Semiconductor Technology from A to Z

Reliability

Burn-in and HTOL Testing

From Burn-in to HTOL Qualification Testing

The basic principle of burn-in and the bathtub curve of the failure rate were already introduced in the Final Test and Binning chapter: a stress test at elevated voltage and temperature anticipates early failures caused by hidden manufacturing defects before components reach the customer.

For reliability-critical applications, however, a simple burn-in lasting only a few hours is not always sufficient. The following sections cover the HTOL test (Highly Accelerated Temperature and Operating Life), a standardized, substantially longer qualification procedure, along with the Arrhenius model, which allows the actual field lifetime of a component to be inferred from short, accelerated tests.

HTOL Test Conditions

Highly Accelerated Temperature and Operating Life (HTOL) testing is a standardized qualification test in which a sample of components – per JEDEC JESD22-A108 often 77 units drawn from at least three different production lots – is stressed for typically 1000 hours at an elevated junction temperature (often 125 °C, or 150 °C for some technologies) and elevated operating voltage under active switching conditions. The units under test are electrically characterized before, during, and after the test to detect parameter drift or functional failures.

To pass the test, it is usually required that no unit fails within the sample (a zero-fail criterion), which for a sample of 77 units statistically corresponds to a failure rate of less than about 0.3 % at 60 % confidence. HTOL primarily covers diffusion-driven and field-dependent aging mechanisms such as electromigration, TDDB, and BTI, complementing ESD and latchup qualification with time-dependent operating reliability.

The Arrhenius Model for Lifetime Prediction

Because testing under nominal conditions for the required field lifetimes of ten years or more is not practical, HTOL tests are run at elevated temperature and the results are extrapolated to the operating temperature using the Arrhenius model. The model describes the rate of a thermally activated aging mechanism as an exponential function $k(T) = A \cdot e^{-E_a/(k \cdot T)}$ of the inverse absolute temperature, weighted by an activation energy E_a characteristic of the respective failure mechanism.

The ratio of failure times at test temperature and operating temperature yields an acceleration factor $AF = e^{(E_a/k) \cdot (1/T_{use} - 1/T_{test})}$. For a typical TDDB mechanism with $E_a \approx 0.7$ eV, a test temperature of 125 °C (398 K), and an assumed operating temperature of 55 °C (328 K), the acceleration factor works out to roughly 40 to 50 – under these assumptions, 1000 test hours therefore correspond to an equivalent field operating time of about 4 to 5 years. Because different failure mechanisms have different activation energies – TDDB and electromigration are typically in the range of 0.6 to 1 eV –, a reliable lifetime prediction requires knowledge of the dominant mechanism.