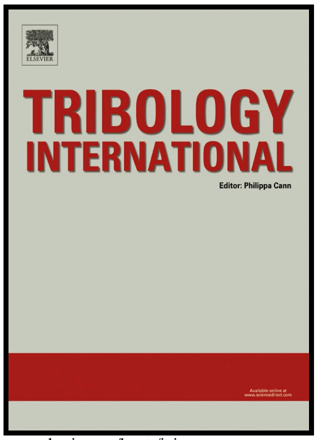




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# A computational stochastic multiscale methodology for MEMS structures involving adhesive contact

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**Abstract**

This work aims at developing a computational stochastic multiscale methodology to quantify the uncertainties of the adhesive contact problems due to capillary effects and van der Waals forces in MEMS. Because the magnitudes of the adhesive forces strongly depend on the surface interaction distances, which in turn evolve with the roughness of the contacting surfaces, the involved structural behaviors suffer from a scatter. To numerically predict the probabilistic behaviors of structures involving adhesion, the proposed method introduces stochastic meso-scale random apparent contact forces which can be integrated into a stochastic finite element model. Because the evaluation of their realizations is expensive, a generator for the random apparent contact force using the polynomial chaos expansion is constructed in an efficient way.

*Keywords:* adhesive contact, random surface, multiscale contact, uncertainty quantification



## 1. Introduction

One of the common failures in microelectromechanical systems (MEMS) is stiction [1, 2, 3, 4, 5, 6, 7, 8], in which two micro surfaces permanently adhere together, e.g. the stiction failure of micro cantilever beams illustrated in Fig. 1(a). The failure is due to the dominance of the adhesive surface forces, such as van der Waals (vdW) forces and capillary forces, in comparison with the body forces. On the one hand, in humid conditions condensing menisci develop between the contacting hydrophilic surfaces, result into relative negative pressures, and lead to the so-called humid stiction, see Fig. 1(b). On the other hand, in dry environments vdW forces become dominant.

MEMS stiction failure is an uncertain phenomenon as it is experimentally observed in [4, 5, 9]. In the present work, a stochastic multiscale model is developed to quantify the uncertainty of MEMS stiction. The model is developed with three assumptions: (i) the considered source of the scatter in stiction is the randomness of contacting surfaces; (ii) the contacting surfaces are nominally flat with nanometers roughness; (iii) to model the capillary forces, the constant pressure assumption is applied [10].

In the adhesive problems of MEMS, due to the comparability between the surface roughness and the ranges of the adhesive forces, the interaction does not involve the whole surface topography but only its highest asperities, see Fig. 1(b) [2]. Moreover, due to the separation of scales between the ranges of the adhesive forces and the structural displacements, the effective contact regions are much smaller than the structural dimensions. For instance, in cases of micro cantilever beams, the effective contact regions are located only around the crack tips defined as the separating point between the unattached part and attached part of the failed beam, see Fig. 1(a). We can thus define three characteristic length scales:

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