Aluminum–germanium alloy forges tough, hermetic seal for electronics in extreme environments

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A mixture of aluminum and germanium forms a tough and impenetrable seal suitable for the sensor casings used at harsh pressures in offshore oil drilling. Credit: Comstock/Thinkstock

Sensors used in harsh conditions, such as deep-sea oil wells, must withstand extreme temperatures and pressures for hundreds of hours without failing. Vivek Chidambaram and co-workers at the A*STAR Institute of Microelectronics, Singapore, have investigated two metal alloys that could give micro-electromechanical system (MEMS) sensors better protection in the toughest environments.

Typical MEMS sensors measure temperature, pressure or vibration, and they are hermetically sealed inside a strong metal casing to prevent air or moisture degrading the sensors' electronics. Chidambaram's team wanted to find cheaper, more durable alternatives to the metal solders, such as gold–tin or copper–tin, which are typically used to seal the case. They tested a 70:30 aluminum–germanium mixture, which has a melting point of about 420 °C. This temperature—the eutectic point—is much lower than that for either metal on its own.

Unlike most conventional packaging materials, aluminum and germanium are compatible with the processes used to manufacture the MEMS. Using the aluminum–germanium sealant should make MEMS manufacturing easier and cheaper, and could also improve the device's performance, says Chidambaram.

The researchers built a stack of 4 alternating wafers of aluminum and germanium, each less than a micrometer thick, and heated the sandwich under pressure to about 400 °C for 2 hours. Although the wafers did not liquefy, this "thermal aging process facilitated bonding prior to melting," explains Chidambaram. Raising the temperature to 475 °C for another 2 hours fully melted the mixture, which then formed a strong seal after cooling—a process known as transient liquid-phase bonding.

Next, the researchers used acoustic microscopy, scanning electron microscopy and X-ray spectroscopy to reveal any voids or other defects in the seals. They found that the thermal aging process improved the quality of the seal. Tests showed that it was strong enough to withstand a shear of 46 megapascals—similar to the pressure exerted by almost half a ton per square centimeter—and was impermeable to water. The material lost little of its strength after being exposed to 300 °C for hundreds of hours.

Chidambaram and his team also tested a platinum–indium seal—which has the highest re-melting point (894 °C) of all the solders being considered for these applications—but it lost its strength after long durations at 300 °C, leaving the aluminum–germanium mixture in pole position as a better seal for MEMS. "Cost effectiveness, better thermo-mechanical properties, and its eutectic microstructure makes it an attractive alternative," says Chidambaram.

More information: Chidambaram, V., Yeung, H. B. & Shan, G. Development of metallic hermetic sealing for MEMS packaging for harsh environment applications. *Journal of Electronic Materials* 41, 2256–2266, 2012.

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