

Study on the depolarization of CCl₄ Raman spectrum by the parameter of polarizer and analyzer

Wang Fengli**, Jiang Lei, Wang Zhanshan
School of Physics Science and Engineering, Tongji University, Shanghai, 200092

ABSTRACT

The performances of different polarizers and analyzers used in the Raman spectrometer are different, they effect the depolarization of Raman spectrum. Three polarizers and three analyzers are characterized using the spectrum of Cary5000 in the wavelength range of 505-610nm. The polarizer are chosen with the best performance and the worst performance among three polarizers. These two polarizers in turn combine with three analyzers to measure the Raman spectrum. The results show that the depolarization of CCl₄ Raman spectrum is closer to theory when using the high transmittance and high polarization for polarizer in narrow wavelength range; The performance of the analyzer effects little on the depolarization, but to reduce the effect, the transmittance and the polarization of the analyzer should be high and the curves are flat in the wavelength range of the measured material's Raman spectrum.

Key word: spectrum of Raman, Degree of depolarization , polarizer, CCl₄

1. INTRODUCTION

In 1928, C.V.Raman found that there were some different frequencies with the incident light's frequency when he did the experiments about the interaction of light with liquid, gas and solid¹. This is called Raman spectrum, and is one kind of scattering spectrum. The difference of frequency with the incident light's frequency is called roman shift. And the roman shift of one medium is only determined by the molecular structure of the medium, and is independent of the incident light. Degree of depolarization is one important parameter of the Raman spectrum, it is used to characterize the polarization of the Raman spectrum and is an important criterion of molecular normal symmetry vibration modes. Raman spectrum is often used in the research of the medium molecular structure, such as medicine, identification of ancient writing, identification of ancient painting, identification of gems, and so on²⁻⁵. Raman spectrum is often used as one important experiment for the students in the majors of physics, chemistry and optics⁶⁻⁷. The liquid medium often used in the experiment is CCl₄. There are two questions about the Raman spectrum, one is the position of peak which can be resolved by shifting. Another is the degree of depolarization, there is large differences with theoretical value. In this paper, the polarization components are focused on to research the reason of difference of degree of depolarization. The performance of the polarization components has great effect on it.

2. THEORY

The structure of CCl₄ is tetrahedron, one carbon atom is in the center and four chlorine atoms are in the tetrahedral four vertices. There are nine dependent harmonic oscillations. These nine oscillations are classified into four categories. There

** Tel:86-21-65981626, Email: wangfengli@tongji.edu.cn

are eight Raman peaks in CCl₄ Raman spectrum. To describe degree of depolarization, one plane is determined first, it's called scattering plane which includes the direction of the incidence light propagation and the direction of observation, such as the XOY plane shown in figure 1. Degree of depolarization is the ratio of the spectrum intensity I_y of parallel scattering plane to the intensity I_z of vertical scattering plane, shown in equation 1. The intensity I_y and I_z can be obtained using one line polarizer by rotating the polarizer to change the direction of polarizing.

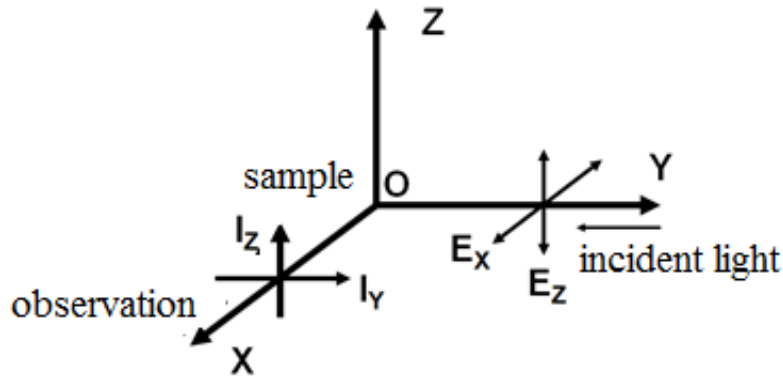


Figure1 Schematic diagram of the direction of incident light, observation and sample

$$\rho = \frac{I_{\parallel XOY}}{I_{\perp XOZ}} = \frac{I_y}{I_z} \quad (1)$$

If the incident light is Linear polarized and the polarization direction is E_z, the theoretical value about the degree of polarization is shown in talbe1.

3. CHARACTERIZATION OF POLARIZATION COMPONENTS

There are three square polarizers and three circle analyzers, which is named as Q1, Q2, Q3 and J1, J2, J3. Before doing experiments, the polarization components are measured using the spectrometer of Cary 5000. For the polarization of the polarizer, the transmittance is measured with the s polarization light and p polarization light at 0° incident angle, respectively. The results are shown in figure1. Figure 1a is the result for square polarizers and figure 1b is for circle analyzers. Comparing the transmittance, the quality of Q1 is best, Q2 is worst. And J3 is best, J1 is worst. The polarization is defined using equation2:

$$P = \frac{|T_S - T_P|}{T_S + T_P} \quad (2)$$

Using equation1, the polarization is obtained with the data in figure1, shown in figure2, figure 2a is for square polarizers and figure 2b is for circle analyzers. The polarizers work in the wavelength range of 532 nm ± 5 nm in the experiment for CCl₄ Raman spectrum, so the quality of Q3 is higher than Q1, and Q2 is worst. The analyzers work in the wavelength range of 505-560 nm for CCl₄ Raman spectrum. So it is difficult to obtain high quality analyzer in so broad wavelength. From figure 2b, it can be seen that the polarization of J3 is worst, its change in the broad wavelength is smallest, the polarization of J1 is best, its change is bigger, and the polarization of J2 is middle but its change is biggest. Considering two parameters of polarization and transmittance for polarizers and analyzers, Q1 is best, Q2 is worst, and J3 is best, J1 and J2 is near.

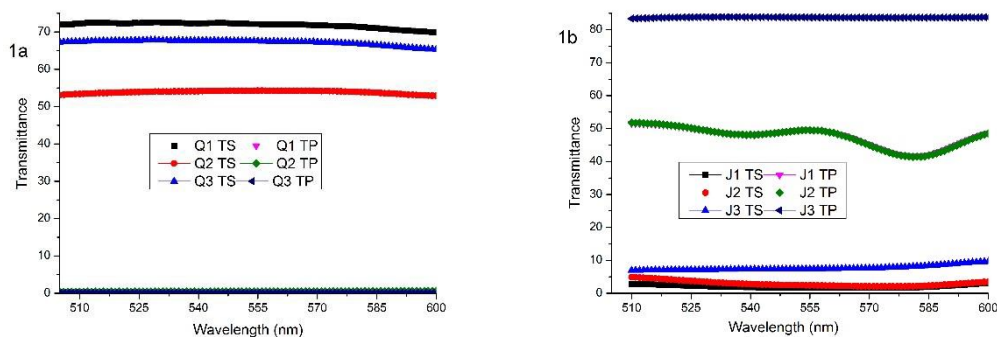


Figure 1 Transmittance of the polarizers and analyzers for s and p polarization light at 0° incident angle, figure 1a is for polarizers and figure 1b is for analyzers

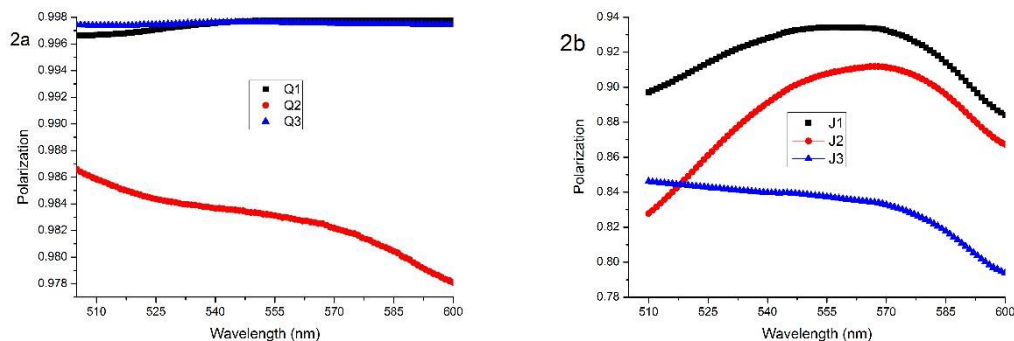


Figure 2 Polarization of polarizers and analyzers, figure 2a is for polarizers and figure 2b is for analyzers

4. EXPERIMENT AND RESULTS

The experiment is done using the Raman spectrometer of LS-II. To reduce the environment effect on data, the spectrometer is always covered by black-out cloth when the experiment is doing. At the same time, the other parameters such as step, integral time, are not changed when doing different experiments. Using the best quality of Q1 and worst quality Q2 with three analyzers, six groups experiments are done to comparing the effect of the characterization of polarizers and analyzers. According to the definition of degree of depolarization for Raman spectrum in equation 1 and the structure of the used Raman spectrometer in the experiments, 0 is expressed the data for the spectrum intensity I_y of parallel scattering plane and 90 is expressed the data for the intensity I_z of vertical scattering plane. Figure 3 shows the data of CCl_4 Raman spectrum for the group of Q1 and J1. Degree of depolarization for CCl_4 Raman spectrum is calculated using the data shown in figure 3 and lists in table 1. The data for spectrum and degree of depolarization for other groups also are obtained using the same method, and the degree of depolarization for other groups are listed in table 1.

The results show that the degree of depolarization is closer to the theoretical value when the polarization of analyzer is flatter than the other two in the broadband wavelength using the same polarizer, just like Q1 and J2, Q2 and J2, these two data are worst in their individual group. At the same time, higher of the transmittance and polarization of the polarizers, closer to the theoretical value using the same analyzer.

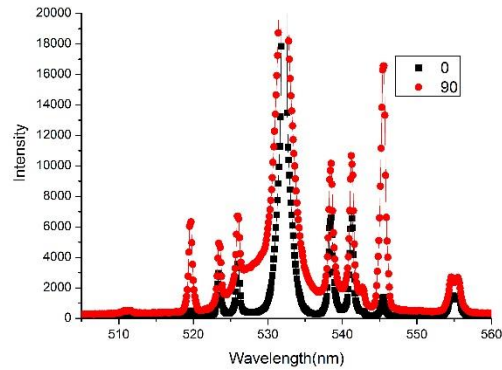


Figure 3 CCl₄ Raman spectrum for the group of Q1 and J1

Table 1 Degree of depolarization of CCl₄ Raman spectrum for six groups and theoretical value

$\lambda(\text{nm})$		519.7	523.4	526	538.5	541.2	545.5	554.6	
Calculated value ρ	Q1	J1	0.07	0.60	0.53	0.65	0.66	0.08	0.55
		J2	0.13	0.64	0.58	0.70	0.70	0.10	0.62
		J3	0.05	0.64	0.60	0.75	0.75	0.02	0.64
	Q2	J1	0.09	0.60	0.67	0.66	0.66	0.08	0.57
		J2	0.11	0.54	0.49	0.58	0.58	0.08	0.51
		J3	0.10	0.59	0.53	0.67	0.68	0.04	0.56
Theoretical value ρ		0	0.75	0.75	0.75	0.75	0	0.75	

5. CONCLUSION

Degree of depolarization of CCl₄ Raman spectrum is investigated by changing the different group of polarizer and analyzer. Polarizer works in a narrow wavelength band, so it's easy to obtain high depolarization ($P > 0.995$) with high transmittance ($T > 70\%$) for Raman spectrum experiment. Analyzer works in a very broadband wavelength, depending on the structure of the measured medium. It's very difficult to obtain the broadband analyzer with high polarization and high transmittance in such broadband wavelength. But its feature effects on degree of depolarization for Raman spectrum. It is one important work to look for one method to fabricate the analyzer with high transmittance and the flat polarization curve in the required wavelength region as far as possible.

6. ACKNOWLEDGEMENT

This work is supported by Special fund for experimental teaching reform of Tongji University.

REFERENCES

- [1] Zhenhua Guo, Raman and the discovery of Raman effect, College physics, 12 (2), 39-44 (1993).
- [2] Kuanguo Li, Guangju Liu, Xianyi Zhang, Xuehan Ji, Zhifeng Cui, An experimental investigation on the polarization characteristics of laser Raman spectrum of organic molecule, Applied laser, 26 (2), 101-104 (2006).

- [3] Jianhua Huang, Lu Yang, Shanshan Yu, Confocal micro Raman spectroscopy for the identification of the binder used in Chinese painted cultural relics, *Spectroscopy and spectral Analysis*, 31(3), 687-690 (2011).
- [4] Jun Zhou, Based on the LRS-III Raman spectrometer to detect black handwriting, *Physical experiment of college*, 27 (6), 27-29(2014).
- [5] Li Chen, Chang Wang, Application of FT-Raman spectroscopy on gemological research, *Chinese journal of spectroscopy laboratory*, 18 (6), 780-784(2001).
- [6] Yan Wu, Yan Xu, Yanping Ma, Zhijin Chen, The analysis and measurement of depolarization of CCl₄, *Physical experiment of college*, 21 (4), 32-35 (2008).
- [7] Haiyan Wang, Zhongqiu Zhang, Yingchun Zhao, Minghui WANG, Study on polarization characteristic of laser Raman spectrum teaching, *College physics*, 22 (11), 40-43(2003).