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Nonlinear absorption in an azo-containing ion liquid crystal polymer in the different excitation regimes

Tingchao He [a], Changshun Wang [a,*], Jinwen Zhang [a], Xiaoqiang Zhang [a], Xueming Lu [b]

[a] Department of Physics, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai 200240, China
[b] School of Chemistry and Chemical Technology, Shanghai Jiao Tong University, Shanghai 200240, China

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ABSTRACT

The nonlinear absorption of an azo-containing ion liquid crystal polymer, in dimethylformamide solution or solid thin film, has been investigated using Z-scan technique. Under the excitation of nanosecond or picosecond pulses at 532 nm, the film presents large saturable absorption (SA), while the solution shows reverse saturable absorption. The alteration of nonlinear absorption behavior is due to the change of excited state cross-section and the time of intersystem crossing in solution and film. Irradiated by a continuous wave laser, SA is observed in both solution and film due to the low excitation optical intensity and thermal effect.

1. Introduction

At present, nonlinear absorption (NLA) properties of conjugated organic molecules with high π-electron densities are at the forefront of research. There are two distinct NLA processes: reverse saturable absorption (RSA) and the saturable absorption (SA). SA, characterized by an increase in transmission with increasing intensity, has been extensively applied in laser physics, such as mode locking, picosecond pulse shaping and optical bistability [1]. RSA is characterized by a reduction in transmission with respect to intensity. Materials with large RSA can effectively limit the throughput energy of incident light. Such materials are of prime importance in optical power-limiting-related applications [2]. There are many papers reporting the SA or RSA properties of organic materials. The most usual method for obtaining SA or RSA materials is chemical synthesis [3–5]. Different electronic effects of the withdrawing substituent will result in different nonlinear absorption behaviors [6]. Also, increasing the optical intensity and pulse width, SA can be converted to the RSA [7]. As a much easier method than chemical synthesis, the alteration of NLA of organic molecules can be realized by changing the donor solvent or adjusting the mixture ratio of donor solvents [8].

Ionic liquid crystals are one kind of materials that combine the properties of liquid crystals and ionic liquids and are a class of liquid-crystalline compounds that contain anions and cations. The ionic character means that some of the properties of the ionic liquid crystals differ significantly from that of conventional liquid crystals. The typical property for ionic liquid crystals is their ion conductivity. The ionic interactions tend to stabilize lamellar mesophases, but ionic liquid crystals also display uncommon mesophases such as the nematic columnar phase [9]. Azo-containing ionic liquid crystal is becoming one of the primary frontiers of research, which combines the peculiar properties of azo dyes, liquid crystal and ionic liquid. Though the nonlinear optical properties of azo-containing ionic liquid crystals have not been widely investigated, they are expected to be good candidates for fabricating nonlinear optical devices. One hand, ionic liquids and ionic liquid crystal have attracted great interest as environment friendly versatile media for synthesis and extraction; on the other hand, azo-polymer materials are interesting for application in optical-limiting and optical switching application for their large optical nonlinearity. Moreover, photoisomerization of azo-molecules makes it easy to modify their linear and nonlinear polarizabilities of molecular as well as optical nonlinear refraction [10].

In the present work, the NLA properties of an azo-containing liquid crystal in dimethylformamide (DMF) solution and solid thin film have been studied. The magnitude and the sign of NLA coefficients were measured using single beam Z-scan technique [11]. The measurements were performed at 532 nm using picosecond, nanosecond and continuous wave lasers. The aim of this investigation is to see how the molecular surrounding and excitation condition affect the NLA of ion liquid crystal polymer.

* Corresponding author. Tel.: +86 21 54749348; fax: +86 21 5474104.
E-mail address: cswang@sjtu.edu.cn (C. Wang).

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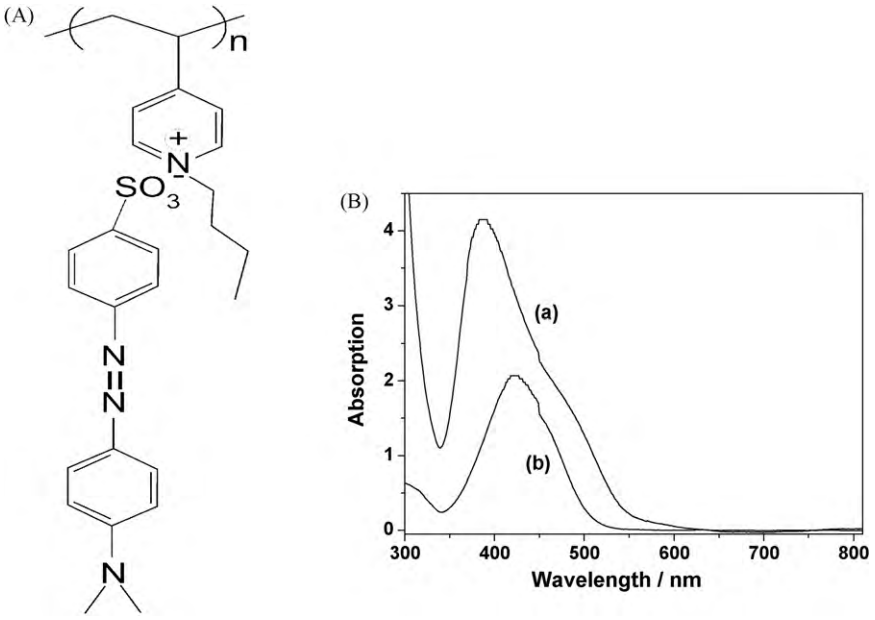

Fig. 1. (A) The molecular structure of azo-containing ionic liquid polymer; (B) the linear absorption spectrum of polymer thin film (a) and solution (b).

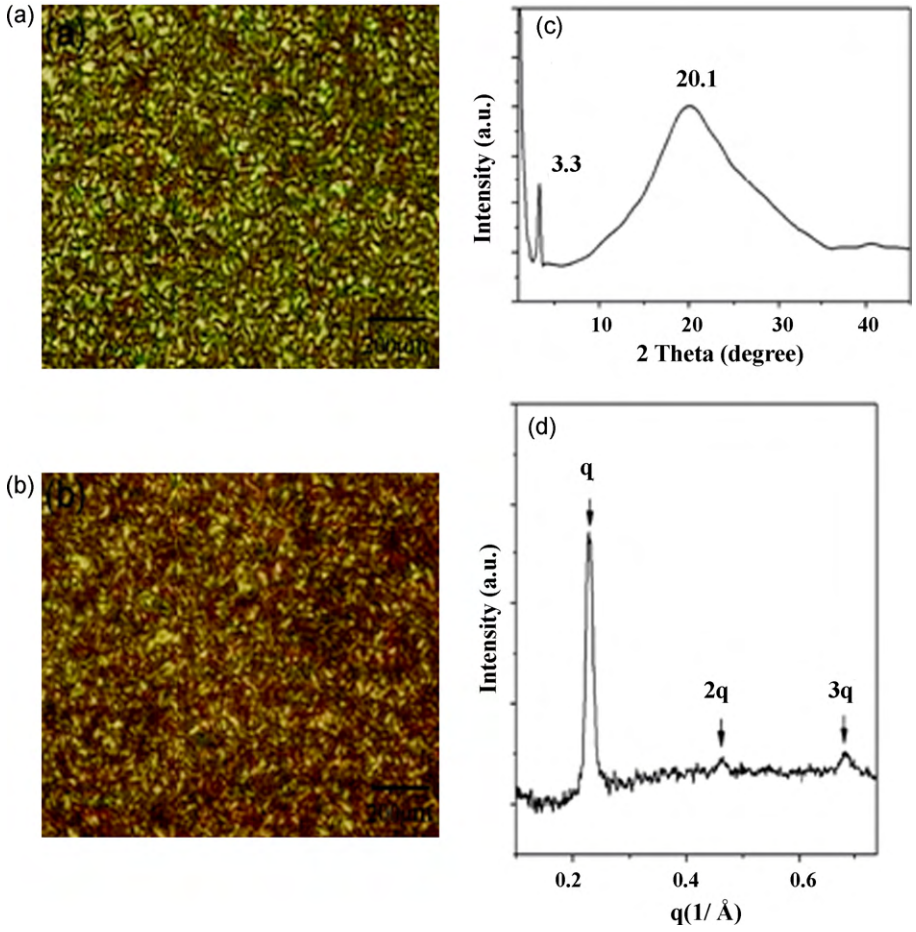

Fig. 2. Characteristic texture of polymer: (a) film cast from chloroform; (b) DMSO solution (ca. 30% in weight) as observed in a polarized optical microscope; (c) WAXD and (d) SAXS patterns of polymer at room temperature.

2. Experimental

The molecular structure of azo-containing ion liquid crystal polymer used in this work is shown in Fig. 1(A). This photosensitive azo-containing ionic liquid was prepared by the ionic self-assembly of poly(ionic liquid) and azo dye. The synthetic method was described in detail in Ref. [12]. The linear absorption spectra of polymer are also shown in Fig. 1(B). The maximum