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Northeastern University

MesoGlue: Room Temperature Metallic Glue

Solder Replacement, High Thermal Conductivity Interface, Bonding Metal to Glass

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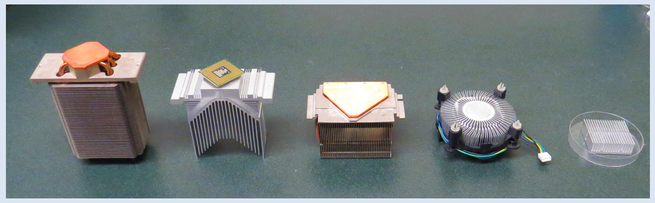
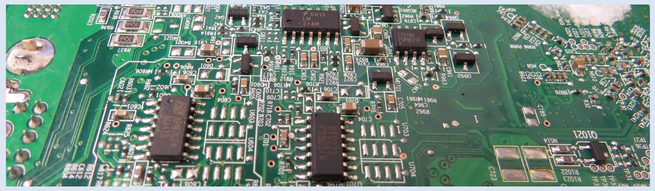
Abstract



Different Sized Heat Sinks Used for Computer CPU Cooling

Removing heat from computer chips is vital to their continued operation. As chips get smaller and more powerful, this becomes an ever more challenging task. A current bottleneck in heat transfer out of components is the material used to connect the chip to a heat sink. These thermal interface materials are usually made of a thermal grease or of a metal solder. Thermal greases suffer from a number of problems. The most significant is low thermal conductivity. Metal solder offers the advantage of improved heat transfer over grease, but compared to certain pure metals, such as copper or silver, the thermal conductivity is still much lower. These pure metals, however, have high melting temperatures that would damage the chip.

We have developed a way to weld or solder things together without using heat to essentially create a metallic glue. By utilizing nanotechnology and our understanding and control of creating certain nanostructures, we can make an all metal connection that sets using only low pressure. This can be used in computers to attach CPUs to heat sinks, which will transfer heat out of the device faster. Our process stands apart from the currently used methods in computer cooling by providing a material that conducts heat 10-20x better. This makes it possible to run current computer chips faster, and to build faster chips as the inability to get sufficient heat out is a challenge to further miniaturization and speed increases.

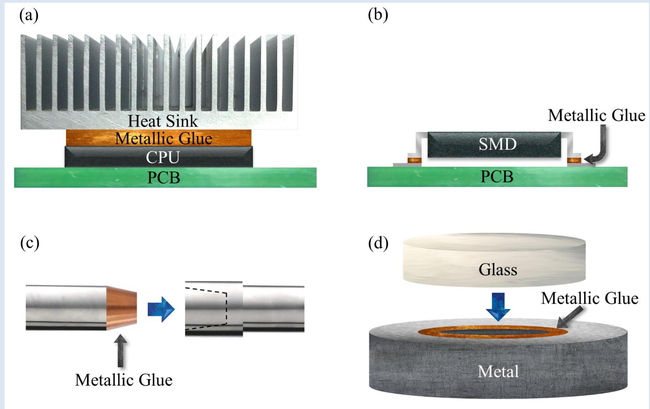


Surface Mount Devices Attached to a Circuit Board

Background – Gluing and Welding

It is a common practice to join two solids together using a third substance in gluing or soldering. Gluing usually refers to the inexpensive and easy joining process that is made at room temperature, in air, and with light or no pressure. Sealing an envelope with polymer glue is a good example. In contrast, soldering usually refers to the joining process that uses added molten metal at higher temperatures, generally much above room temperature. Similarly, welding and brazing also involve high temperature melting. The joining from such high temperature processes, as compared to polymer glue, is mechanically strong, effectively conducts electricity and heat, degrades slowly, if at all, in ambient, and its leak resistance to air and moisture goes from good to better with time due to oxidation, but the high temperatures required to form the bond can damage heat sensitive components.

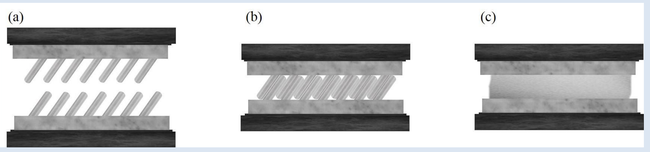
Applications



Various Applications of Metallic Glue:
(a) A CPU on a printed circuit board connected to a heat sink
(b) A surface mount device attached to a printed circuit board
(c) A press-fit pipe fitting for environments where welding is dangerous or impossible
(d) A glass plate attached to metal with a different coefficient of thermal expansion to cover a cavity with a hermetic seal.

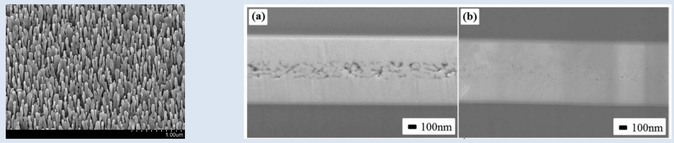
A Vacuum Viewport Using a Glass to Metal Seal

Results

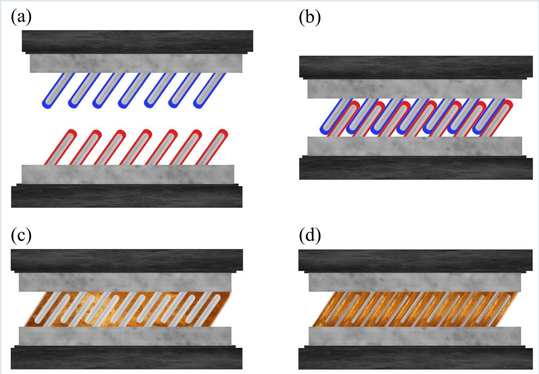


Bonding surfaces together with metal at room temperature can be done with the help of nanostructures. Shown above, two surfaces, which are to be bonded together, are facing one another (a). Each surface is covered with silver nanorods. When the mating surfaces are brought together, the large spacing of the nanorods allows them to slide between those on the opposing surface and to interpenetrate (b). Because of the small diameter of the nanorods a mechanism of surface diffusion becomes active, so diffusion on the nanorod surface is much faster than on flat surfaces. The contact of the sides of the nanorods through interpenetration provides high surface area contact, maximizing the effects of the fast surface diffusion, causing the sides to bond together (c).

Results



The left SEM image above shows silver nanorods on a surface before bonding. The right SEM images show a cross section of the metal glue after two surfaces have been bonded. When pressed together at room temperature at 9MPa some voids occur (a). To reduce the void concentration a higher processing temperature is needed. As shown in (b), performing the gluing process at 100°C will largely eliminate the voids.



Core-shell nanorods have a different metal coating on the outside of the nanorods, shown as red and blue above (a). The coatings, when pressed together, combine to form a liquid alloy at room temperature (b-c). This then solidifies to form a solid metal bond (d). This offers certain advantages. First, the use of eutectic alloys through the core-shell nanorods will reduce or completely eliminate the voids. As a result, the leak resistance will further increase, and the heat conduction will become even more effective. Second, the presence of liquid alloys instead of solids will likely reduce the processing pressure from a few megapascals to a fraction of a megapascal, or finger-tip pressure.

Conclusion

Through advancement in nanoscience a new technology is available to metallically glue two solids together at room temperature, in air, and under a small pressure. Such metallic glues can serve as excellent conductors for heat dissipation and electrical current in electronic devices and also as leak-resistant seals for vacuum environments. The potential market of these applications is large and growing.

References

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