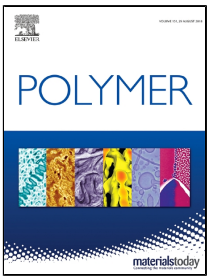
# Accepted Manuscript




Contact-induced stiffening in Ultrathin Amorphous Polystyrene Films

Hao Liu, Wentao Liu, Toshinori Fujie, Ken Nakajima

| | |
|---|---|
| PII: | S0032-3861(18)30795-X |
| DOI: | 10.1016/j.polymer.2018.08.050 |
| Reference: | JPOL 20857 |
| To appear in: | *Polymer* |
| Received Date: | 16 May 2018 |
| Accepted Date: | 22 August 2018 |

Please cite this article as: Hao Liu, Wentao Liu, Toshinori Fujie, Ken Nakajima, Contact-induced stiffening in Ultrathin Amorphous Polystyrene Films, *Polymer* (2018), doi: 10.1016/j.polymer.2018.08.050

# Contact-induced stiffening in Ultrathin Amorphous Polystyrene Films

Hao Liu[1], Wentao Liu[1], Toshinori Fujie[2,3], Ken Nakajima[4]

[1] School of Materials Science and Engineering, Zhengzhou University, No.100 Science Avenue, Zhengzhou, Henan, 450001, China
[2]Waseda Institute for Advanced Study, Waseda University, 2-2 Wakamatsu-cho, Shinjuku, Tokyo, 162-8480, Japan
[3]Japan Science and Technology Agency, PRESTO, 4-1-8, Honcho, Kawaguchi-shi, Saitama 332-0012, Japan
[4]Department of Chemical Science and Engineering, School of Materials and Chemical Technology, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo, 152-8550, Japan

ABSTRACT: Ultrathin polystyrene (PS) films ranging from 14 nm to 316 nm were measured by atomic force microscopy (AFM) based nanomechanical mapping. Both supported and freestanding films were investigated to estimate the possible effect of the substrate. The as prepared supported ultrathin PS films show evident increase of Young's moduli and heterogeneities when the film thickness is reduced to less than 40 nm, whereas no clear thickness dependence can be found for ultrathin films after annealing. Besides, as prepared freestanding PS films thinner than 40 nm also show increased Young's moduli as decrease of the film thickness. The observed increased Young's moduli could be associated with the nano-confined film and contact load of the hard cantilever probe, where the adjacent molecular chains are perturbed and form a mechanically confined phase at the probe/polymer interface. Moreover, since as prepared and annealed ultrathin PS films show different thickness dependence in Young's moduli, it implies residual stress, confinement state of polymer chains, chain conformation, etc., which can be changed by annealing, affect the observed contact stiffening.

KEYWORDS: ultrathin amorphous polystyrene films; atomic force microscopy; Young's modulus