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New Heat Sink Technique for Semiconductors

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The limited efficiency of electronic devices leads to the generation of waste heat. This heat affects, in general, the device performance and therefore it must be extracted from the active device area. This requires low thermal impedance and highly effective heat transfer. For global chip, cooling proposals have been made which allow high-performance heat exchange through microchanneled heat sinks. For single devices, effective cooling can be obtained through active-area-down mounting. However, connectivity of the individual devices requires a complicated and expensive structured-substrate technology. The commonly used C4 solder-bump technology allows full connectivity, but does not offer high-performance cooling capabilities.

Highly effective one-dimensional heat extraction, perpendicular to the active plane, can be obtained through local, individual heat sinks. Such a configuration allows active-area-up mounting and connectivity to the (patterned) top side of the device. In addition, thermal decoupling of the devices is obtained, reducing thermally-induced crosstalk. This technique can be applied to any semiconductor device or circuit; the figure shows application to an AlGaAs semiconductor laser.

After standard laser fabrication (top side of the wafer), a photolithographic mask is formed on the wafer backside aligned to the front side. This mask leaves openings underneath the active laser areas. Reactive ion etching (RIE) holes, with vertical side walls, are etched into the GaAs wafer through the mask openings. Such an etching process can have very high etching rate ratios so that the GaAs effectively stop at the AlGaAs cladding layer or at a layer purposely grown into the vertical epitaxial structure. The remaining top layer can be made as thin as 5-10 micrometers, reducing the thermal resistance to below 120 K/W. After removal of the etching mask, a back side contact metal is evaporated, using a tilted and rotating substrate holder followed by electroplating on the backside of the wafer, completely filling the via holes with gold.

An ideal supplement to the gold-filled via holes, is an electroplated heat spreader on top of the laser, as indicated in the figure.

Adding another photolithographic mask step allows removal of the GaAs between the gold studs, enabling separated heat-sink studs for individual devices or parts of an integrated circuit.