Analysis of gallium phosphide nanoparticles agglomeration phenomenon based on Raman spectrum

Hailing Li, Sheng Bin, Gengxin Sun and Shuiqing Jiang

Applied Technology College, Qingdao University, No.308, Ningxia Road, Qingdao, China
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ABSTRACT

In this paper, from the standpoint of Raman spectrum research aspect in material science, Raman spectrum analysis of graphite and diamond microcrystal retained by gallium phosphide nanoparticles is introduced. We found that molecular configuration of basic fuchsin adsorbed on gallium phosphide nanoparticles through experiments. Based on these, Raman scattering is used for analyzing basic fuchsin adsorbed on surface of gallium phosphide nanoparticles. Moreover, we discuss the corresponding meanings of agglomeration phenomenon from the perspective of material.

Key words: Raman spectrum; Gallium phosphide nanoparticles; Agglomeration phenomenon; Basic fuchsin
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INTRODUCTION

RAMAN SPECTRUM OF GALLIUM PHOSPHIDE NANOPARTICLES
Comparing to common Gallium Phosphide(GaP) single crystal material, it is enormously different with Gallium Phosphide nanoparticles in physical and chemical properties, which causes that there are potential application value in fields of Nano optical and electronic devices.

According to analyzing oscillation spectrum of Gallium phosphide nanoparticles[1,2], there are P-O bond,P=O bond and O-H bond among surface ofGallium phosphide nanoparticles. In this section, we will use Raman spectrum to analyze nano Free State carbon mixed in Gallium Phosphide nanoparticles for understanding deeply the physical and chemical properties of Gallium Phosphide nanoparticles which was synthesized by Benzene-thermal method.
Raman spectrum of Gallium Phosphide nanoparticles which was synthesized by Benzene-thermal method is shown in Figure 1.
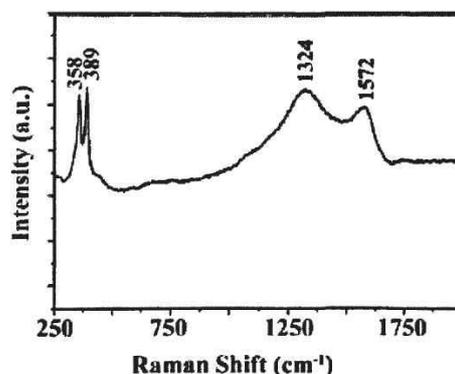
Fig.1 Raman spectrum of Gallium Phosphide nanoparticles

From Figure 1, we can see that in the scope of 250~2000 cm^{-1}, there are four strongscattering peaks, peaks in 358 cm^{-1} and 389 cm^{-1} belong to and LO vibration. Moreover, there are two wide and strong scattering peaks in the scope of 1000~1700 cm^{-1}, which is individually located in 1324 cm^{-1} and 1572 cm^{-1}, chemical substances having nothing to do with Gallium Phosphide nanoparticles cause appearing of the two peaks.Hudgens found that vibration peak of P=O was individually located in 1280~1390 cm^{-1} and 1330~1340 cm^{-1}[3]. So we can draw a conclusion that there is a great deal of carbon in specimen of Gallium Phosphide nanoparticles.

Chemical substances which draw carbon into Gallium Phosphide nanoparticles should be dimethylbenzene which acts as reaction medium. Gallium Phosphide nanoparticles is continuously heated for a long time when the temperature is higher than boiling point of dimethyl benzene, but the two strong scattering peaks are also observed, it reveals that the two scattering peaks do not come from dimethylbenzene. Based on above analysis, substance which best fits the experiment results of Raman spectrum is Free State carbon instead of organic combined state carbon.

There is a sharp peak in 1580 cm^{-1}in natural monocrystalline graphite[4]. The peak would become wider with increasing of disordering between graphite, peak located in 1360 cm^{-1} would appear when disordering increased to a certain extent. The scattering peak of graphite fit well to scattering peak located in 1572 cm^{-1}ofGallium Phosphide nanoparticles. It can be inferred that a part of Free State carbon among Gallium Phosphide nanoparticles exists in the form of graphite.

Diamond is another important existence pattern of Free State carbon. Raman peak of diamond is located 1332 cm^{-1}, from Figure 1, we can see that there is scattering peak nearby 1332 cm^{-1} in Raman spectrum of Gallium Phosphide nanoparticles, the wide and strong scattering peak is located in 1324 cm^{-1}. But feature vibration of diamond would move about 10 cm^{-1}to low frequency after heating, it would be located in 1323 cm^{-1}, so it also can be inferred that a part of free state carbon among Gallium Phosphide nanoparticles exists in the form of diamond.

MOLECULAR CONFIGURATION OF BASIC FUCHSINADSORBED ON GALLIUM PHOSPHIDE NANOPARTICLES
Structure of fuchsin dye adopted in this paper is shown inFigure 2.
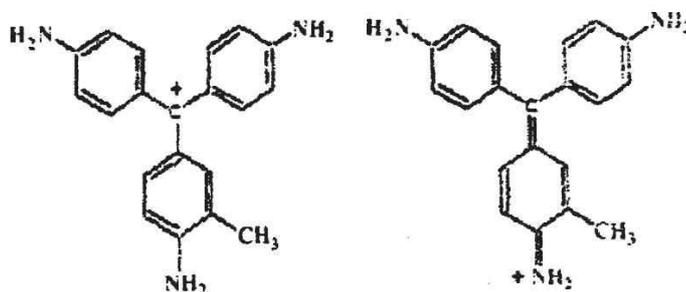
Fig.2 Structure of fuchsin dye diagram

Finally, we place Gallium Phosphide nanoparticles adsorbed basic fuchsin in desiccator to dry, thus, manufacturing Gallium Phosphide nanoparticles is specimen whose surface adsorbed basic fuchsin.Raman spectrum of high concentration and low concentration basic fuchsin and basic fuchsin adsorbed on Gallium Phosphide nanoparticles are individually shown inFigure 3 and Figure 4.
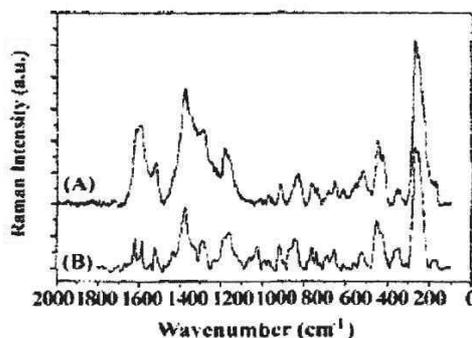
Fig.3 Raman spectrum of basic fuchsin in high concentration solution

Comparing spectrum (A) tospectrum (B) in Figure 3, we observe that there is a wide scattering peak area from 1200 cm^{-1} to 1320 cm^{-1} in surfacespectrum, and a new chemical bond P-O-C^{+} maybe formed.
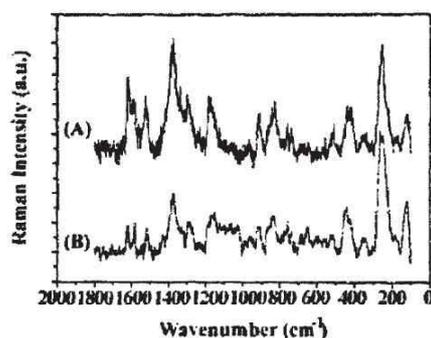
Fig.4 Raman spectrum of basic fuchsin inlow concentration solution

On the contrary, similar phenomenon isnot observed in surfacespectrum of spectrum (A) in Figure 4, it illustrates that there is not new forming chemical bond in low concentration solution.

There are two kinds of molecular configuration—end-on and flat—for basic fuchsin adsorbed on Gallium Phosphide nanoparticles. In consideration of adsorption rate of dye molecules is in proportionate to the concentration of the solution. In high concentration solution, a large number dye molecules arrive surface of Gallium Phosphide nanoparticles during unit of time, under these circumstances, its molecular configuration mainly includes end-on and flat, and flat structure is prerequisite of forming new chemical bond P-O-C^{+}. In high concentration solution, its molecular configuration only includes flat.

RAMAN SPECTRUM OF BASIC FUCHSIN ADSORBED ON GALLIUM PHOSPHIDE NANOPARTICLES

Raman spectrum of basic fuchsin and surface enhancement are shown in Figure 5.
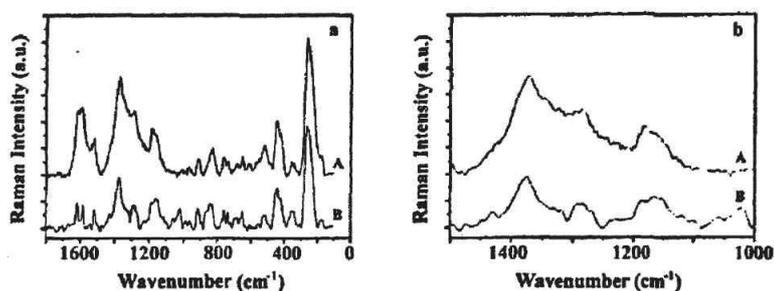
Fig.5 Raman spectrum of basic fuchsin and surface enhancement

Surface enhancement Raman spectrum can be defined by enhancement factor (EF) as follows[5]:

$$EF = \frac{I_{REL}}{(n_{ad}/n_{crys})} \cdot \frac{1}{f_{sh}} . \quad (1)$$

Where, n_{ad} representthe number of dye moleculesadsorbed on Gallium Phosphide nanoparticles, n_{crys} representthe number ofpure dye crystalmolecules, it is defined as follows:

$$n_{crys} = \frac{\rho_{crys} \cdot V_{crys} \cdot N_A}{M} \quad (2)$$

Where, ρ_{crys} is density, V_{crys} is scatteringrangevolume, M is molar mass of dye molecules, N_A is Avogadro constant.

n_{ad} can be defined as follows:

$$n_{ad} = \rho_{GaP} \cdot V_{GaP} \cdot \alpha \cdot N_A \quad (3)$$

Where, ρ_{GaP} is cumulative density, V_{GaP} is scatteringrangevolume of GaP, α is energy absorbed by unit mass ($mol \cdot g^{-1}$).

α can be expressed as follows:

$$\alpha = \frac{C_{ad} \cdot V_{sat}}{W_{GaP}} \quad (4)$$

Where, C_{ad} is dye concentration adsorbed on GaP, V_{sat} is volume of dye (50ml) source solution, W_{GaP} is mass of GaP nanoparticle (50mg).

In this paper, C_{ad} can be derivatedas follows:

$$C_{ad} = C_0 - C_{s\tan} \cdot \frac{A_{sus}}{A_{s\tan}} \quad (5)$$

We assume $V_{crys} \approx V_{GaP}$, and apply parameter ($n_{ad} / n_{crys} \approx 0.17$) toequation (1), the value of EF is 67, which is in accord withHayashi's experiment result [6]. According to enhancement factor, we can conclude that basic fuchsin has absorbed on surface of GaP nanoparticles. But we also found that Raman spectrum is different in different location of surface for the same specimen.

The problem we encountered in Raman spectrum research would probably resolve through complex network. Because basic fuchsin absorbed randomly on GaP nanoparticles, so network which consists of nanoparticles has characteristics of randomness, and topological structure of network has fractal character. We can test and verify our surmise through agglomeration experiments.

CONCLUSION

Based on above works, we draw the conclusions thatthe existence of graphite and diamond mierocrystals in Gallium Phosphide nanoparticles has been proved, the molecular configuration of basic fuchsin adsorbed on Gallium Phosphide nanoparticles has close relation with concentration of dye solution, for the dye molecules absorbed on the surface of Gallium Phosphide nanoparticles, there are two main configurations adopted: flat and end-on.

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