Georgia Tech Investigates Liquid Crystal Polymer for NASA Applications

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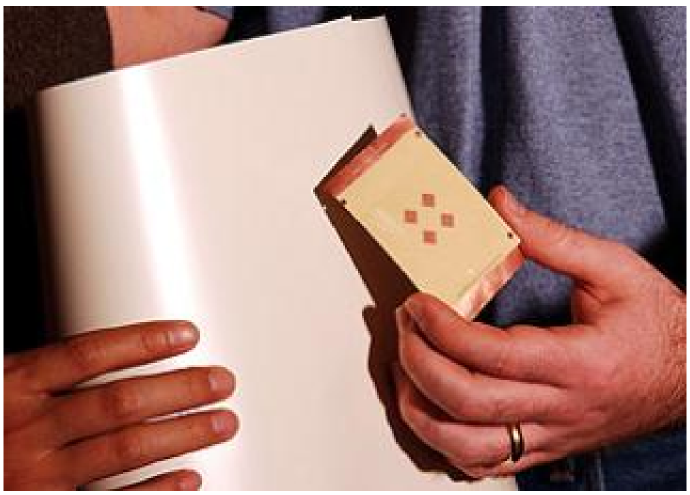

This close-up shows an antenna array embedded on liquid crystal polymer (right). To the left is a large sheet of the flexible, weather-resistant polymer. Georgia Tech Photo: Gary Meek

Researchers at the Georgia Institute of Technology have received funding from the NASA/Earth Science Technology Office to evaluate a material called liquid crystal polymer (LCP) for electronics applications in space.

The ultra-thin, paper-like plastic can incorporate a variety of electronic circuits, yet it molds to any shape and appears to perform well in the extreme temperatures and intense radiation encountered by NASA spacecraft.

George E. Ponchak, a co-investigator and senior research engineer at NASA's Glenn Research Center in Cleveland, Ohio, said research to date indicates that LCP outperforms conventional materials for antennas and circuit boards in high-frequency radio applications aboard space vehicles.

"I think the chances are very high that LCP will be practical for a variety of NASA applications," Ponchak said.

Light weight is the material's biggest potential benefit to NASA, he said. Flexible LCP antennas would be lighter than today's structured antennas, and LCP-based circuits molded to available spacecraft areas could eliminate heavy metal boxes that currently house rigid circuit boards.

"Less weight lets us move to a smaller launch system, which in turn saves a lot of money," Ponchak said.

John Papapolymerou, a professor in the Georgia Tech School of Electrical and Computer Engineering, explains that LCP's unique structure – aromatic crystal polyester comprised of benzene rings, acetyloxy polymers, and carboxyl groups – allows it to be heat resistant, flexible and strong while also possessing excellent electrical performance.

Moreover, the material can serve as a highly efficient substrate – material on which semiconductor chips are attached – as well as the backplane that connects those chips together, said Papapolymerou, who with Prof. Manos Tentzeris leads a team researching LCP. Even micro-electromechanical system (MEMS) devices could be embedded on LCP, along with integrated circuits.

"It's like having a PC board type of technology that has many other advantages," Papapolymerou said. "We are already developing LCP-based technology for NASA applications, and I think eventually you will see LCP in next-generation consumer systems."

Among the material's advantages:

-- It is "near-hermetic" – highly resistant to humidity and other environmental conditions. It could be applied almost like wallpaper to space and other vehicles, forming large antennas aloft.

-- It effectively processes radio frequencies (RF) up to 110 GHz, which is well into the millimeter wave range used for radars as well as for military and scientific communications. By contrast, conventional circuit-board RF capabilities dwindle swiftly above 5 GHz.

-- It is cheaper to make than competing hermetic technologies such as ceramic substrates.

-- Its thermal-expansion properties allow it to form multi-layer structures that won't crack or delaminate. That could lead to three-dimensional circuits that provide both reliability and a smaller footprint.

Papapolymerou and Tentzeris have received two three-year awards from the NASA/Earth Science Technology Office to pursue LCP-related applications. They are currently developing a precipitation-radar application that NASA could use to monitor global water cycling. In addition to NASA, the National Science Foundation is also supporting Georgia Tech's LCP work.

Recent LCP-related publications by the Georgia Tech LCP team have appeared in *IEEE Microwave and Wireless Components Letters, IEEE Antennas and Wireless Propagation Letters, and IEEE Transactions on Advanced Packaging*.

NASA's Ponchak notes that LCP still has hurdles to clear before it can be used in space. Though the material has performed well at high temperatures, it must still complete low-temperature and radiation tests. If it passes those tests, it could be incorporated into NASA spacecraft designs within two years, he said.

Papapolymerou believes that RF circuits for communications and radar are LCP's most promising application thus far. But Georgia Tech engineers are also investigating the robust polymer's capacity to embed analog and digital chips, RF MEMS devices and RF circuits together in one flexible, weather-resistant package.

Currently, Papapolymerou said, his team is weighing the reliability of RF MEMS switches embedded in LCP. Since RF MEMS devices have moving parts, they are more sensitive to environmental conditions than solid-state devices like chips and RF arrays.

LCP, which has been commercially available for many years, wasn't always a good candidate for environmentally demanding applications, Papapolymerou said. Ten years ago the malleable material tore easily, but changes in LCP chemistry have dramatically improved its strength and reliability.

The low cost of conventional circuit boards will probably bar the material from most applications below 5 GHz, he believes. But above that threshold LCP could have numerous uses, including wireless LAN at 60 GHz and military applications at 30, 40 and 94 GHz . Promising NASA applications include remote sensing precipitation radars at 14 and 35 GHz.

Tentzeris believes that LCP and other similar flexible organics could also be used for a new generation of ultra-wideband sensor and secure communication applications. The flexible nature of LCP, he said, allows easy integration with complex surfaces such as airplanes, cars and trucks. In addition, its light weight and thermal expansion properties could make possible low-cost portable multifunction modules operating in different frequency bands and standards.

He stresses that a major advantage of LCP-type organics lies in the fact that their electrical properties feature only a slight change for frequencies ranging from the low-end of the cellular communications (900-1800 MHz) to the high-end short-range broadband telecom, sensor and radar bands (110 GHz).

Currently, Tentzeris said, his team is developing ultra-broadband / multiband antennas and embedded functions on LCP that could be used for reconfigurable frequency and data-rate telecom and sensor applications. His team is also investigating novel 3D meta-material ideas utilizing LCP to develop flexible lenses and dramatically improve the power efficiency of RF/sensor modules.

Costs must come down before commercial LCP applications can take off, Papapolymerou said. But as production and demand for LCP-based circuits increase, commercial use could become more likely. In fact, he said, LCP-based circuits may play a role in next-generation consumer applications such as sophisticated communications products.

“Devices that must provide a lot of bandwidth – that’s where you will need a substrate that has good, low-cost, small-footprint performance at frequencies like 30 or 60 GHz,” Papapolymerou said. “Conventional circuit-board material will not do the job anymore.”

Source: Georgia Institute of Technology