MODELING OF THERMAL JOINT RESISTANCE OF POLYMER–METAL ROUGH INTERFACES

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OVERVIEW

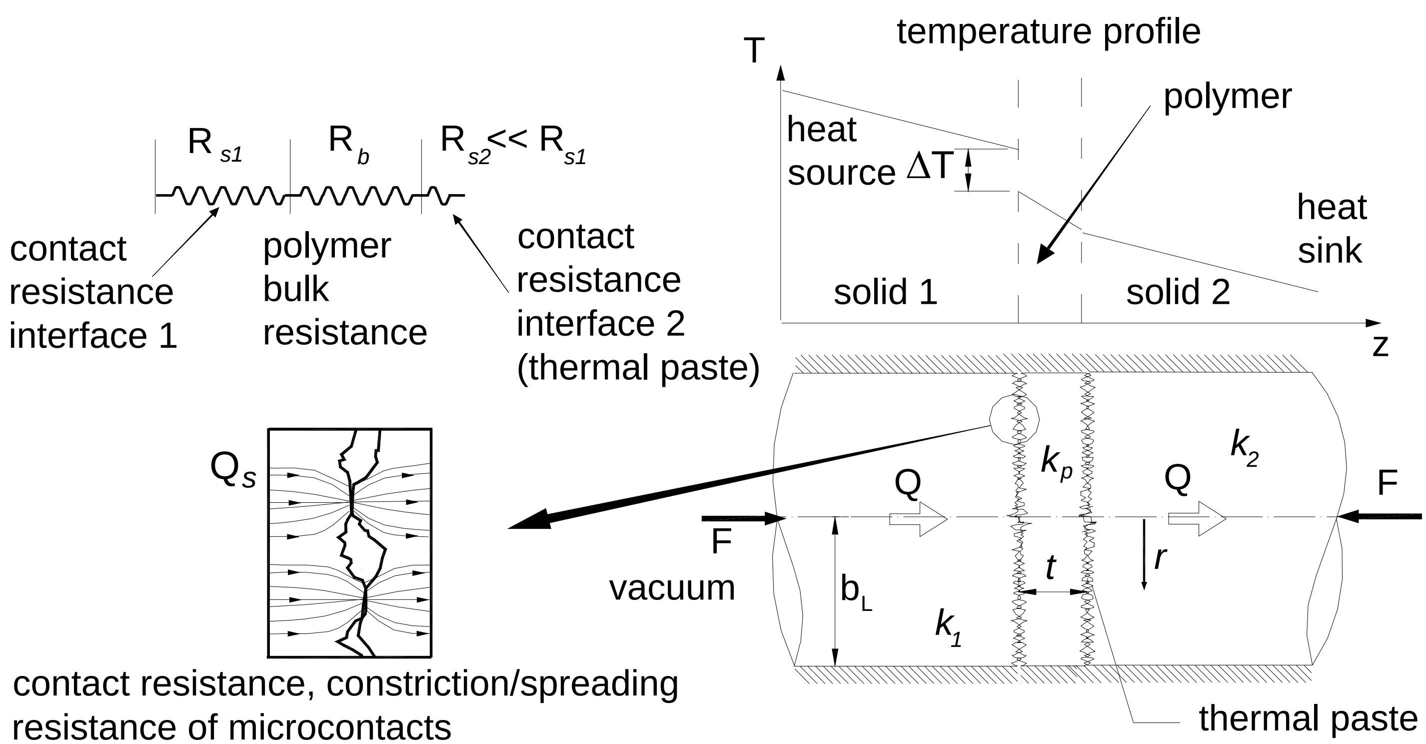
- Motivations and Objectives
- Problem Statement
- Thermal Resistance of Microcontacts
- Deformation Mode of Asperities
- Present Model
- Comparison with Experimental Data
- Conclusions

MOTIVATIONS AND OBJECTIVES

- polymers are being used in many engineering applications
- most of Thermal Interstitial Materials (TIM) used in microelectronic cooling are polymers filled with conductive particles
- only a few studies, mostly experimental, exist in the literature
- develop a compact model for predicting the TCR of polymer-metal interface in a vacuum

PROBLEM STATEMENT

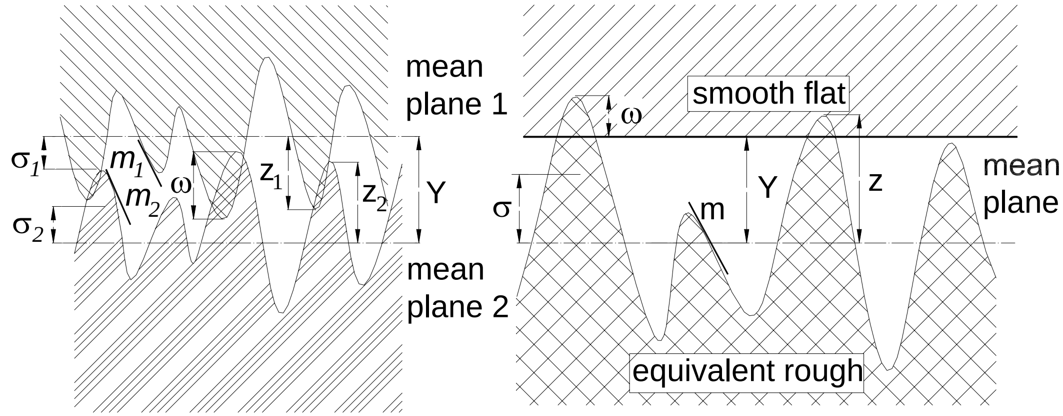
only conduction through microcontacts



$$R_j = R_s + R_b \qquad R_b = \frac{t}{A_a\, k_p}$$

<u>assumptions</u>

- Gaussian roughness, isotropic
- surfaces are conforming
- microcontacts do not interfere
- only normal forces
- deformation mechanics is determined only by equivalent rough surface



a) section through two contacting surfaces

b) corresponding section through equivalent rough - smooth flat

$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2}$$

$$m = \sqrt{m_1^2 + m_2^2}$$

PLASTIC AND ELASTIC MODELS

- plastic model: Cooper, Mikic, Yovanovich (1969)
- elastic model: Mikic (1974)

  – assumed $A_{elastic} / A_{plastic} = 1/2$

  – proposed an "effective elastic microhardness" H_e

$$H_e = \frac{E'm}{\sqrt{2}} \qquad \text{where}$$

$$\frac{1}{E'} = \frac{1-\upsilon_1^2}{E_1} + \frac{1-\upsilon_2^2}{E_2}$$

- a priori assumption of deformation mode could lead to physically impossible "effective elastic microhardness" values

$$H_e > H_{mic} \qquad \text{impossible}$$

DEFORMATION MODE OF ASPERITIES

plasticity index introduced by Mikic (1974)

$$\gamma = \frac{H_{mic}}{E'm}$$

$$\frac{1}{E'} = \frac{1-\upsilon_1^2}{E_1} + \frac{1-\upsilon_2^2}{E_2}$$

$$\begin{cases} \gamma \le 0.33 & \text{plastic} \\ 0.33 \le \gamma \le 3.0 & \text{transition} \\ \gamma \le 3.0 & \text{elastic} \end{cases}$$

Polymer	***E*** GPa	**H_{mic}** GPa	γ
ABS	2.90	0.17	0.30
Delrin	3.59	0.37	0.46
Nylon	2.11	0.41	0.90
Phenolic	6.80	0.36	0.26
Polycarbonate	2.39	0.14	0.32
Polyethylene	3.00	0.13	0.17
Polypropylene	1.33	0.41	0.97
PVC	2.50	0.15	0.37
Teflon	0.46	0.20	1.78

- Mikic concluded, as Greenwood and Williamson did, that the mode of deformation is not sensitive to applied load

- almost all polymer asperities deform plastically

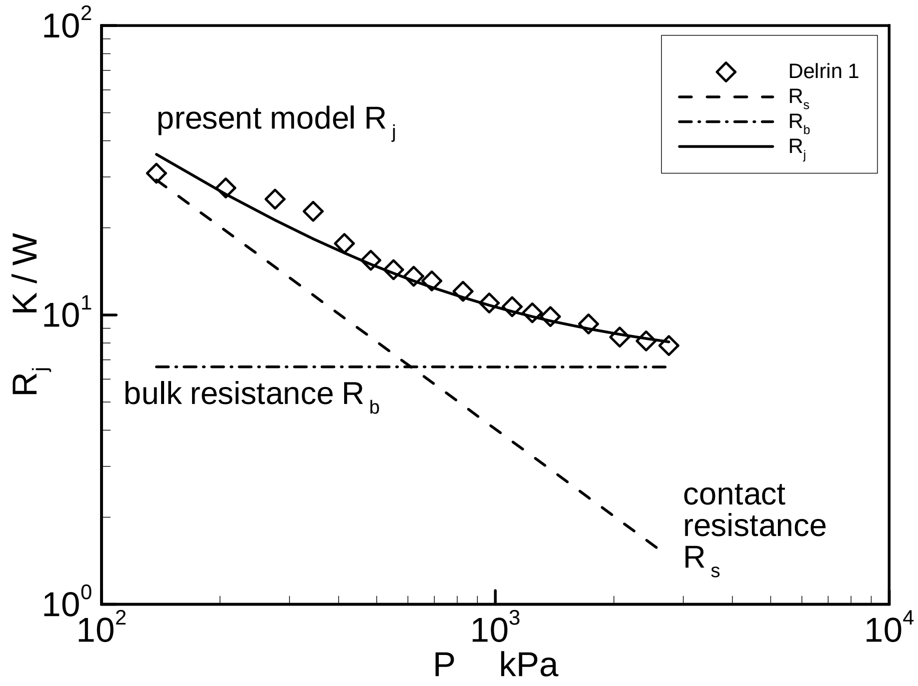
PRESENT MODEL

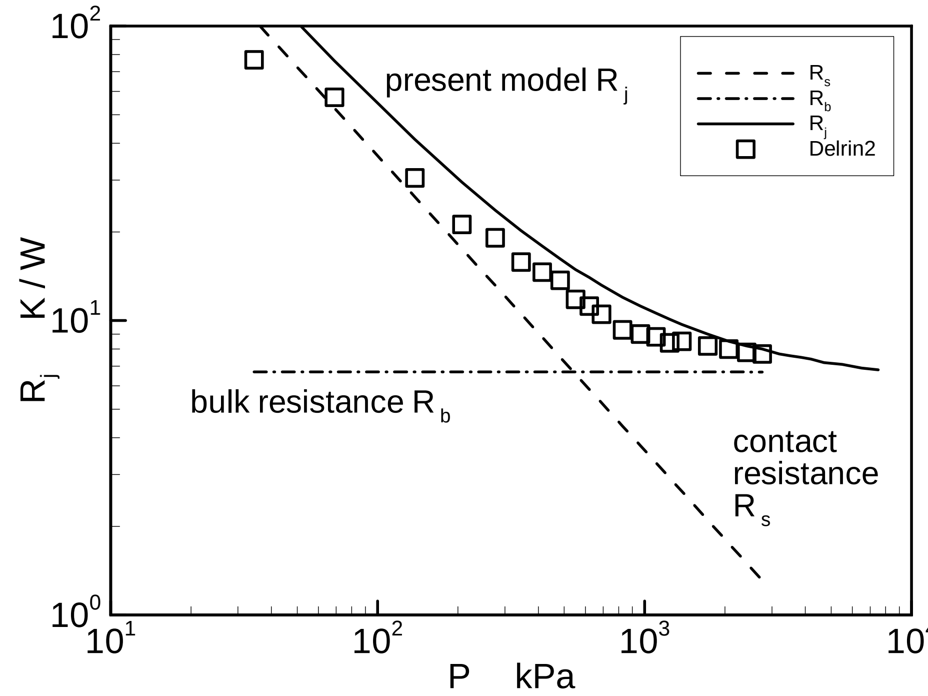
- surface asperities have Gaussian distribution
    - "equivalent rough surface" approximation was used
- microcontacts deform plastically
    - microhardness was measured for polymers studied
- microcontacts constriction/spreading and polymer bulk resistances are assumed to be in series
    - Bahrami et al. [17] plastic model was used

$$R_j = \frac{0.565 H_{mic} (\sigma / m)}{k_s P A_a} + \frac{t_0 \left(1 - P / E_p\right)}{k_p A_a}$$

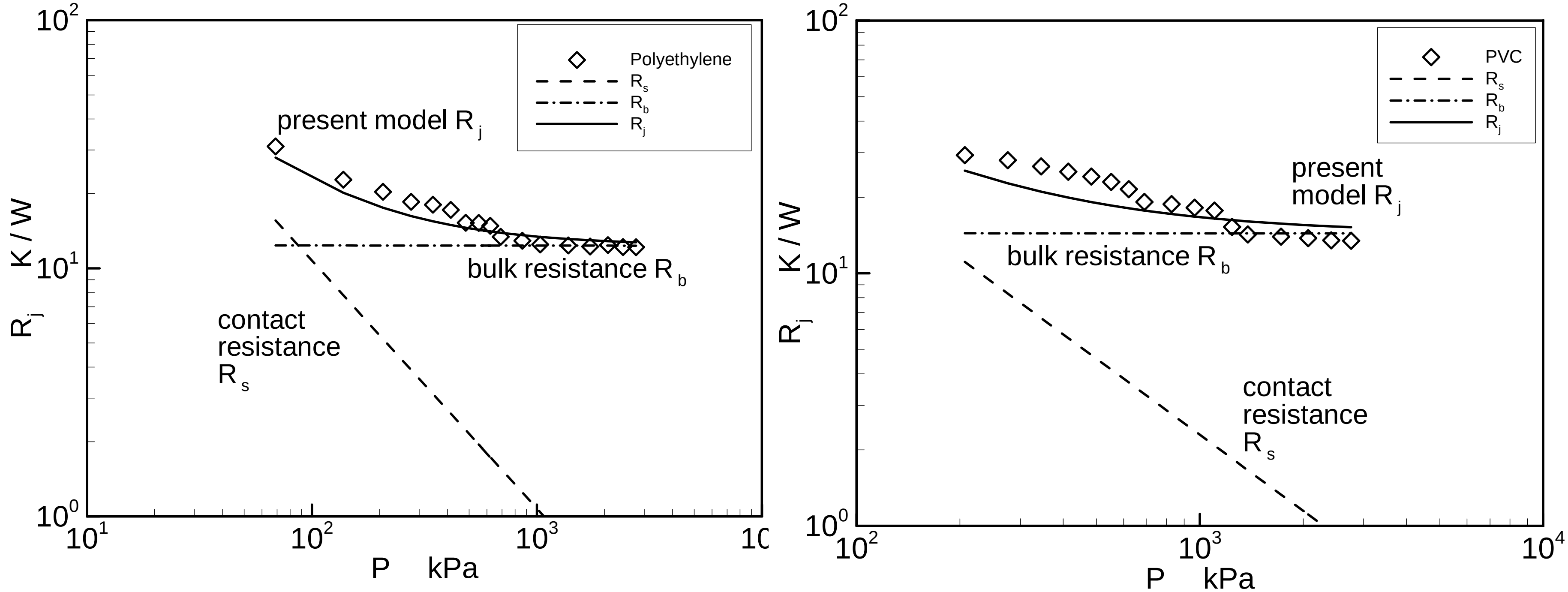
- joint temperatures are less than polymer glass temperatures

COMPARISON WITH DATA





COMPARISON WITH DATA



NON-DIMENSINAL PARAMETER

a non-dimensional parameter is proposed

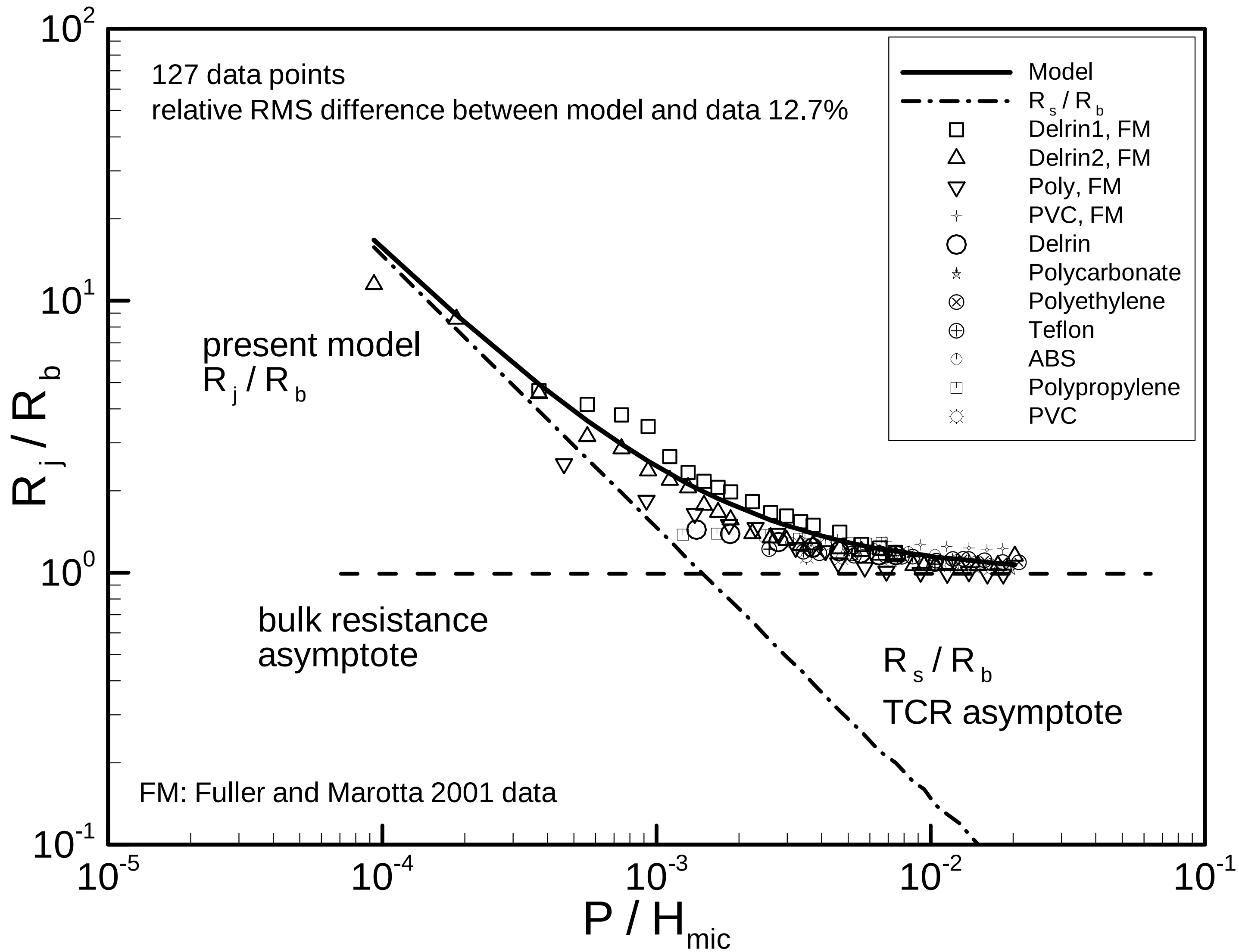
$$R_j^* = \frac{R_j}{R_b} = 1 + \Theta$$

$$\Theta = \frac{R_s}{R_b} = \frac{0.565 k^* (\sigma / m)}{P^* t_0 (1 - P / E_p)} \qquad k^* = k_p / k_s \qquad P^* = P / H_{mic}$$

based on non-dimensional parameter

$$\begin{cases} \Theta << 1 & R_b \text{ controls } R_j \\ \Theta \approx 1 & R_b, R_s \text{ important} \\ \Theta >> 1 & R_s \text{ controls } R_j \end{cases}$$

COMPARISAON WITH EXPERIMENTAL DATA



SUMMARY AND CONCLUSIONS

- it is shown that the deformation mode of asperities is plastic in most of polymers studied
- a compact model is developed that assumes plastic deformation in asperities
- comparison of the present model with experimental data shows good agreement
- a non-dimensional parameter is introduced that specifies the significance of the microcontacts constriction/spreading resistance over the polymer layer bulk resistance

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