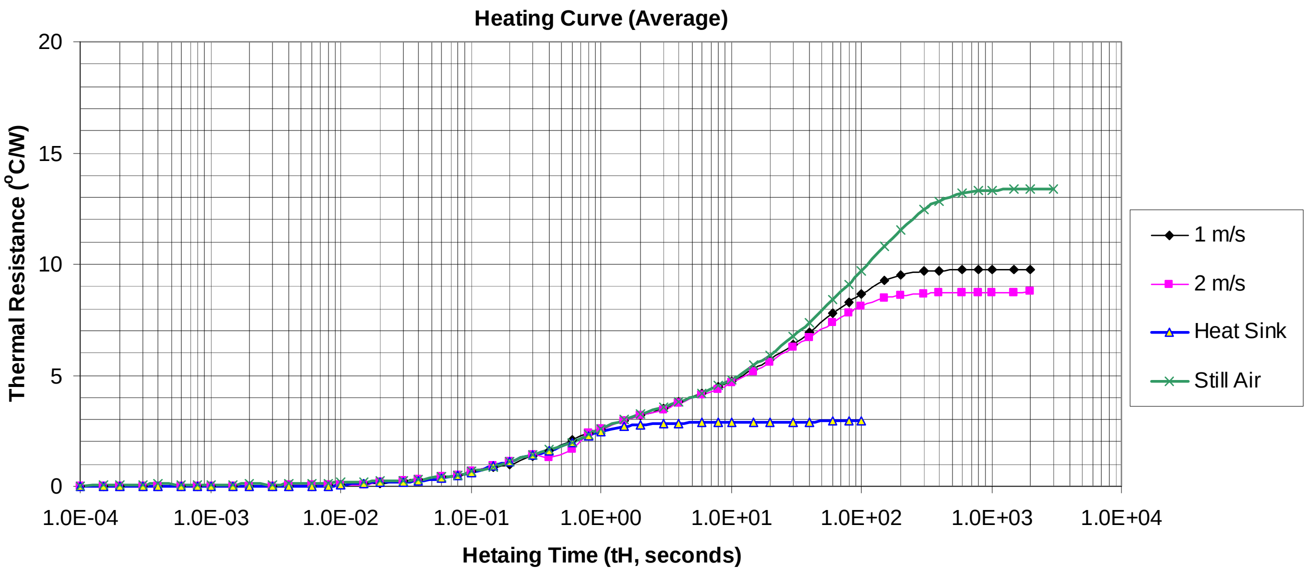
HEATING CURVES AID THERMAL CHARACTERIZATION

Heating Curves are excellent tools for characterizing and understanding heat flow in semiconductor devices. The curves show how a device parameter proportional to junction temperature (T_J) responds to the application of power (referred to as Heating Power [P_H]) as a function of time (t_H) that P_H is applied when the device is subjected to different environmental conditions. The proportional parameter can be the absolute value of T_J, the change in T_J from its initial value (referred to as ΔT_J), thermal impedance (Z_θ), or most commonly as thermal resistance from junction-to-defined condition X (θ_{JX}). A Heating Curve example is shown below. This particular set of curves were generated for a 480-ball, 35 mm square, thermally-enhanced BGA package containing a 19 mm square application die tested in substrate isolation diode mode (see TB-01 for description of this test mode); the package was mounted on a 2s2p thermal test board (see JEDEC JESD51-9).



These curves show how the heat generated internal to the semiconductor die (or chip) propagates from the heat-producing junction, through the die, through the mounting surface, into the package, and finally into the test environment. Once the heat generated internally matches the heat leaving the package, a steady-state condition occurs and the curve flattens out. Plotting the curves for different test environment conditions - natural convection condition inside a one cubic foot enclosure for θ_{JA} (per JEDEC JESD51-2) on top, followed by a forced convection condition for θ_{JMA} (per JESD51-6) for two (or more) different air velocities, and finally an "infinite" heat sink condition for θ_{JC} on the bottom - clearly illustrates the impact of each test environment. Notice that the curves overlay each other up until the heat flow has reached the package outer surface - at this point the curves deviate to reflect the different ways the heat flows into the environment.

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HEATING CURVES AID THERMAL CHARACTERIZATION (cont'd)

A Heating Curve is useful in several ways:

First, the smoothness of the curve demonstrates the consistency of the data and helps to validate the data values. A data point grossly off the curve would clearly be suspect.

Second, the onset of the steady-state condition is clearly evident from the curve. Maintaining the heating power beyond the onset heating time point yields no further information about the semiconductor device. Picking a t_H value to insure steady state but not much longer reduces total measurement time.

Third, the curve reveals information about the package assembly. Because the heat must flow from the highest temperature point (i.e., the device junction(s)) to the environment through the package, assembly problems, such as die attachment, can be readily seen. Thermal transient die attachment evaluation, using optimized values of P_H and t_H, can implemented in production as a check of the assembly process without imposing much cost burden.

Fourth, a graph showing Heating Curves for several different defined environmental conditions is helpful for estimating device thermal behavior in other environmental conditions. For example, using the graph above, a forced convection environment of air flowing at 0.5 m/s would produce a θ_{JMA} value about halfway between the top two curves. Similarly, air flowing at 5 m/s would yield a θ_{JMA} value slightly above the bottom curve.

Fifth, the combination graph can be used to accurately estimate the time required for junction stabilization for different conditions. Because many electronic circuits, especially analog-oriented ones, are have temperature dependent performance, knowing this time is helpful in performing circuit test and calibration procedures and for determining operation warm-up times.

Data collection for heating curve generation can be implemented in many ways. The best way is to use test equipment (such as *TEA* thermal test systems) that has a built-in automatic heating curve measurement mode. Seven data points (at 1, 1.5, 2, 3, 4, 6, and 8) per t_H decade space the data out linearly over the decade and make it easy to create the curve.

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