spectra of the composite is thought as sum effect of epoxy matrix and PT powder as shown in Fig. 3(b). When external field is 400 V/mm, the absorption edge of the composite shifts toward long wavelength apparently. However, no observable shift of absorption edge for epoxy has been measured experimentally. The gap energy calculated by extrapolating the absorbency to zero shifts from 2.95 eV to 2.75 eV under external DC electric field. In PT suspension system, the shifting of absorption edge toward long wavelength is also observed when external electric field is applied.

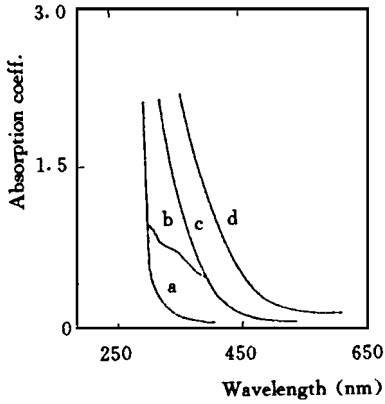

Fig. 3 Absorption spectra of solid sample, thickness in 0.27 mm, (a) epoxy, (b) composites (E= 0), (c) PT powder and (d) composites (E= 400 V/mm)

The field induced light scattering is about 50%, while transmitted light can be increased by 60% with increasing of external field applied on PT suspension. Optical absorption edge is shifted from 2.95 eV to 2.76 eV in nano PT composites. All experimental results indicate that there is a strong interaction between PT particles and dispersed systems under external AC and DC electric field. All optical properties can be modified by applying electric field on composites.

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电场对 $PbTiO_3$超微粒子 0-3型纳米复合材料性能的影响

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摘 要 将溶胶-凝胶工艺制备的 $PbTiO_3$超微粒子分散在液体和环氧树脂中,研究这类 0-3型复合材料在不同电场作用下材料的光散射和光透过率以及材料吸收边的影响规律.

关键词 纳米复合材料,超微粒子

分类号 O 648.17

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中山大学学报 (自然科学版)
第 36卷 第 2期 ACTA SCIENTIARUM NATURALIUM Vol. 36 No. 2
1997年 3月 UNIVERSITATIS SUNYATSENI Mar. 1997

Effect of Electric Field on Properties of 0–3 Nano-Composites with $PbTiO_3$ Ultrafine Particles*

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Abstract $PbTiO_3$ polar ultrafine powder derived from sol-gel process is dispersed in liquid and epoxy matrices. Electric field-induced light scattering and transmission of 0–3 nano-composites are investigated. Changes of absorption edge of the compositions under applied electric field are measured.

Keywords nano-composites, ultrafine powder
Classification number O 648.17

Recently, there has been a significant increase in new and multi-functional nonlinear optic, electric-optic materials to meet very rapid development of electronics and optoelectronics. Fine composite material is a very important choice to solve the problems in single phase material when optimizing its figure of merit for certain applications. Because of very short wavelength of excitations to avoid penal scattering, nanometer composite is required. There are two kinds of size effect for nano materials, they are thermodynamic size effect and quantum size effect[1,2]. It is well known that the properties of nano materials are quite different from their bulk materials. New and better properties might be appeared through sum and product effects by manipulation symmetry and connectivity of each component of nano-composite materials[3].

So far, a lot of work has been done on preparation of fine composite materials. Ultrafine $PbTiO_3$ (PT) powders in the size of 20~ 80 nm were dispersed in various liquid condition. Experimental results indicate that optical properties of the dispersions are able to be modified by applied electric field. The absorption edge and epoxy matrix are also observed. Changes of scattered light, transmitted light and light absorption of the composites under external electric field are carefully studied under various of PT dispersions shifts toward long wavelength. A study of electric field effect on properties of the composites has been carefully carried out.

1 Experimental

Ultrafine PT powder was successfully prepared by sol-gel method[4]. Powder obtained

* 国家"863"高技术新材料研究基金和广东省自然科学基金 (930222)资助项目
收稿日期: 1996-05-06 周歧发,男, 34岁,副教授

is in soft aggregation, the size of aggregation is about 200~ 300 nm. Ultrasonic treatment is used to deaggregate PT powders. The deaggregated PT powder dispersed in liquid is in the range of 20 to 50 nm. Liquid dispersants are dibutyl phthalate, tributyl phosphate and acetophenone, etc.

Liquid suspensions can be easily prepared by ultrasonic treatment, the weight fraction of PT powders was about 0.05%. To prepare solid composites containing 1% of PT powder, ultrafine PT powders were dispersed in epoxy matrix, then mixed with C_2H_5OH, ultrasonic dispersed for 30 minutes. The mixture was then heated at 70℃ to allow complete solvent volatilization under stirring, then placed in a mold. Solid composite formed through solidification of epoxy mixture under applied DC electric field. Samples were polished to ensure that the faces were parallel. Two kinds of light scattering have been investigated on both liquid suspension sample and solid composite sample. They are longitudinal mode in which electric field is parallel to the incident light beam and transverse mode in which electric field is perpendicular to the incident light beam.

2 Results and conclusions

2.1 Scattered light

Scattered light behavior depends upon internal structure of material. In our experiment, no observable changes of scattered light under external electric field for all dispersants such as liquid and epoxy have been detected. Therefore, any change of scattered light of composites is supposed to stem from the change of configuration of the powder-matrix system. When external electric field is applied on the sample, change of its optical property is an expression of change in its internal ordering configuration. As shown in Fig. 1(a), scattered light decreases with increasing of DC electric field under longitudinal mode. When electric field is higher than 500 V/mm, scattered light has no significant change. However, scattered light increases apparently with increaseing of DC electric field under transverse mode. This is mainly due to the differences in scattering cross section along incident light beam under different mode of electric field. During solidification of epoxy matrices the ordering degree and configuration of PT particles are quite different under various mode and magnitude of DC electric field. In PT dispersed liquid systems, change of scattered light is the same as above result.

Effects of DC and AC electric field on light scattering behavior of PT liquid suspension are different. Experiments show that the ordering effect of DC field to polar particles is much stronger than that of AC field. In other words, to establish the same degree of ordering, AC field should be higher than DC. However, PT colloidal particles are negatively charged when dispersed in organic solvents. Translational movement of PT colloidal particles takes place under DC electric field, causing aggregation and sedimentation of particles on bottom and electrode, which reduce the stability of suspension and spoil the ordering of the system. The result is given in Fig. 1(b). Compared with those under AC field, under DC field the change of scattered light is larger in low electric field region and smaller in high one, the saturation field is smaller. So AC field is much better than DC field to investigate field induced optical properties of PT suspension.

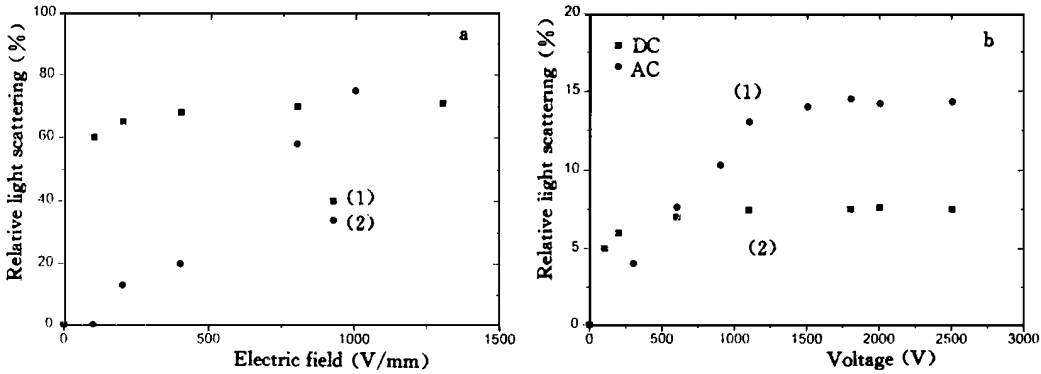

Fig. 1 Change of scattered light(Δ Is) under external electric field [Δ Is= (Ise-Iso) /Iso* 100. Iso, Ise are scattered ilght when field at zero and E respectively]

(a) PT/epoxy composites, scattering angle is 5°, (1) Transverse mode(Δ Is), (2) Longitudinal mode ($-\Delta$ Is)

(b) PT suspension under transverse field, (1) AC (50 Hz), (2) DC

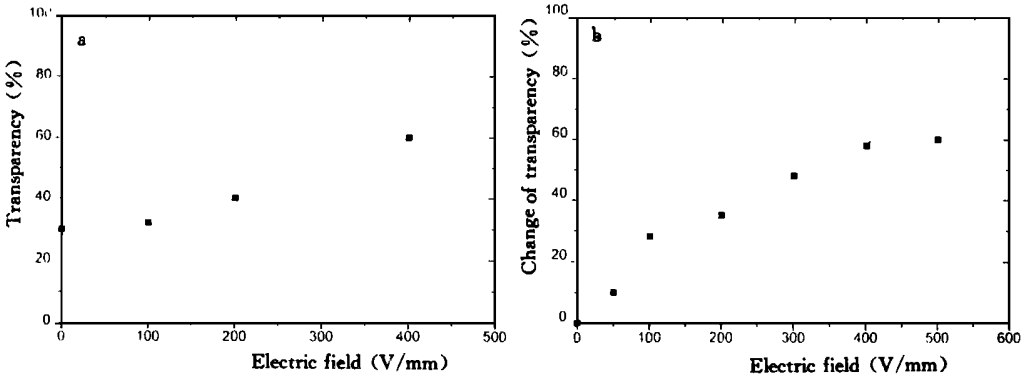

Fig. 2 Change of transmitted light under external electric fidld, wavelength is 630 nm

(a) PT/epoxy composites at DC field during solidification, thickness in 0.27mm

(b) PT dispersed in acetophenone at AC field, thickness is 0.8 mm

2.2 Transmitted light

Change of transmitted light at different wavelength under external electric field has been investigated, the results of solid sample are shown in Fig. 2(a). Transparency of composite sample increases with increasing of solidification electric field. Change of transmitted light is about 30% when solidification electric field is 400 V/mm. Fig. 2(b) is the transparency curves of PT suspension in acetophenone under external AC electric field. Experiments show that maximum change of transmitted light in suspension system can be as high as 60% .

2.3 Optical absorption spectra

Fig. 3 shows the ultraviolet absorption spectra of solid samples in different conditions. The potical absorption curves of epoxy are quite different from that of PT ultrafine powder. The energy band structure of the two kinds members of the composite is quite different. Without applying electric field on sample during solidification, optical absorption