices have no parts that will wear out. They have no heat-generating gears or bearings. Without motors for power, they make little acoustic sound and do not produce any stray signals that can lead to EMI problems. [9]

Piezofans can potentially provide low-noise and long-term cooling solutions for modern LED systems. When an AC voltage is applied at the Piezoelectric cantilever's resonant frequency (typically 115V at 60 Hz), the tip of the fan displaces to cause air movement. The vortices

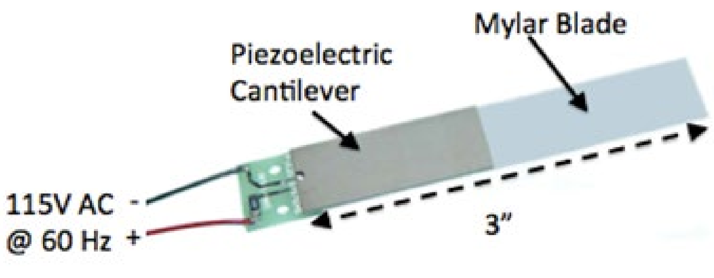

Figure 3. A Piezoelectric Fan Blade Starts Instantly to Provide a High Velocity Airflow Stream (Piezo Systems, Inc.) [11]

flowing from the tip of the blade provide unique airflow patterns for LED cooling applications. Current research is focused on the design of heat-sinks for cooling LED's with piezoelectric fans, to take advantage of their unique flow patterns. This research is focused on (1) experimental heat transfer analysis, (2) computational design and analysis using COMSOL multi-physics and (3) flow visualization of piezoelectric fans to optimize heat-sink designs. [10]

Piezo Jets

Piezo jets offer new cooling technology developed by General Electric, based on electric cooling elements originally developed for use in jet engines. This promises to provide extremely compact, efficient cooling for future electronic devices. The Dual Piezoelectric Cooling Jets, or DCJs, is a system of bellows that provide high-velocity jets of air to cool components down far more efficiently than just convection alone. These DCJ devices were developed to reduce the amount of pressure losses and loading characteristics in aircraft engines, as well as power generation in gas and wind turbines, according to GE. They are specially designed to avoid the conventional fan's issues involving sound, vibration, size and power consumption. Using less than half the power of conventional fans, DCJs allow as much as 30 minutes of extra battery life. [12]

Piezoelectronic Issues

Though they typically use less power than circular fans, a technical challenge to piezoelectric technology is the high operating voltage (> 100 V) needed for conventional Piezofans. This voltage can be reduced by electrically connecting multiple Piezo layers in parallel. [8] The multilayer technology may also be used to reduce the length of the piezoelectric actuator and get the same amplitude as a longer one. The multilayer Piezo technology has not been applied to electronics cooling due to some key material science issues, yield and reliability. With progress, the Piezo industry may overcome various materials, thermal and mechanical challenges to become widely used for electronics cooling.

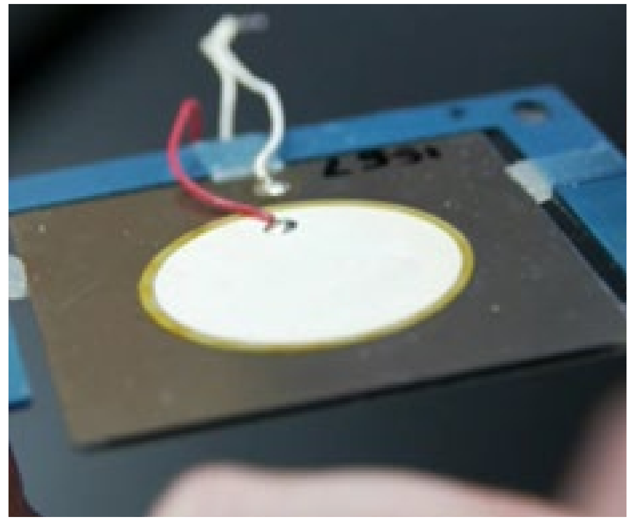

Figure 4. Dual Piezoelectric Cooling Jets are Just 4mm Thick and Use Less Than Half the Power of Conventional Fans [12]

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