

ELECTRONIC PACKAGING

Materials and Their Properties

Michael G. Pecht
Rakesh Agarwal
Patrick McCluskey
Terrance Dishongh
Sirus Javadpour
Rahul Mahajan

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Michael G. Pecht

CALCE Electronics Packaging Research Center
University of Maryland, College Park

Rakesh Agarwal

Delco Electronics, Kokoma, Indiana

Patrick McCluskey

Terrance Dishongh

Sirus Javadpour

Rahul Mahajan

CALCE Electronics Packaging Research Center
University of Maryland, College Park



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Volumetric resistivity is a bulk material property that varies with temperature, moisture content, applied voltage and the time duration of the applied voltage. Volumetric resistivity and resistance are related by the expression

$$\rho_v = \frac{RA}{l} \quad (7)$$

where ρ_v is the volumetric resistivity, R is the electrical resistance, A is the effective cross-section area, and l is the effective length of the test piece. Resistance is expressed in ohms and is dependent on the geometry of the conductor. In general, a material with higher resistivity is a better insulator. Specifications ASTM D 257 and ASTM D 1829 describe the test methods for volumetric resistivity measurements.

Insulation resistance, IR. Insulation resistance is more a measure of the quality of insulation provided by a packaging architecture than a real material property. Although expressed in terms of leakage current, with units of nano amperes (nA), IR measures the resistance offered by an insulating material to a direct impressed voltage across the lead and case of the component part. It is useful for comparative evaluations of materials for given test conditions. Both volumetric and surface resistances contribute to the leakage current. Low insulation resistance indicates inadequate insulation of the conductor paths. The tests are performed according to Test Method 1003 of MIL-STD 883C.

Arc resistance, Dt_{arc} . The arc resistance of a material is defined as the elapsed time before the action of an arc at the surface of the material forms a conducting path. The arc resistance, expressed in seconds, is indicative of the ability of the material to resist the formation of an arc. Materials that form a permanent carbonized path due to the action of an arc are said to "track". Arc resistance is affected by surface conditions such as cleanliness and dryness. A high value of arc resistance is desirable to avoid electric breakdown along the insulation surface through arcing. The test method for arc resistance is described in ASTM D 495.

1.2 Thermal and Thermomechanical Properties

An electronic material experiences a range of steady-state temperatures, temperature gradients, rates of temperature change, temperature cycles, and thermal shocks through manufacturing, storage, and operation. Thermal properties of electronic materials that are significant in enduring such life cycle profiles include thermal conductivity, deflection temperature, glass transition temperature (typical for polymeric materials), and the coefficient of thermal expansion.

Deflection temperature, T_d . Deflection temperature is the temperature at which a specified deflection occurs in a specimen under a selected load and loading method. Test method ASTM D 648 specifies the loading for deflection temperature measurements. The temperature is indicative of the mechanical load-carrying capability of a material. The deflection temperature of polymeric materials and composites may approximate their glass transition temperature, especially for thermoplastics. For a thermoset polymer, the degree of cure can lead to significant differences between deflection temperature and glass transition temperature. In the case of reinforced laminates, the relief of residual stresses can further complicate the correlation.

Thermal conductivity, k . Heat conduction is described by Fourier's Law. For one-dimensional heat conduction through a plane wall with a temperature distribution $T(x)$, the heat equation is expressed as

$$q_x = -k \frac{dT}{dx} \quad (8)$$

where q_x (W/m^2) is the heat transfer rate per unit area perpendicular to the direction of the heat flow, and dT/dx ($^{\circ}C/m$) is the temperature gradient in the x -direction. The proportionality constant k is a heat transport property known as thermal conductivity, expressed in Watts per meter per degree centigrade ($W/m-^{\circ}C$). The minus sign in eq. (8) is required to assure positive heat flow in the direction of a falling or negative temperature gradient.

Table 4. Comparison of thermal conductivity and resistivity of various polymers, ceramics and metals

Material	Thermal conductivity, k ($W/m-^{\circ}C$)	Volumetric resistivity, ($\mu\Omega\text{-cm}$)
Diamond	2000	
Copper	380	10^{22}
Berylia	286	0.34
Aluminum	210	10^{20}
Aluminum nitride	200	0.52
Molybdenum	130	10^{19}
Lead	36	1
Alumina	30	4.4
Polyurethane	3.3	10^{20}
Epoxy glass	0.3	10^{16}
Polyimide	0.2	10^{21}
Acrylic coating	0.2	10^{20}
Acrylic	0.2	10^{21}
		10^{21}