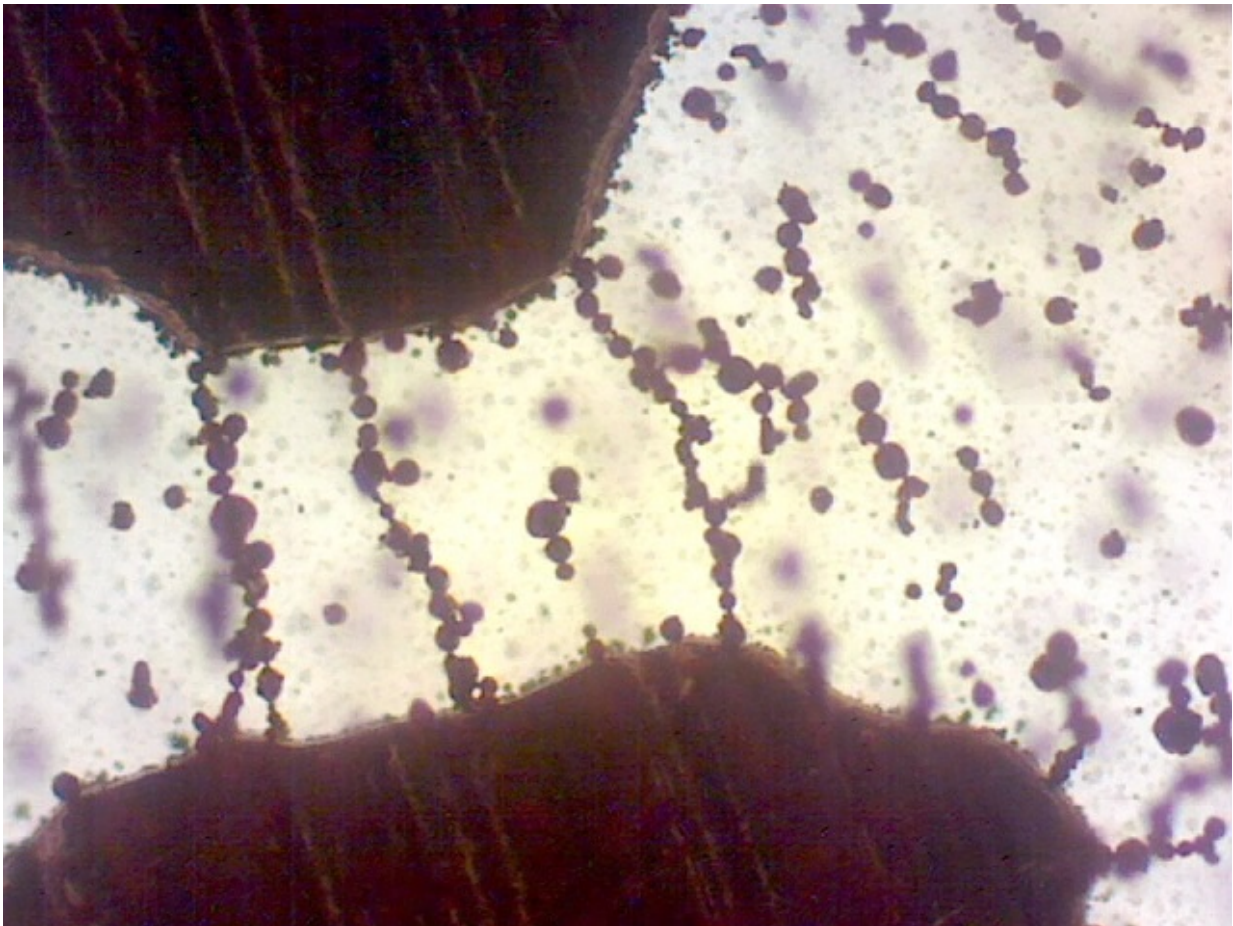


Maze-solving automatons can repair broken circuits (w/ video)

April 7 2015, by Lisa Zyga



This screenshot from the video below shows the self-healing of an open circuit fault. When a fault occurs, an electric field develops in the gap, which polarizes the conductive particles in the fluid. The positively charged end of each polarized particle aligns with the negatively charged end of another particle due to dipole interactions, causing the particles to form a bridge between the two electrodes. Credit: Nair, et al. ©2015 AIP Publishing

(Phys.org)—Modern electronic circuits may provide unprecedented flexibility and robustness, but even the best-made circuits are subject to open circuit faults—breaks caused by thermal, mechanical and electrical stress. In a new study, scientists have developed an intelligent self-healing mechanism that can locate open circuit faults—even when not in the line of sight—and then repair them by building bridges of tiny conductive particles to close the gap. The real-time repair mechanism could be especially useful for space technology, allowing open faults on satellites to be repaired without the need for expensive operations.

The researchers, led by Sanjiv Sambandan at the Indian Institute of Science in Bangalore and the Vikram Sarabhai Space Center in Trivandrum, India, have published a paper on the new [repair mechanism](#) in a recent issue of *Applied Physics Letters*.

"The immediate short-term significance of this work lies in the [applications](#) towards repairing open faults present in vias, solder joins, and interconnects on electronic boards subjected to harsh environments," Sambandan told *Phys.org*. "The fact that the board reliability can be improved by an 'add-on sticker' is a great bonus."

The "add-on" repair mechanism consists of a drop of insulating silicon oil containing conductive particles—either spherical copper particles or metallic carbon nanotubes. When the circuit is functioning correctly, this dispersion remains stationary and inert. But when a fault occurs somewhere in the circuit, an electric field develops in the gap, which polarizes the conductive particles and triggers the dispersion to move to repair the fault. The polarized particles, which have a positively charged end and a negatively charged end, line up across the open fault, bridging the gap and repairing the connection.

Even though the repair mechanism consists simply of particles dispersed in oil, the researchers also describe the dispersion as a "maze-solving thermodynamic automaton." Its ability to solve mazes arises from the fact that the strength of the electric field is highest along the circuit path through the fault, so that the [electric field](#) basically pulls the automaton in the correct direction. This mechanism can also be understood thermodynamically, as the conductive path is created in order to maximize the entropy production rate.

Although the repair mechanism can heal an open fault so that current can again flow through the circuit, it still has some shortcomings in terms of resistance and current capacity. The mechanism works best when the circuit does not carry much current; because the repair bridge is much thinner than the original line, it is not as robust as the original.

Still, the method has the advantages that it works quickly and autonomously, which could make it useful for repairing open faults on satellites and other difficult-to-reach locations. The technique could also have applications for weight assignment in neural networks—biological-inspired systems that learn by adapting the weights of the links between nodes/neurons.

"This technology provides options for the engineering of printed circuit boards meant to operate in harsh conditions, such as space or battlefields," Sambandan said. "However, the ability to form structures in fluids has applications in several areas of engineering."

The researchers plan to investigate these applications and more in the future.

"Immediate plans are to make the repair more robust by improving current capacities," Sambandan said. "With some imagination with regards to materials used and the modulation of the dynamics, we are

investigating novel sensing and actuation devices for applications in areas such as health care, device fabrication, etc."

More information: Aswathi Nair, et al. "Maze solving automatons for self-healing of open interconnects: Modular add-on for circuit boards." *Applied Physics Letters*. DOI: [10.1063/1.4916513](https://doi.org/10.1063/1.4916513)

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