A brief Introduction to CTE and CuW, CuMo

Thermal Management Materials

Introduction

Normally, material will expand when heated and shrink when cooled. In same temperature conditions, different materials experience different amounts of expansion or contraction. This is a big issue in the field of electronic packaging where we often mount one kind of material over another kind of material. Thermal stress will occur at the interface between the two materials as a result of thermal expansion difference. This stress tends to cause material to bend, deform or crack when the product undergoes repeated tempatuture cyclings in a time span. Fig 1 illustrates the cyclic stress caused by CTE mismatch.

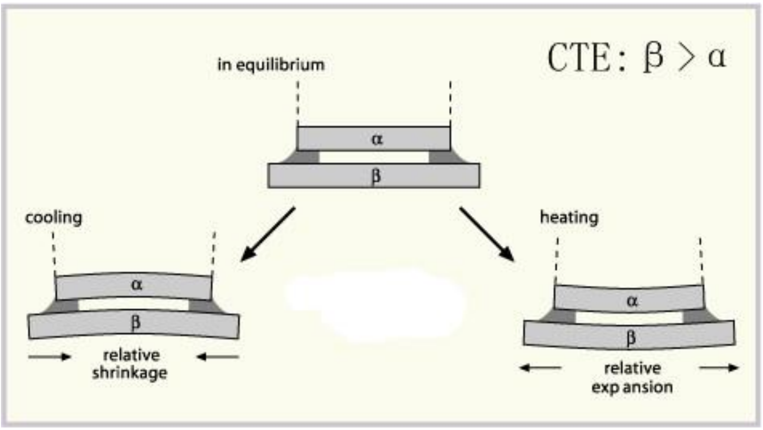

Fig 1. CTE mismatch producing cyclic stress (Courtesy of http://www.ami.ac.uk/courses/topics/0162_sctm/)

Coefficient of Thermal Expansion (CTE) is a key pamameter for measuring the thermal expansion qualities of materials.

Definition of CTE

The coefficient of thermal expansion describes how the size of an object changes with a change in temperature. Specifically, it measures the fractional change in size per degree change in temperature at a constant pressure. Several types of coefficients have been developed: volumetric, area, and linear.

In the field of electronic packaging, the linear CTE is oftern used. It is defined as the average coefficient of linear expansion: when the temperature changes from t_1 to t_2, the coresponding length changes from L_1 to L_2.

$$\bar{\alpha}=\frac{L_2-L_1}{L_1(t_2-t_1)}=\frac{\Delta L}{L_1\Delta t}$$

As Δt approaches zero, the preceding limit (pressure P is constant) is defined as the differential linear expansion coefficient:

$$\alpha_t=\frac{1}{L}\left(\frac{\partial L}{\partial t}\right)_P$$

Compared to the average coefficient of linear expansion, the differential coefficient of expansion is the expansion coefficient at a certain point and temperature. For engineering applications, we often use the average expansion coefficients. Table 1 lists the CTEs of some common thermal management materials.

Table 1 Coefficients of thermal expansion of thermal management materials

Material	CTE($10^{-6}K^{-1}$)	Material	CTE($10^{-6}K^{-1}$)
		W	4.6
		Mo	5.4
		Invar	0.4
		Kovar	4.2
Si	4.1	Al	22
Ge	5.5	Cu	17
SiC	4.0	Au96.85%-Si	12.3
GaAs	7.5	Au80%-Sn	15.9
InP	28	Au88%-Ge	13.4
96%Al_2O_3	6.3	W85-Cu	6.9
AlN	4.2	Mo85-Cu	6.7
BeO	6.4	CMC1:1:1	8.9
Epoxy	5.4	CPC1:4:1	7.8
		SiC70%-Al	7.0
		Si75%-Al	6.5
		C_f/Cu	6.5

W-Cu and Mo-CuThermal Management Material

Copper tungsten (CuW or WCu), combining the merits of tungsten and copper, is widely used as electrodes and heat sinks. Tungsten has a very high melting point, high density, and low CTE. Copper is a good electrical and thermal conductor. Copper tungsten (CuW or WCu), enjoys the low CTE of tungsten and high thermal conductivity of copper. What is more, its CTE and conductivity can be adjusted by changing the Cu/W ratio.Table 2 shows typical properties of some common W-Cu materials.

Table 2 Typical properties of heat sink grade W-Cu

Name	Density(g/cm^3)	CTE($10^{-6}K^{-1}$)	TC(W/mK)	Young's modulus(Gpa)	Hardness(HV10)
W90Cu	17.0	6.5	190-200	330	300

W88Cu	16.9	6.8	190-200	320	290
W85Cu	16.3	7.0	200-210	310	280
W80Cu	15.6	8.0	210-220	280	260

Molybdenum copper (MoCu or CuMo) is a rising material in electronic packaging applications. It has a high thermal conductivity and adjustable CTEs that are closely matched to those of die materials. As molybdenum in MoCu has a relatively low density compared to tungsten in WCu, the use of MoCu can reduce the weight of packaging materials. This unique advantage makes MoCu a good choice in aerospace, instrumentation, and portable equipment industries. Typical technical properties of commonly used MoCu materials are shown in Table 3

Table 3 Typical properties of heat sink grade Mo-Cu

Physical property	Mo50Cu50	Mo60Cu40	Mo70Cu30	Mo80Cu20	Mo85Cu15
Composition (wt%)	50%Mo Cu:balance	60%Mo Cu:balance	70%Mo Cu:balance	80%Mo Cu:balance	85%Mo Cu:balance
Density at 20°C(g/cm^3)	9.5	9.6	9.7	9.9	10.0
CTE at 20°C(ppm/K)	9.9	9.5	7.5	7.2	6.8
Thermal conductivity (W/mK)	250	215	195	175	165
Soecific heat at 100°C(J/kgK)	323	310	301	_	275
Specific electrical resistance at 20°C(μΩm)	0.028	_	0.37	_	_
Young's modulus at 20°C(Gpa)	172	_	225	_	248
Flexural strength(MPa)	_	_	_	1103	1138
Hardness(HV10)	150	_	170	_	_