

ADHESION FORCES BETWEEN MICA SURFACES IN UNDERSATURATED VAPORS OF HYDROCARBONS

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INTRODUCTION

Miniaturization of machine elements, especially of information systems, has become remarkable with the progress in technology in recent years. In micromechanical systems, surface forces, e.g., van der Waals force [1, 2] or meniscus force [3], which have been neglected in the conventional and relatively large mechanical systems, become important and have considerable effect on their dynamic characteristics.

In this study, adhesion forces between mica surfaces in undersaturated vapors of several kind of hydrocarbon liquids are measured as a function of the relative vapor pressure of the liquids.

APPARATUS AND SPECIMENS

The apparatus used is shown schematically in Fig. 1. Adhering surfaces are in a crossed cylinder configuration. Cleaved mica is glued on the two cylindrical lenses (A, B) which are supported by parallel leaf springs. The parallel spring which supports the cylindrical lens A is displaced by the adhesion force and the displacement of the spring is measured by a high resolution non-contact capacitive displacement sensor. Movement in X direction between the cylindrical surfaces can be applied by an elastic stage which is driven by a piezoelectric actuator and can realize smooth movement of the cylindrical surface. The apparatus is put in a chamber in which the vapor pressure of a liquid can be controlled. The experiments are carried out in room temperature (about 25 °C).

The hydrocarbon liquids used for the vapor atmosphere are *n*-hexane, *n*-octane, *n*-decane and cyclohexane.

EXPERIMENTAL RESULTS

Measured adhesion forces F_{ad} as a function of relative vapor pressure p/p_s of each liquid are shown in Fig. 2, where p_s is the saturated vapor pressure. The adhesion force under the dry condition (◄) can be explained by the JKR theory [4]. It is found that the

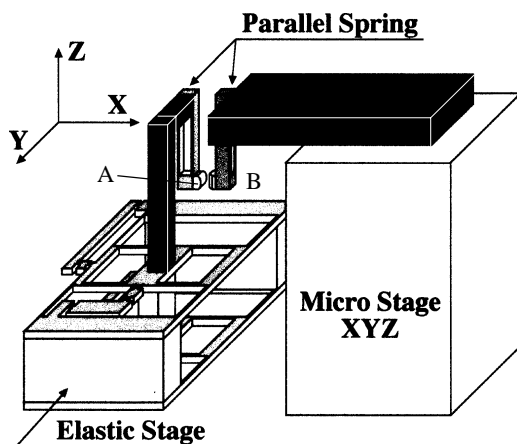


Fig. 1 Experimental set up shown schematically

adhesion force decreases gradually and becomes constant value with increase in the relative vapor pressure. The constant value of the adhesion force corresponds with the meniscus force generated by the Laplace pressure at the surface energy of each liquid, which means that the meniscus shows macroscopic bulk property.

Relation between the nondimensional adhesion force F_{ad}^* and nondimensional Kelvin radius r_K/σ_m is shown in Fig. 3, where $F_{ad}^* = (F_{ad} - 4\pi R\gamma_L)/(3\pi R\gamma_s - 4\pi R\gamma_L) + 1$, R : radius of curvature of the cylindrical surface, γ_L : surface energy of liquid, γ_s : surface energy of solid, $r_K = -\gamma_L V/RT \ln(p/p_s)$: the Kelvin radius, V : volume per 1 mol, R : gas constant, T : temperature, σ_m : average diameter of liquid molecule. Note that $F_{ad}^* = 1$ when the adhesion force F_{ad} is equal to the meniscus force by the macroscopic Laplace pressure and $F_{ad}^* = 2$ when F_{ad} corresponds with the JKR theory. It is found that cyclohexane which has cyclic molecular structure shows bulk property at small Kelvin radius ($r_K \approx \sigma_m$), but with respect to the liquids whose molecular structure is linear chain, relatively large meniscus radius ($r_K > 2\sigma_m$) is required.

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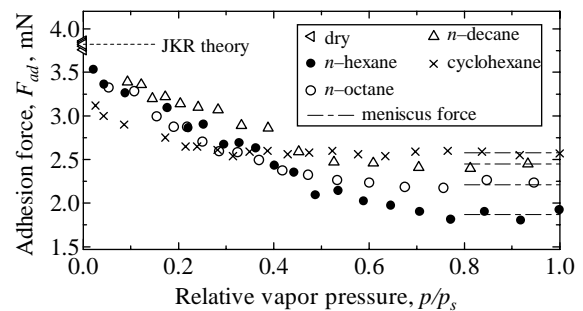


Fig. 2 Adhesion force as a function of relative vapor pressure

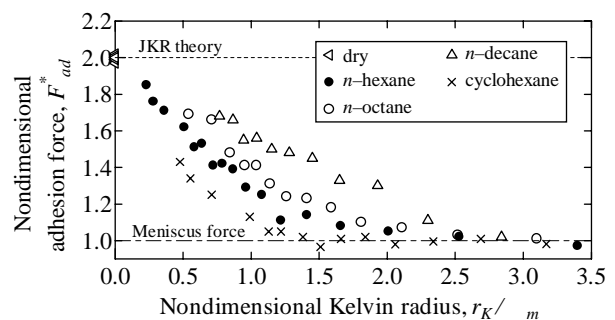


Fig. 3 Nondimensional adhesion force and Kelvin radius