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Semiflexible crossing-avoiding trails on plane-filling fractals

I. Živić[a,*], S. Elezović-Hadžić[b], S. Milošević[b]

[a] Faculty of Science, University of Kragujevac, R. Domanovića 12, 34000 Kragujevac, Serbia
[b] University of Belgrade, Faculty of Physics, P.O.Box 44, 11001 Belgrade, Serbia

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ABSTRACT

We have studied the statistics of semiflexible polymer chains modeled by crossing-avoiding trails (CAT) situated on the family of plane-filling (PF) fractals. The fractals are compact, that is, their fractal dimension d_f is equal to 2 for all members of the fractal family. By applying the exact and Monte Carlo real-space renormalization group method we have calculated the critical exponent ν, which governs the scaling behavior of the end-to-end distance of the polymer, as well as the entropic critical exponent γ, for a large set of fractals, and various values of polymer flexibility. Our results, obtained for CAT model on PF fractals, show that both critical exponents depend on the polymer flexibility, in such a way that less flexible polymer chains display enlarged values of ν, and diminished values of γ. We have compared the obtained results for CAT model with the known results for the self-avoiding walk and self-avoiding trail models and discussed the influence of excluded volume effect on the values of semiflexible polymer critical exponents, for a large set of studied compact fractals.

1. Introduction

It is well known that polymers show scale invariant properties, so that fractal concepts provide a fruitful mathematical grounds within which different aspects of polymer behavior can be analyzed [1]. Statistics of various lattice walk models which can capture the critical properties of linear polymer chains (i.e., non-trivial power-laws in the behavior of different quantities) has been studied as an ongoing problem in statistical mechanics [2]. The self-avoiding random walk (SAW) model [3], as a canonical model, has been usually applied, in such a way that steps of the walk have been identified with monomers which comprise the polymer chain, while the surrounding solvent has been represented by a lattice. SAW is a random walk that must not contain self-intersections, which means that on a lattice the walker cannot visit a site more than once – such a restriction corresponds to the excluded -volume interactions of monomers within the polymer chain. Less repulsive excluded-volume interactions may be modeled by random walks formed in such a way that they never visit the same bond more than once (bond-avoiding walk) [4]. This model, which we refer to as to the self-avoiding trail (SAT) model has been effectively applied to study the statistic of flexible polymers on regular (Euclidean) [5–8] and semiregular lattices [9,10]. Within the SAT model the lattice sites may be revisited in two ways: by collision (where path touches itself), or by crossing (where path crosses itself), which enables one to generalize this model by assigning the weight w_x to the crossing site, and the weight w_c to the collision site [11,12]. For various values of w_x and w_c assorted types of self-avoiding walk models may be devised. For instance, the case $w_x = w_c = 0$ describes the standard SAW model, while the case $w_x = w_c = 1$ corresponds to the SAT model. The third, intermediate case ($w_x = 0$ and $w_c = 1$), in which the crossings are forbidden and collisions are allowed we refer here to the crossing-avoiding trail (CAT) model. This model coincides with the $O(n)$ model (in the limit $n \to 0$) initially introduced by Blöte and Nienhuis

* Corresponding author. Tel.: +381 34 335 039; fax: +381 34 335 040.
E-mail addresses: ivanz@kg.ac.rs (I. Živić), suki@ff.bg.ac.rs (S. Elezović-Hadžić), savam@ff.bg.ac.rs (S. Milošević).

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