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A probabilistic model of the adhesive contact forces between rough surfaces in the MEMS stiction context

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Abstract

Stiction is a common failure mechanism in microelectromechanical systems (MEMS) in which two interacting bodies permanently adhere together. This problem is due to the comparability of adhesive surface forces (e.g. Van der Waals forces, capillary forces) and body forces in the MEMS context.

To predict the adhesive contact forces coupled with stiction phenomenon, the combination of the Nayak statistical approach with the asperity-based theories is a common solution. However, this method contains some limitations due to the underlying assumptions: infinite size of the interacting rough surfaces and negligibility of asperity interactions. Furthermore, the Nayak solution suffers from a considerable dependency on the choice of the minimum wave length considered in the surface representation, which remains difficult to select.

The main goal of our research is to propose an improved method (i) which accounts for the finite size of the interacting surfaces, (ii) accounts for the uncertainties related to these surface topologies, (iii) in which the minimum wave length selection is physically based, and (iv) in which the validity of the asperity-based theories is demonstrated.

From the topology measurements of MEMS samples, an analysis of the power spectral density function is carried out to determine the minimum relevant wave length for the problem of interest (here capillary stiction). We also show that at this scale of interest the asperity-based theories remain valid for polysilicon materials.

Moreover, instead of considering infinite surfaces as in the Nayak approach, a set of surfaces, whose sizes are representative of the MEMS structure, is generated based on the approximated power spectral density analysis and using the Monte Carlo method. From this description of the contacting surfaces, the adhesive contact forces can be evaluated by applying the asperity contact theories, leading to a probabilistic distribution of the adhesive contact forces.

In addition, as the contact forces are rooted from the micro-scale adhesive forces, while their consequence, stiction, happens at the macro-scale of the considered device,

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the multi-scale nature of the phenomenon is accounted for. To predict this macro-scale behavior in a probabilistic form, the uncertainty quantification process is coupled with a multiscale analysis.

Key words: Asperity contact, multiscale contact, random field, stiction, surface topography.

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