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Supplementary Materials: Transient Liquid Phase Bonding of Al-6063 to Steel Alloy UNS S32304

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The Arrhenius equation for diffusion coefficient is [1]:

$$D_L = D_0 \exp\left(-\frac{Q}{RTemp}\right) \quad (1)$$

where Q is the activation energy (Q = 38900 cal/mol), D_0 is the diffusion coefficient of Cu in liquid Al, R is the gas constant (R = 8.314) and $Temp$ is the absolute temperature in Kelvin [2].

Du et al. (2003) used solid–liquid contacting technique to calculate $D_0 = 8.1 \times 10^{-7} \mathrm{m}^2/\mathrm{s}$ for Cu diffusion in Al at temperatures ranging from (831–919) K [1].

$$D_L = 8.1 \times 10^{-7} \exp\left(-\frac{38900}{8.314 * Temp}\right)$$

The dissolution rate of Cu interlayer can be derived from Equation (1) (Equation (2))

$$V_S = \frac{dY}{dt} = K_1 \sqrt{\left(\frac{D_L}{t}\right)} \quad (2)$$

where V_S is the dissolution rate of Cu interlayer.

While, the interface displacement follows a general square root law (Equation (3)) [3,4].

$$Y = K_1 \sqrt{4 D_L t} \quad (3)$$

where, t is the total time required for complete dissolution, Y is the position of solid/liquid interface at time t, K_1 is a constant that has a range between 0.13 and 1.18 for different binary systems. For Al-Cu phase diagram K is 0.13 [3,4].

Assuming that the interlayer has an initial thickness T, $T = K_1 \sqrt{4 D_L t}$, thus, $t = \frac{T^2}{4 K_1^2 D_L}$.

Table S1. shows the calculations of t and V_S at different bonding temperatures. An inverse linear relationship between the bonding temperature and total dissolution time of the interlayer can be observed in Figure S1. The total dissolution time of 10 μm thick Cu foil decreased from 0.54 s at 550 °C to 0.47 s at 570 °C. In addition, there was a direct correlation between bonding temperature and interlayer dissolution rate. The highest dissolution rate achieved was 1.06×10^{-5} m/s at 570 °C.

Table S1. Dissolution time and rate of Cu interlayer at different bonding temperatures.

Temperature (K)	D_L	t(s)	V_S(m/s)
823	2.75×10^{-9}	0.54	9.29×10^{-6}
828	2.85×10^{-9}	0.52	9.63×10^{-6}
833	2.95×10^{-9}	0.50	9.99×10^{-6}
843	3.15×10^{-9}	0.47	1.06×10^{-5}

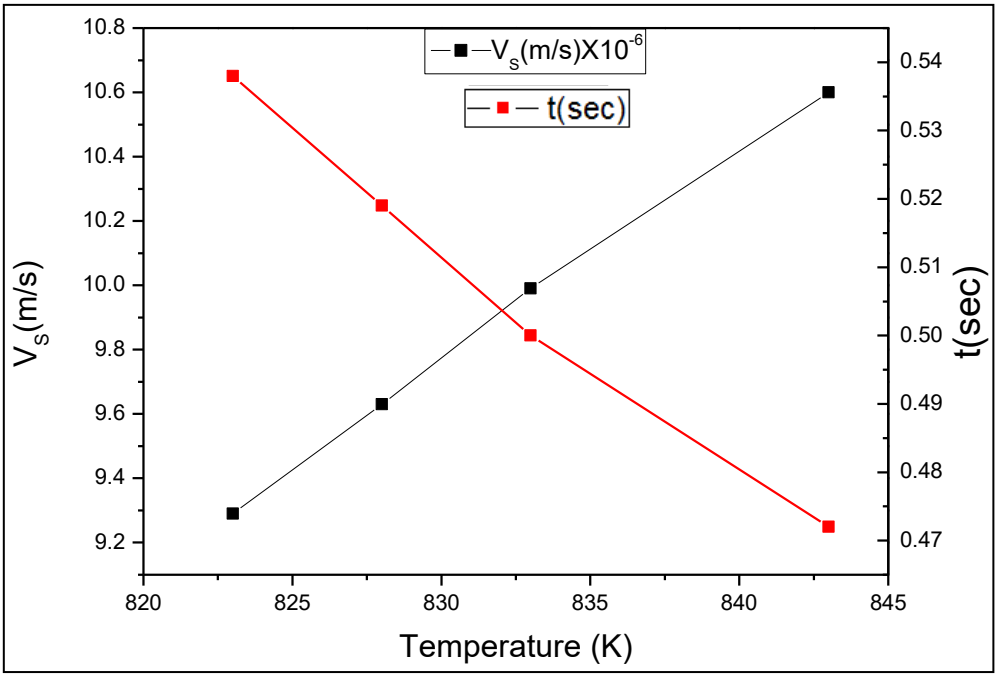

Figure S1. Effect of bonding temperature on t and V_S of Cu interlayer.

References

1. Du, Y.; Chang, Y.A.; Huang, B.; Gong, W.; Jin, Z.; Xu, H.; Yuan, Z.; Liu, Y.; He, Y.; Xie, F.Y. Diffusion coefficients of some solutes in fcc and liquid Al: Critical evaluation and correlation. *Mater. Sci. Eng. A* **2003**, *363*, 140–151.
2. Nag, P.K. *Engineering Thermodynamics*, 5th ed.; McGraw Hill Education: New Delhi, India, 2013; p. 914.
3. Shirzadi, A.A. Diffusion Bonding Aluminium Alloys and Composites: New Approaches and Modelling. In *Department of Materials Science and Metallurgy*; University of Cambridge: Cambridge, UK, 1998; p. 158.
4. Wu, M.F.; Si, N.C. Chen, J. Contact reactive brazing of Al alloy/Cu/stainless steel joints and dissolution behaviors of interlayer. *Trans. Nonferrous Met. Soc. China* **2011**, *21*, 1035–1039.