Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(7):1315-1318

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Empirical analysis of basic fuchsin adsorbed on gallium phosphide agglomeration network based on complex network

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ABSTRACT

Recent years, complex networks have provided a natural framework to describe a variety of large systems in many fields of science. In this paper, from the research aspect in chemical science, empirical researches of basic fuchsin adsorbed on gallium phosphide (GaP) agglomeration network have been done. We applied complex network theory to analyze the topological structure characteristics of the agglomeration network, and explain that why intensity of Raman spectrum is different in different location of the same surface of specimen through complex networks theory.

Key words: Complex networks; agglomeration network; Raman spectrum; basic fuchsin; gallium phosphide

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INTRODUCTION

The theoretical research and practical application of complex networks has become an important tool for solving many problems of the natural and social systems, and it has been widely used in the fields of sociology, economics, statistics, physics, chemistry and bioinformatics [1-4]. Since the pioneering work by Watts and Strogatz [5] on small-world networks and Barabasi and Albert [6] on scale-free networks, complex networks have recently received much attention from different scientific communities.

Although a large number of complex networks researches in chemistry have been done, complex network theory has seldom been applied in Raman spectrum of chemical substances. In this paper, an empirical research of an agglomeration network is done. We adopt corresponding complex network method to study some problems in Raman spectrum analysis, we use complex network theory to convert real agglomerations into network models and analyze the topological structure characteristics of the network. Moreover, we discuss the corresponding meanings of these structural characteristics from the perspective of chemical researchers.

1. RAMAN SPECTRUM OF BASIC FUCHSIN ADSORBED ON SURFACE OF GALLIUM PHOSPHIDE

Basic fuchsin acts as one kind chloride which ionizes in water solution and can be divided into organic kation and Cl^{-1}, structure of kation is shown in Fig. 1.

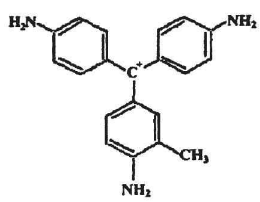

Fig. 1: Structure of kation

Gallium phosphide nanoparticles can be synthetised by GaCl3 and Na3P in dimethylbenzene, the chemical reaction equation as follows:

$$GaCl_3 + Na_3P \rightarrow GaP(nanoparticles) + 3NaCl \tag{1}$$

In order to separate out NaCl from GaP nanoparticles, we use ionized water of basic fuchsin solution to clean them several times. At last, Gallium Phosphide nanoparticles adsorbed basic fuchsin is placed in desiccator to dry, thus, surface of Gallium Phosphide nanoparticles can be performed Raman spectrum.

Raman spectrum of common basic fuchsin and surface of Gallium Phosphide nanoparticles adsorbed basic fuchsin are shown in Fig. 2.

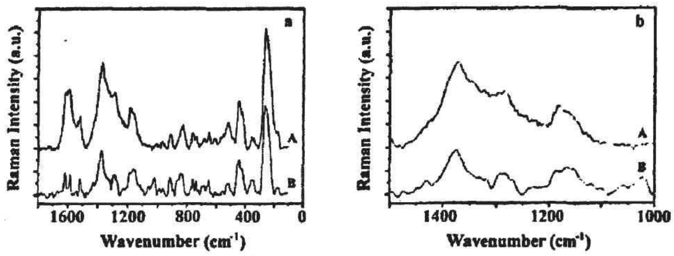

Fig. 2: Raman spectrum of basic fuchsin and surface of Gallium Phosphide nanoparticles

From Fig. 2 we can see that Raman spectrum is different in different location of the same surface of specimen, we thought that it is caused by nanoparticles arrangement, so empirical analysis of nanoparticles agglomeration network based on complex network is introduced.

2. EMPIRICAL ANALYSIS OF AGGLOMERATION NETWORK

We placed individually 200mg GaP in 50ml deionized water high concentration solution and low concentration solution for four years, nanoparticles through filter membrane gradually agglomerate and is transformed into agglomerations. We choose the most complete agglomeration in high concentration solution and low concentration solution to observe and research, optical microscopic (500 times zoom) picture is shown in Fig. 3.

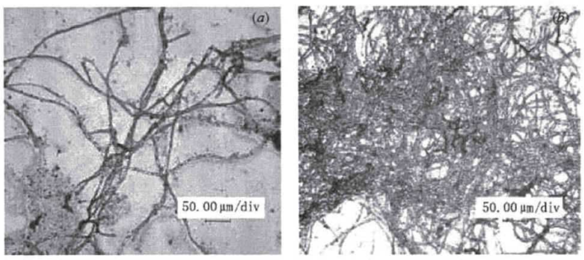

Fig. 3: (a) optical microscopic picture in low concentration solution (b) optical microscopic picture in high concentration solution

Then we cut the optical microscopic picture into slices, the networks of top slice under kamada-kawa energy mode is shown in Fig. 4.

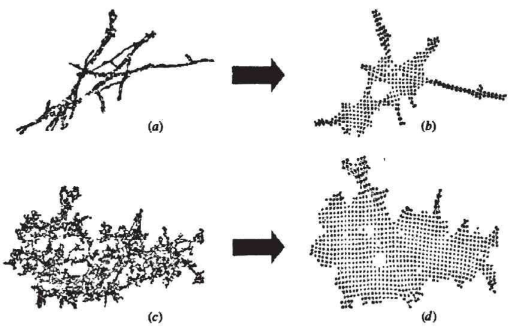

Fig. 4: (a) and (c) optical microscopic picture before top slice (b) and (d) networks under kamada-kawa energy mode

It is different from small-world networks and scale-free networks, every node of agglomeration network tends to connect eight neighbor nodes. Degree distribution of high concentration solution agglomeration network and low concentration solution agglomeration network is shown in Fig. 5.

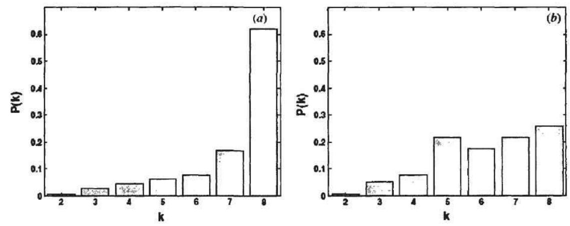

Fig. 5: (a) Degree distribution of high concentration solution agglomeration network (b) Degree distribution of low concentration solution agglomeration network

According to statistical analysis, clustering coefficient of high concentration solution agglomeration network is 0.41, clustering coefficient of high concentration solution agglomeration network is 0.48. Fig. 6 plots the distribution of clustering coefficient vs. degree. It reveals that the number of nodes is small but clustering coefficient is high. It shows that agglomeration process is mainly restrictions to space factor.

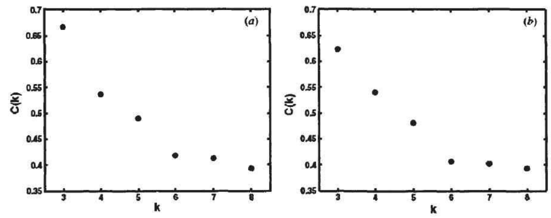

Fig. 6: (a) Distribution of clustering coefficient vs. degree of high concentration solution agglomeration network (b) Distribution of clustering coefficient vs. degree of low concentration solution agglomeration network

According to statistical analysis, average path length of high concentration solution and low concentration solution agglomeration network are individually 14 and 16.6. It shows that nanoparticles prefer to agglomerate firmly to form stable structure.

Through analyzing degree distribution, clustering coefficient and average path length of agglomeration network, we found that the agglomeration network is neither small-world network nor scale-free network, its characteristics of topology is very different from social networks and technical networks.

According to nodes with small degree tend to be connected to other nodes with large degree or small degree, networks can be divided into disassortative mixing networks or assortative mixing networks [7-9]. Degree correlation of high concentration solution and low concentration solution agglomeration network are all assortative. The degree correlation is shown in Fig. 7.

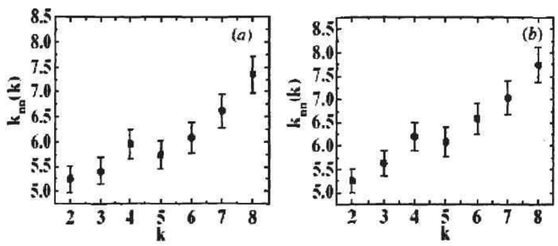

Fig. 7: (a) Degree correlation of low concentration solution agglomeration network (b) Degree correlation of high concentration solution agglomeration network

Based on above empirical analysis, we draw the conclusion that in agglomeration process, nanoparticles prefer to agglomerate firmly to form stable structure, and at the same time synchronizing capacity of agglomerations increase gradually.

For the purpose of validating our conclusion, we choose two nodes whose number of nanoparticles is similar, but topological structure is different. Intensity of Raman spectrum is shown in Fig. 8.

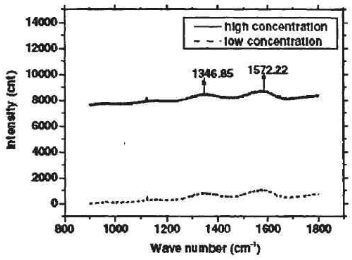

Fig. 8: Raman spectrum of two agglomerations

The two nodes is located centre of two agglomerations, it is obvious that pixels of high concentration solution obtained higher intensity, and pixels of low concentration solution absorbed less photon, which is in accord with our conclusion.

CONCLUSION

Through our empirical analysis, we found a lot of topological characteristics of the agglomeration network. These topological characteristics reveal physical cause of intensity of Raman spectrum. Because of difference of topology characteristics, scattering intensity of Raman spectrum would be different, the phenomenon is explained reasonably by complex network theory.

Acknowledgments
The authors wish to thank the National Natural Science Foundation of China under Grant No.60974085, and The National Natural Fund Major Projects under Grant No.91120035..

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