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Lattice Model of Sweeping Interface for Drying Process in Water-Granule Mixture

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概要：水-粉体混合系の乾燥過程におけるパタン形成ダイナミクスを記述する為に、侵入パーコレーションモデルを変形して、掃き寄せ界面の格子模型を構成した。このモデルが、YamazakiとMizuguchiの実験[1]で見られるような迷路状パタンを生成することを示した。初期の粉体濃度を変化させることによって、生成されたパタンがパーコレーション転移を起こすが、数値シミュレーションによって得られた臨界指数は、通常のパーコレーション転移のものとは異なるものであった。掃き寄せ界面によって生成されたパタンには、同一クラスタ-上の2点を結ぶ径路が一つしかないという特徴（ループのない構造）が、この転移の性質に大きく影響しているようだ。

Abstract: We construct a lattice model for a sweeping interface to describe the pattern formation process in drying of water-granule mixture, and demonstrate that the model generates labyrinthine patterns similar to those observed in the experiment[1]. Simulations show that there is a percolation transition in the pattern upon changing the granule density, but the estimated critical exponents for the transition are different from those for the conventional percolation transition. Loopless cluster structure in the pattern might be responsible for the difference.

Phenomenon: Yamazaki and Mizuguchi[1] have demonstrated that labyrinthine patterns appear when they dry the water-granule mixture sandwiched between the two glass plates. The physical process may be described as follows; As the water evaporates from the gap between the plates, the wet region tends to shrink, thus the pressure in the water decreases. This pressure difference gives the driving force to move the interface between the water and the air at the part where the friction of granules with the glass plates is smallest. As the interface moves, it sweeps the dispersed granules to collect them along it; Consequently, the interface becomes more difficult to move as it accumulates the granules. The granules eventually get stuck and form a pattern after drying.

Lattice Model of Sweeping Interface: To describe such sweeping process, the phase field model[2, 3] and the boundary dynamics[4] have been proposed, focusing different aspects of the phenomenon. In this report, we present a simple lattice model of sweeping interface based upon the invasion percolation model[5].

The idea is simple; Regarding the extension of dry region into the wet region upon drying as the invasion process, we describe it by the invasion percolation model[6]. The random numbers assigned for each lattice site are taken as the granular density. At each invading process, the interface site with the smallest friction, or the smallest granular density, is invaded(dried).

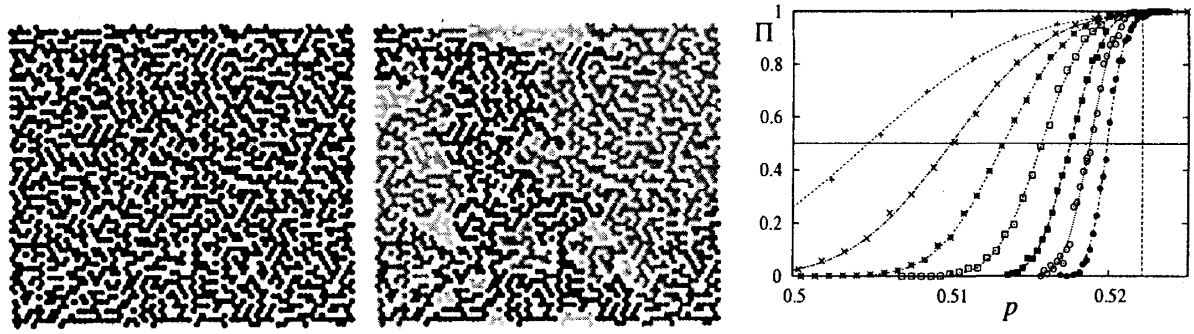

Figure 1: A labyrinthine pattern produced by the model (left), the cluster decomposition of the same pattern (middle), and the percolation probability Π vs. occupation ratio p for the system of the size $L \times L$ with $L = 2^7 \sim 2^{13}$ (right).

Only difference from the invasion percolation is that the random number of the invaded site is redistributed over the neighboring wet sites. When the granular density exceeds the threshold at a site, the granules of the site get stuck, therefore will not be redistributed upon drying. The surface tension effect may be taken into account in the determination of the weakest site. We use the triangular lattice for smaller system anisotropy.

Percolation Transition: The left panel in the figure shows a pattern produced by the model. It is reminiscent of that by the experiment[1]. The black circles represent the sites with the stuck granules and the white region has been swept away by the interface. One can see that any part of white region is connected to outside. In the middle panel, the same pattern is decomposed into clusters by painting with various tones; One of the clusters is percolating, and each cluster is highly branched without any loop, i.e. there is only one path that connects any two sites on a same cluster. The percolation probability Π vs. the occupation ratio p in the final patterns are plotted in the right panel for various system size L. Remarkable difference from the corresponding plot for the ordinary percolation is the absence of the fixed point where all the plots for various L intersect; For the present model, Π is a decreasing function of L for a given p. We suspect that this comes from the loopless structure of clusters in the labyrinthine patterns; Any parts of large cluster are marginally connected through a single path, therefore, the percolating cluster is more difficult to appear in larger system for a given p.

References

[1] Y. Yamazaki and T. Mizuguchi, J. Phys. Soc. Jpn. **69** (2000) 2387.

[2] Y. Yamazaki, M. Mimura, T. Watanabe, and T. Mizuguchi, unpublished.

[3] T. Iwashita, Y. Hayase, and H. Nakanishi, J. Phys. Soc. Jpn. **74** (2005) 1657.

[4] H. Nakanishi, arXiv: cond-mat/0508622, to be published in Phys. Rev. E (2006).

[5] H. Nakanishi, R. Yamamoto, Y. Hayase, and N. Mitarai, arXiv: cond-mat/0606256.

[6] D. Wilkinson and J.F. Willemsen, J. Phys. A **16** (1983) 3365.