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Fluorescence, spectroscopic and NLO properties of green tea extract in deoxyribonucleic acid

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ABSTRACT

Natural, purely biological deoxyribonucleic acid (DNA)–green tea extract (GTE) complexes at different concentrations were prepared and characterized for their spectroscopic, fluorescent, linear and nonlinear optical properties. The complexes can be processed into good optical quality thin films by solution casting. They fluoresce when excited in UV absorption band, with a significantly larger quantum yield for the DNA–GTE complex than for a pure GTE solution. The thin film refractive indices were determined by Fabry–Perot (FP) interference patterns. The third-order nonlinear optical (NLO) properties of thin films were determined by the optical third-harmonic generation technique at 1064.2 nm fundamental wavelength. The phase of THG susceptibility was determined from the concentration variation of THG susceptibility. It reveals presence of a two-photon resonance with a band lying in the optical gap.

1. Introduction

One of the important problems which humanity is facing at its present stage of development is the pollution and the limited resources. Therefore, the use of natural products originating from renewable sources is one of the ways helping to handle. It is connected with the development of green chemistry, based on using natural dyes and biopolymers. These important survival aspects push the interest of scientists towards the biological materials which originate from renewable resources and are biodegradable. Among them the biopolymers, like deoxyribonucleic acid (DNA) and collagen, show very interesting properties to be used as possible matrices for active molecules for application in photonics. They are able to replace synthetic polymers and bring more through their particular, helical structure. These biopolymers are extracted from the waste produced by the food processing industry and their sources are practically unlimited. Their degradation time, if unprotected, is much faster than that of synthetic polymers in similar conditions what is important to avoid the already mentioned pollution problems.

DNA is known to exhibit a double strand helical structure [1,2] (cf. Fig. 1), offering three possibilities for doping with photosensitive molecules: intercalation in minor and/or major groves, electrostatic interaction due to the fact that the backbone of the helix is charged negatively, the charge being counterbalanced by the sodium ion Na^+, and statistically, as in the case of synthetic polymers (see e.g. Rau et al. [3]). It could be also chemically modified with photoactive molecules by the advanced organic synthesis. Ogata and coworkers [4,5] elaborated a technology allowing to obtain large quantity of pure DNA from the salmon sperm.

Similarly, the scientists turn their attention to natural photosensitive materials, which can be extracted from flowers or from fruits, leaves, like anthocyanines, showing some photosensitive properties interesting for photonic applications [6]. These molecules were also considered for solar energy conversion in electrochemical cells [7] showing at present the largest solar conversion quantum efficiency among the organic photovoltaic cells.

As active chromophore we use the green tea extract (GTE) which is reputed for its powerful antioxidant and antibacterial activity. The polyphenolic fraction of green tea has been reported to have multiple pharmacological actions [8–11], such as: improvement of the blood flow, elimination of alcohol and toxins, improvement of resistance to diseases, prevention of cancer and cardiovascular diseases.

The High Performance Liquid Chromatography (HPLC) analysis shows that most of the polyphenols present in green tea are flavonoids, commonly known as catechins [12,13]. As presented in Fig. 2 these are (−)-epicatechin (EC), (−)-epicatechin-3-gallate (ECG), (−)-epigallocatechin (EGC) and (−)-epigallocatechin-3-gallate (EGCG) molecules.

In this paper we report the preparation of complexes of DNA with GTE. The complexes form regular thin film by spin coating technique. They were characterized for spectroscopic,

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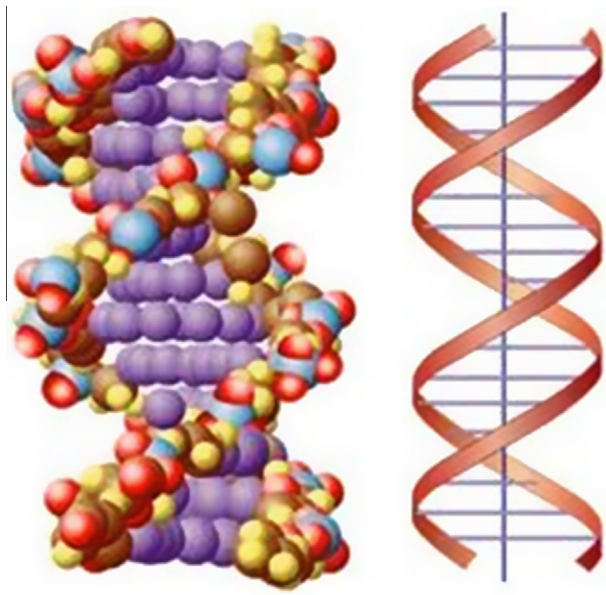

Fig. 1. Chemical structure of DNA.

fluorescence, linear and nonlinear optical properties. The nonlinear optical (NLO) properties characterization of functionalized thin films was performed by the optical third harmonic generation (THG) measurements at 1064.2 nm fundamental wavelength. Both DNA and GTE are transparent at the fundamental wavelength. GTE shows a small absorption at harmonic wavelength which can be taken into account as it is discussed in the experimental part of this paper.

2. Materials and thin films processing

The low molecular mass deoxyribonucleic acid, extracted from salmon sperm was purchased from Sigma Aldrich Company. It was used as supplied. The used green tea extract contains as main components: polyphenols (51.8%), catechins (39.4%), EGC (9.5%), DL–C (1.92%), EG–GG (15.5%), EC (3.8%), GCG (2.6%), ECG (5.9%) and caffeine (9.8%). In order to obtain the DNA–GTE complexes firstly DNA was solubilized in deionized water under stirring. After that a precise amount of GTE, to obtain the desired concentration, was added to the DNA solution and heated to about 50 °C to increase the solubility. Complexes with three GTE concentrations were prepared: 5, 10 and 15 w%. As substrates for thin film fabrication commercial microscope glass slides, pure silica plates and ITO covered glass substrates were used after their careful cleaning. They were dried by heating to 50 °C in vacuum in order to remove the solvent. Films deposited on ITO covered substrates were used for refractive index measurements. Pure silica substrates were used for UV–VIS spectroscopy and for the fluorescence study. The thin films thickness was determined by the profilometry technique using DEKTAK 120 model profilometer of KLA Tencor.

3. Results and discussion

3.1. UV–VIS absorption spectra

The UV–VIS absorption spectra were obtained using JASCO spectrometer. As it can be seen from Fig. 3, both GTE and DNA exhibit large transparency range. The DNA absorption is located around 270 nm and is due to the phenyl rings. It overlaps with the absorption band of GTE in the wavelength range 250–320 nm. Beyond wavelength of 320 nm the absorption originates

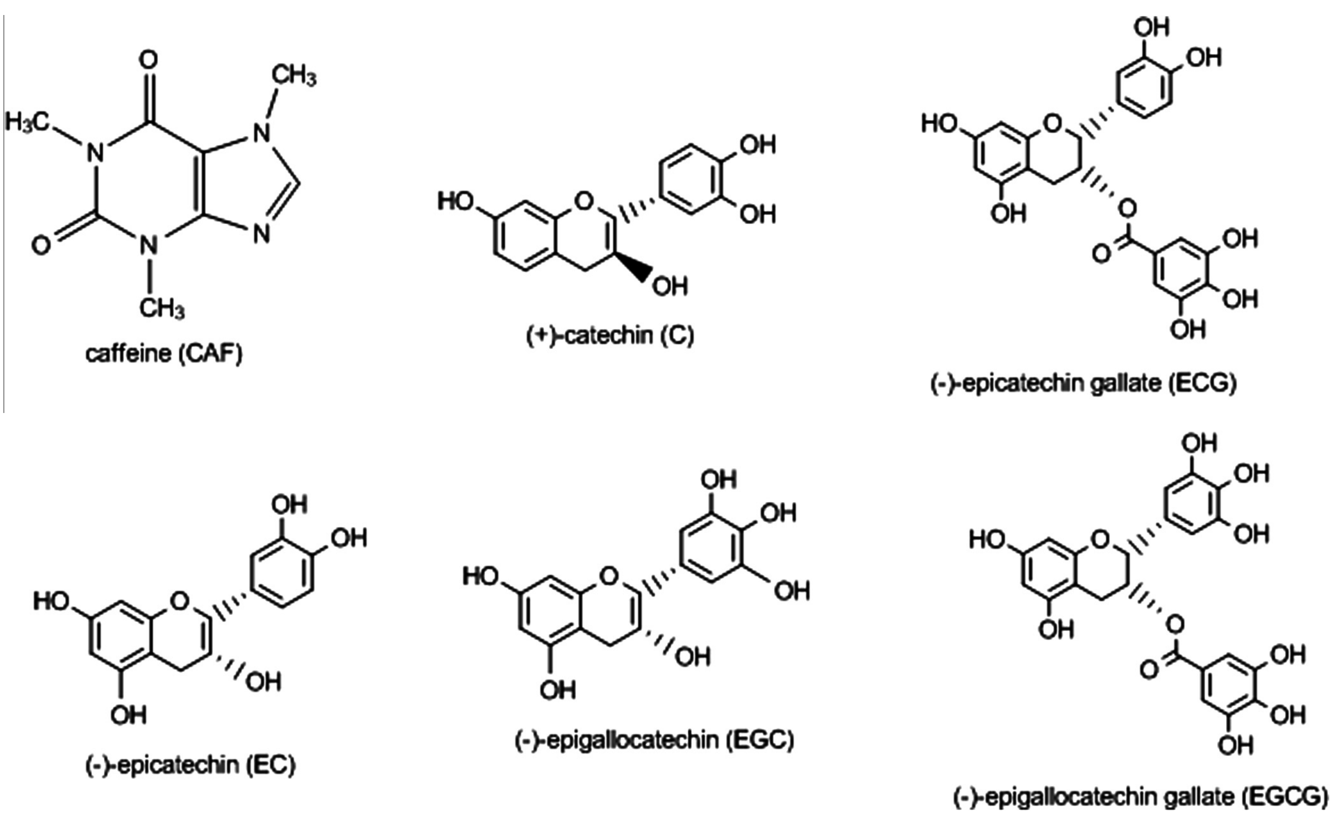

Fig. 2. Chemical structures of bioactive compounds present in green tea extract.