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Optical limiting behavior of new fullerene derivatives

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Abstract

The optical limiting behavior of $C_{60}Ph_5Cl$, $C_{60}Cl_6$, and $C_{70}Cl_{10}$ in toluene solution has been measured at 532 nm with nanosecond pulses. The limiting threshold for $C_{60}Ph_5Cl$, $C_{60}Cl_6$, and $C_{70}Cl_{10}$ were 4, 8, and 8 J/cm^2, respectively. The limiting action was strongly influenced by the number of conjugated double bonds and the nature of the ligand. Both lower limiting thresholds and throughputs make these new fullerene derivative compounds good promising candidates for optical limiting materials in the toluene solution.

Keywords: Optical limiting; Fullerene derivatives; Nonlinear optics

1. Introduction

Since the development of laser technology, the research on materials and devices for protection of solid-state sensors and human eyes from intense optical beams generated much interest in the development of optical limiting materials [1–3]. Many publications on optical limiting materials were focused on nonlinear optical organometallic compounds [4,5] and semiconductor materials [6], because of their large nonlinearity and ultra-fast response time [7]. C_{60} and its derivatives attracted

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considerable interest since the photophysical properties of these molecules are suitable for obtaining a good optical limiting behavior over the entire visible spectrum and in the near-infrared spectral region [8]. Recently, fullerene derivatives have been investigated, some of them may give performance approaching C_{60} such as C_{60} amine, and C_{60} alcohol [9]. Fulleropyrrolidines and cyclopentadienyl fullerene derivatives in toluene solutions were studied at two different wavelengths: 532 and 652 nm [10]. It was found that C_{60} has shown a better optical limiting performance than its derivatives at 532 nm, but some derivatives are shown to be better than C_{60} at 652 nm [10].

There are several different mechanisms that could explain the optical limiting behavior such as reverse saturable absorption (RSA); two-photon absorption, nonlinear refraction, and optically induced scattering [11,12].

In this paper, we investigate the optical limiting behavior of new fullerene derivatives such as $C_{60}Ph_5Cl$ and $C_{60}Cl_6$, and $C_{70}Cl_{10}$ that has not been reported before. These materials were provided as a gift from the Sussex Fullerene Center and used as received.

2. Experimental

The optical limiting behavior of the studied compounds was measured in toluene solution at a concentration of 10^{-4} mol/l using a 10-mm thick quartz cell. The optical limiting measurements were performed with frequency doubled Nd:YAG laser system. Pulses of 7 ns and 1 Hz repetition rate were focused onto the sample cell through a lens with 50 mm focal length. In order to avoid damaging of the quartz cell, the sample was located away from the focus (3 mm); the diameter of the laser beam at the sample was approximately 250 μm in the $1/e^2$ diameter. The energy of the incident and the output pulses were measured using a calorimeter sensor (Scientech PHF 50 energy detector).

3. Results and discussion

UV–visible absorption spectra of the studied compounds were recorded using Shimadzo spectrophotometer before and after the optical limiting measurements in order to make sure that there was no degradation of the samples as a result of the high-intensity laser pulses. The two UV–visible absorption spectra were found to be identical before and after irradiation. Fig. 1 shows the UV-visible absorption spectra of the studied compounds after irradiation. The ligand of the substituent groups distorts the C_{60} sphere due to the resultant breaking of π-conjugation symmetry in C_{60}. There are new allowed transitions that appear in the absorption spectra, which were attributed to the features characteristics of C_{60} derivatives.

Fig. 2 shows the variation of the output fluence as a function of the input fluence, which points out the optical limiting behavior of $C_{60}Ph_5Cl$, $C_{60}Cl_6$, and $C_{70}Cl_{10}$. The variation is linear only when the input fluence is less than 4 J/cm^2 for $C_{60}Ph_5Cl$ and