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On the critical behaviour of a surface interacting linear polymer chain

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Abstract

A method based on a real space renormalization group transformation is developed to describe the critical behaviour of a surface interacting linear flexible polymer chain, represented by a self-avoiding walk. It is shown that a lattice model based on a central rule in which the starting point of the walk and the surface are taken to be in the middle of one cell, provides a suitable framework to study both the penetrable and impenetrable surfaces. In contrast to this, a method based on a corner rule in which the starting point of the walk and the surface are fixed to be one corner of a cell cannot describe the behaviour of a chain interacting with an impenetrable surface. The value of crossover exponent found by us for a square lattice are in agreement with those expected to be exact for both the cases.

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1. Introduction

The problem of surface effects on conformation statistics of long flexible polymer chains in solution has been the focus of much attention in recent years [1–18] both because of its merit as an interesting problem in statistical mechanics and because of its practical importance with applications even in biology and technology. While in practical applications one does not usually operate in the vicinity of the critical point, it is of considerable interest to understand how changes in the strength of the surface interactions affect the adsorption behaviour of polymers.

Owing to subtle competition between the gain of internal energy and the corresponding loss of configurational entropy at the surface the configurational properties of polymer chains interacting with a surface may get strongly modified relative to their bulk properties. The general picture that has emerged from the theoretical [11, 13]

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increased the value of ϕ found from the corner rule approaches to the de Gennes [16] scaling value $1 - \nu$.

From the central rule we find that the value of ϕ for the impenetrable surface is close to 0.5. From various methods based on Monte Carlo simulations [4, 6, 10, 15], exact enumerations [26], transfer matrix [27], and the conformal invariance theory [28], it is believed that exact value of ϕ is 0.5. We, however, note that our value has an increasing tendency as the value of b is increased and it has already crossed the exact value of ϕ for cell-to-cell (5 to 3) transformation. Partly this is due to the fact that ν exponent calculated from this method is slightly overestimated and therefore λ_b (an eigenvalue for bulk) is underestimated. It may be that as $b/b' \to 1$ or $b \to \infty$ the value of ϕ approaches to 0.5 from above.

From Table 3 we find that for a penetrable surface the value of ϕ decreases as b is increased in agreement with the trend found for the corner rule. The value given in Table 3 for ϕ, however, differs from that found from the corner rule for same cell size. We expect that the value of ϕ for the central rule will also converge to $1 - \nu$ for larger cell size.

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References

[1] E. Eisenriegler, Polymer Near Surfaces (World Scientific, Singapore, 1993).
[2] K. De'Bell and T. Lookman, Rev. Mod. Phys. 65 (1993) 87.
[3] D.P. Foster, E. Orlandini and M.C. Tesi, J. Phys. A: Math. Gen. 25 (1992) L1211.
[4] H.K. Janssen and A. Lyssy, J. Phys. A: Math. Gen. 25 (1992) 1679.
[5] E. Orlandini et al., Phys. Rev. B 48 (1993) 4203.
[6] P.Y. Lai, Phy. Rev. E 49 (1994) 5420.
[7] V. Bubanja, M. Knezevic and J. Vannimenus, J. Stat. Phys. 71 (1993) 1.
[8] C. Vanderzande, A.L. Stella and F. Seno, Phys. Rev. Lett. 67 (1991) 2757.
[9] I. Zivic, S. Milosevic and H.E. Stanley, Phys. Rev. E 49 (1994) 636.
[10] R. Hegger and P. Grassberger, J. Phys. A: Math. Gen. 27 (1994) 4069.
[11] P.G. de Gennes, Adv. Colloidal Interface Sci. 27 (1987) 189.
[12] D. Napper, Polymeric Stabilization of Colloidal Dispersion (Academic Press, London, 1983).
[13] E. Bouchaud, A. Aurvray, J.P. Cotten, M. Daoud, B. Farnoux and G. Jannink, Application and Scaling to the Study of Polymer at Interfaces, Prog. Surf. Sci. 27 (1988) 5.
[14] J.M. Hammersley, G.M. Torrie and S.G. Whittington, J. Phys. A: Math. Gen. 15 (1982) 539.
[15] E. Eisenriegler, K. Kremer and K. Binder, J. Chem. Phys. 77 (1982) 6296.
[16] P.G. de Gennes, Scaling Concepts in Polymer Physics (Cornell Univ. Press, Ithaca, 1979); P.G. de Gennes, J. Phys. (Paris) 37 (1976) 1445.
[17] K. Binder, Phase Transition and Critical Phenomena, eds. C. Domb and J.L. Leboweitz, Vol. 7 (Academic Press, London, 1983).
[18] M.D. Housley and K.K. Statruly, Dynamics of Biological Membrane (Wiley, New York, 1982).
[19] H.E. Stanley, P.J. Reynolds, S. Render and F. Family, Real Space Renormalization, eds. T.W. Burkhardt and J.M. Van Leeuwen (Springer, 1982) 169.