THERMAL CONTACT RESISTANCE: EFFECT OF ELASTIC DEFORMATION

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OVERVIEW

• introduction and motivation
• microhardness
• model
• present model
• parametric study
• comparison with experimental data
• conclusions
INTRODUCTION

• due to load constraints in *microelectronics* and *avionics* applications, **Thermal Contact Resistance** (TCR) at low contact pressure is important

• Milanez et al. (2003) experimentally showed that existing *plastic* models over-predict TCR at low contact pressures

• new analytical model is developed that predicts TCR at low pressure

• model considers the effect of elastic deformation underneath *plastically* deformed microcontacts
PROBLEM STATEMENT

- contact of conforming rough surfaces in a vacuum

- real contact area is less than 1% of nominal contact area

- using plasticity index, one finds the deformation mode of asperities is **plastic**

- existing plastic TCR models neglect the elastic deformation beneath microcontacts

As a result of elastic deformation, separation between planes reduces, thus:

- more microcontacts are created
• microhardness is not a constant of material

• as indentation depth increases, microhardness decreases

experimental data from Hegazy (1985)
• microcontacts are assumed to deform **plastically**

• elasticity theory is used to determine elastic deformation of half-space due to microcontacts

• elastic deflections due to self and neighboring microcontacts are superimposed to find total deformation

modeled geometry of contact
• at low contact pressures, effects of neighboring microcontacts can be ignored.

• as $\varepsilon$ increases, effect of neighboring microcontacts become significant, also displacement of mean plane increases

• as a result, the net elastic deformation beneath the microcontact becomes smaller and eventually approaches zero at relatively large loads

$$\varepsilon = \sqrt{(A_r / A_a)}$$

$$\omega^* = \pi E' \omega / 4 H_{mic} L$$
EFFECT OF ELASTIC DEFORMATION ON CONTACT PARAMETERS

- ratio of separations $\lambda_0/\lambda > 1$, due to elastic deformation effect
- ratio of microcontacts radius $a/a_0 < 1$, but absolute radius of microcontacts, $a$, increases by increasing the load
- effective microhardness $H_{mic}$ decreases as load increases
• as a result of smaller separation:

• more microcontacts are formed \( n / n_0 > 1 \)

• real contact area is increased, \( A_r / A_{r0} > 1 \)

• thermal resistance is decreased, \( R_{j0} / R_j > 1 \)
four values of $E' = 20$, 60, 160 GPa, and $\infty$ (pure plastic model) selected

difference between model and pure plastic model decreases as $P/H_{\text{mic}}$ increases

beyond certain pressure, difference between pure plastic model and the present model (three values of $E'$) becomes negligible

effect of elastic deformation is more important at low loads
COMPARISON WITH MILANEZ ET AL DATA

experimental data from Milanez et al. (2003)
COMPARISON WITH HEGAZY DATA

Material: Nickel 200
- $\sigma = 0.92 \, \mu m$, $m = 0.110$
- $k_s = 75.28 \, W/mK$
- $E' = 112.09 \, GPa$
- $c_1 = 6.3 \, GPa$, $c_2 = -0.264$
- $b_L = 125 \, mm$
- $H^* = 0.033$

Material: Zr-2.5%wt.
- $\sigma = 0.99 \, \mu m$, $m = 0.083$
- $k_s = 21.3 \, W/mK$
- $E' = 57.26 \, GPa$
- $c_1 = 5.88 \, GPa$, $c_2 = -0.267$
- $b_L = 125 \, mm$
- $H^* = 0.053$

Relative difference $(R_{j0} - R_j)/R_{j0}$ in the applied load range is 17%.

Relative difference $(R_{j0} - R_j)/R_{j0}$ in the applied load range is 30%.

Experimental data from Hegazy (1985)
SUMMARY AND CONCLUSIONS

• new analytical model is proposed for TCR of conforming rough joints in vacuum that accounts for elastic deformation of substrate

• as a result of elastic deformation, mean separations between two contacting surfaces becomes smaller; thus
  – more microcontacts are nucleated,
  – real contact area is increased,
  – thermal contact resistance is decreased

• elastic deformation effect becomes less important at higher loads
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QUESTION?

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