Journal of Photochemistry & Photobiology A: Chemistry 401 (2020) 112783

Contents lists available at ScienceDirect

Journal of Photochemistry & Photobiology A: Chemistry

journal homepage: www.elsevier.com/locate/jphotochem

Meso-substituted-BODIPY based fluorescent biomarker: Spectral characteristics, photostability and possibilities for practical application

Galina. B. Guseva[a,*], Elena V. Antina[a], Mikhail B. Berezin[a], Roman S. Pavelyev[b], Airat R. Kayumov[b], Irshad S. Sharafutdinov[b], Svetlana A. Lisovskaya[c,d], Olga A. Lodochnikova[b,e], Daut R. Islamov[b,e], Konstantin S. Usachev[b], Sergei V. Boichuk[c], Liliya E. Nikitina[b,c]

[a] G. A. Krestov Institute of Solution Chemistry of Russian Academy of Sciences (ISC RAS), 1 Akademicheskaya st., 153045, Ivanovo, Russian Federation
[b] Kazan Federal University, 18 Kremlyovskaya st., 420008, Kazan, Russian Federation
[c] Kazan State Medical University, 49 Butlerova st., 420012, Kazan, Russian Federation
[d] Scientific Research Institute of Epidemiology and Microbiology, 67 Bolshaya Krasnaya st., 420015, Kazan, Russian Federation
[e] Arbuzov Institute of Organic and Physical Chemistry, FRC Kazan Scientific Center, Russian Academy of Sciences, 8 Arbuzov, 420088, Kazan, Russian Federation

ARTICLE INFO

Keywords:
BODIPY
Fluorescent dyes
Biomarker
Spectral properties
Photostability

ABSTRACT

A fluorescent biomarker based on the boron(III) complex with *meso*-4-methoxycarbonylbutyl-substituted 3,3′,5,5′-tetramethyl-2,2′-dipyrromethene (BODIPY) was synthesized. The BODIPY exhibits a large extinction coefficient (lgε ~4.82–5.00) at 496–501 nm and high fluorescence quantum yield (~77–100 %) in the blue-green region of the spectrum (509–518 nm). The maximal fluorescence quantum yield (φ) is observed in non-polar media (~100 %) while φ slightly decreases to ~90 % in alcohols (with the exception of octanol-1) and to ~77 % in electron-donating dimethyl sulfoxide (DMSO). The BODIPY fluorophore demonstrates high photostability with the half-life of 41.4 and 91 h in toluene and cyclohexane, respectively. The proposed luminophore preferentially stains gram-positive bacteria and can be used for differential staining of gram-positive and gram-negative bacteria in mixed cultures. BODIPY also accumulates in the cytoplasm of the mammalian cells giving polar micro-speckled staining pattern which is more intensive in the tumor cells when compared to the fibroblasts. The pronounced affinity of BODIPY to mitochondria of eukaryotic cells could be used for specific staining of these organelles.

1. Introduction

Over the past few decades, the dipyrromethene borofluoride complexes (BODIPY) family has gained high popularity among chemists, biochemists, and physicists due to a unique set of practically significant properties of BODIPY luminophores [1–5]. These fluorescent compounds are characterized by intense absorption and emission in phototherapy, broadly adjustable quantum yields of luminescence and generation of singlet oxygen, biocompatibility, low toxicity, photo- and thermal stability [6–8].

The most intensively developing areas of the BODIPY applications are biomedical investigations (as fluorescent sensors, switches, probes, markers of biologically active compounds) [9–11] and medicine (as photosensitizers, antibacterial agents) [12,13]. It has been demonstrated in several studies that low-molecular weight, low-polar hydrophobic BODIPY molecules easily penetrate into the lipid layers of cell membranes and bind to hydrophobic parts of proteins [14,15]. These properties of BODIPY luminophores define their wide use for fluorescent staining of cells, organelles and individual biomolecules [16–18] that allows studying in details cells morphology and molecular mechanisms of cell functioning. Thus, BODIPYs have been tested to label various biologically active compounds such as vitamins, steroid hormones, adenosine, etc. [19–21]. Some studies [22–26] have shown the possible use of BODIPYs as fluorescent labels of mammalian lipids, unicellular algae, as well as to track the distribution of lipids in fungal cells. Moreover, BODIPY-based photosensitizers have been shown to be capable selectively inactivate pathogenic microorganisms like *Staphylococcus aureus*, *Escherichia coli*, *Candida albicans* [27,28].

The molecular design capabilities of BODIPY, in particular, the introduction of an alkyl moiety containing reactive terminal groups (carboxyl, ether, etc.) into the *meso*-position of the indacene core increases the lipophilicity of the dye molecule that in turn creates favorable conditions for the dye penetration through the cell membrane and provides covalent binding of the luminophore to biologically active

* Corresponding author.
E-mail address: gbg@isc-ras.ru (G.B. Guseva).

https://doi.org/10.1016/j.jphotochem.2020.112783
Received 8 April 2020; Received in revised form 2 July 2020; Accepted 14 July 2020
Available online 17 July 2020