Pergamon

Tetrahedron Letters 43 (2002) 6457–6459

TETRAHEDRON LETTERS

Towards fluorescence sensing polyamidoamine (PAMAM) dendritic architectures

Samaresh Ghosh and Ajit K. Banthia*

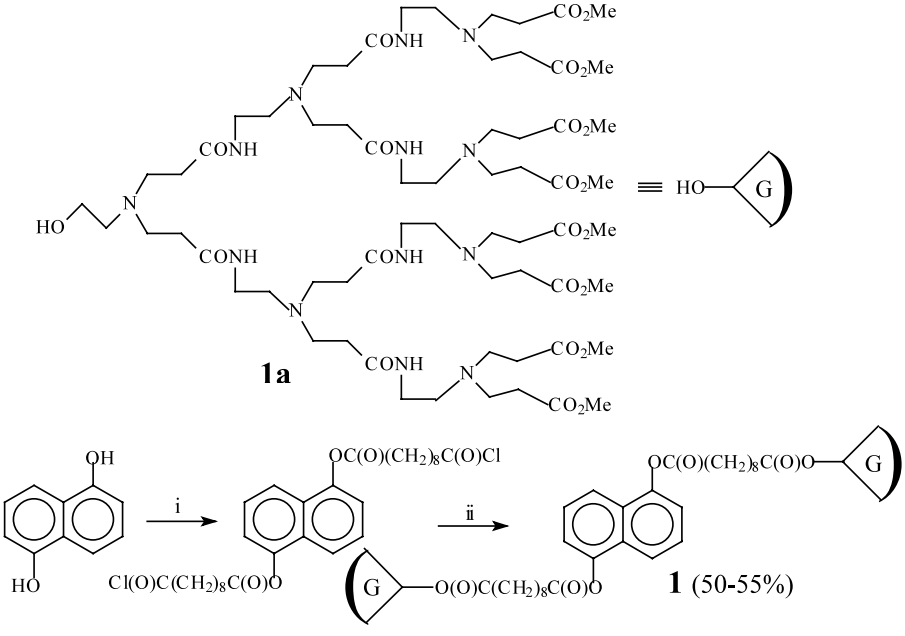
Materials Science Centre, Indian Institute of Technology, Kharagpur 721302, India

Received 22 February 2002; revised 12 June 2002; accepted 28 June 2002

Abstract—A novel polyamidoamine (PAMAM) dendrimer (G2.5) **1** with a naphthalene core unit has been prepared and was found to display acid sensitive fluorescence signal amplification making it of potential use as a pH sensor material.

The ability of certain supramolecular systems to modulate luminescence properties in the presence of other molecules is a key feature associated with a number of processes in chemistry and biology.[1] In this regard, naphthalene systems are fascinating chromophores due to their interesting and potentially useful luminescence characteristics.[2,3] Polyamidoamine (PAMAM) dendritic architectures[4,5] are a specific class of compounds that comprise one of the fastest growing areas of research within the diverse pool of branched polymers because of their novel structural properties and attractive potential applications. In this context, a challenging target is the construction of well-defined fluorescent labeled PAMAM dendrimers possessing fluorophore core units.

We report herein, for the first time, a divergent construction of the novel PAMAM dendrimer (G2.5) **1** possessing a naphthalene core unit together with its



Scheme 1. *Reagents and conditions*: (i) Sebacoyl chloride, CH_2Cl_2, warm, 1 h; (ii) **1a**, CH_2Cl_2, Et_3N, rt, overnight stirring.

Keywords: polyamidoamine; dendrimer; fluorescence.

* Corresponding author. E-mail: abanthia@hotmail.com

0040-4039/02/$ - see front matter
PII: S0040-4039(02)01323-0

fluorescence signaling in response to other molecules (e.g. carboxylic acids). The design is based on our idea that recognition events at the binding sites of the amidoamine moieties of the dendritic branches would be communicated efficiently to the fluorescence properties of the naphthalene moiety.

The synthesis of PAMAM dendrimer **1** was performed utilizing 1,5-dihydroxynaphthalene, sebacoyl chloride and the ester terminated dendritic wedge **1a** according to the Scheme 1. Ester terminated dendritic wedge **1a** was synthesized via Michael addition and exhaustive amidation processes in accordance with our previously reported procedure.[4b] Dendrimer **1**, isolated in 50–55% yield, was gummy in nature and very soluble in halogenated organic solvents such as $CHCl_3$, CH_2Cl_2 etc. The PAMAM dendrimer **1** gave satisfactory elemental analysis and had spectroscopic data (FT-IR, ^1H and ^{13}C NMR)[6] consistent with its structure. The dendrimer **1** exhibits broad, red-shifted absorption bands in its UV spectrum ([**1**] = 1.92×10^{-5} M, λ_{max} = 240 and 280 nm) which changes with solvent polarity ($CHCl_3$, CH_3CN, CH_3OH) (Fig. 1: inset) and exhibits naphthalene fluorescence at λ_{max} 350–357 nm as well as a broad band at λ_{max} 425–450 nm which is typical of excimer fluorescence. The relative intensity of the monomer and excimer emission bands was dependent on solvent polarity, indicating intermolecular excimer formation. However, system **1** shows strong fluorescence in $CHCl_3$ at 27°C ([**1**] = 1.92×10^{-5} M, λ_{exc} 280 nm), the intensity of which gradually decreases on successive addition of AcOH (up to 0.058 M) and TFA (up to 0.021 M) as evidenced in Figs. 2 and 3. The observed quenching of the naphthalene emission upon the addition of TFA/AcOH is probably associated with intimate interactions of the naphthalene excited state with the amide and ester subunits as well as the carboxylate counter anions[7] originating from quaternization of the amine subunits. However, with addition of TFA, the fluorescence quenching became much more efficient as is evidenced in Fig. 4, indicating better complexation (e.g. H-bonding) as well as protonation of the amine, amide and ester subunits of **1**. The corresponding hyperchromic shift as well as the appearance of a broad band centered at 350 nm in the UV–vis spectra (inset of Figs. 2 and 3), upon addition of TFA/AcOH, supported the close interaction events between the carboxylic acid bound dendritic sectors with the naphthalene core in the ground state. The Stern–Volmer plot (Fig. 4) showed stronger quenching with TFA than AcOH demonstrating the better chemosensitivity of **1** for TFA. The complexation behavior of **1** with AcOH/TFA was further confirmed by ^1H NMR spectroscopy. On addition of the strong acid, TFA, to the $CDCl_3$ solution of **1**, facile protonation of the tertiary nitrogens occurs as is evidenced by the appearance of protonated ammonium groups at δ 7.5 ppm. Furthermore, the significant

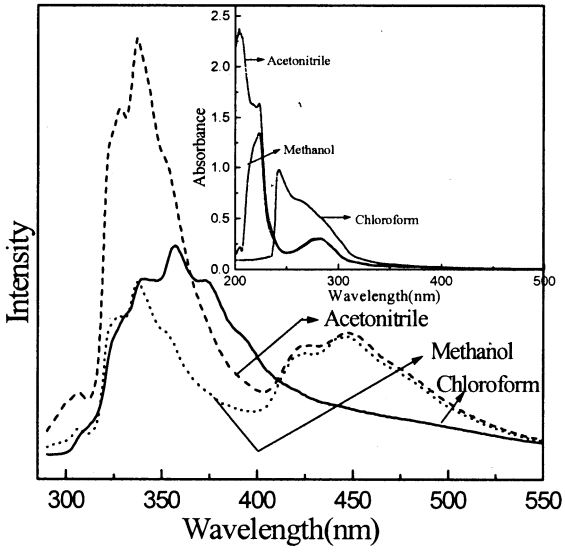


Figure 1. Fluorescence spectra of **1** in different solvents; λ_{exc} = 280 nm. Inset: Corresponding UV–vis spectra of **1**.

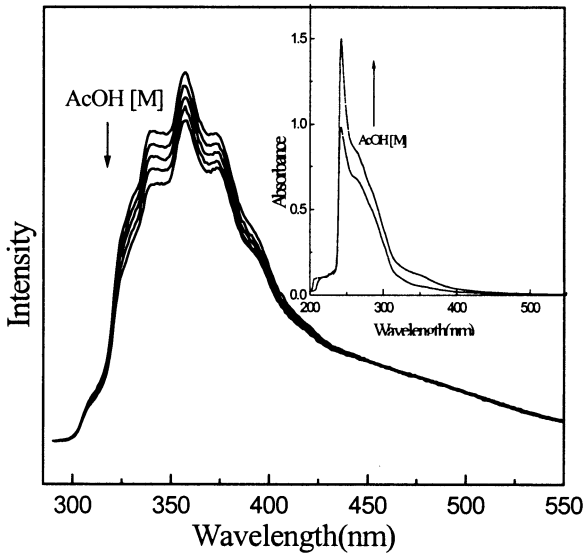


Figure 2. Fluorescence spectra of **1** (1.92×10^{-5} M) in $CHCl_3$ (λ_{exc} = 280 nm) upon addition of AcOH. Inset: Change of UV–vis spectra of **1** upon addition of AcOH.

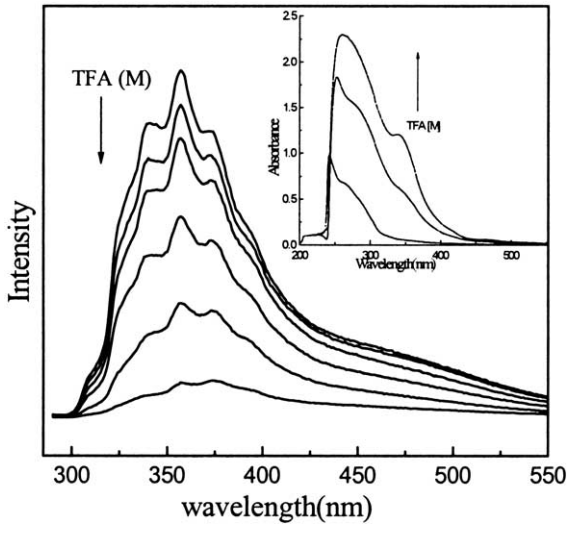


Figure 3. Fluorescence spectra of **1** (1.92×10^{-5} M) in $CHCl_3$ (λ_{exc} = 280 nm) upon addition of TFA. Inset: Change of UV–vis spectra of **1** upon addition of TFA.

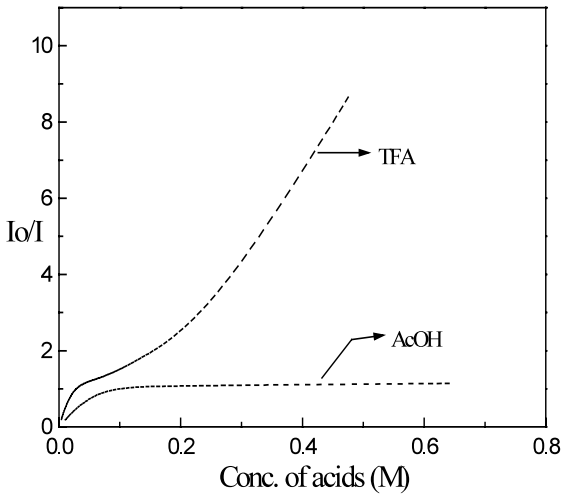


Figure 4. Stern–Volmer plot of I_0/I versus conc. of acids (M).

broadening of the dendritic CONHC$\underline{H}_2$ protons at δ 3.30 and the moderate downfield shift of the methyl ester protons (from δ 3.66 to δ 3.70, $\Delta\delta = 0.04$ ppm) were also observed, which is indicative of complexation of **1** with TFA. Similar, albeit weak complexation events were also noticed for AcOH but no signal due to ammonium groups was evident in the region δ 7.5–7.3 ppm suggesting its inability to quaternize 3° nitrogens. Therefore, the trifluoroacetate counterions originated from the quarternization on TFA addition probably play an additional role for significant fluorescent quenching and thus **1** exhibits better chemosensitivity toward TFA.

In conclusion, we have demonstrated that the dendritic scaffold **1** represents a simple, easy to make member of a hitherto unexplored class of luminescent supramolecular chemosensors of acids that exhibits greater sensitivity towards TFA in comparison to AcOH. Owing to the anticipated transduction of recognition events based on the complexation of acids with dendritic functional subunits into a fluorescence signal, the placing of other fluorophore units at the core of this PAMAM dendritic system **1** will represent a fascinating challenge. The design and synthesis of more elaborate PAMAM dendritic systems incorporating other fluorophore core units and subsequent investigation of their fluorescence signaling events are in progress.

References

1. Sakamoto, M.; Ueno, A.; Mihara, H. *Chem. Commun.* **2000**, 1741–1742.
2. (a) Kubo, Y.; Tsukahara, M.; Ishihara, S.; Tokita, S. *Chem. Commun.* **2000**, 653–654; (b) Nelissen, H. F. M.; Venema, F.; Uittenbogaard, R. M.; Feiters, M. C.; Nolte, R. J. M. *J. Chem. Soc., Perkin Trans. 2* **1997**, 2045.
3. (a) Ikeda, H.; Nakamura, M.; Ise, N.; Oguma, N.; Nakamura, A.; Ikeda, T.; Toda, F.; Ueno, A. *J. Am. Chem. Soc.* **1996**, *118*, 980; (b) Cardona, C. M.; Alvarez, J.; Kaifer, A. E.; McCarley, T. D.; Pandey, S.; Baker, G. A.; Bonzagni, N. J.; Bright, F. V. *J. Am. Chem. Soc.* **2000**, *122*, 6139–6144.
4. (a) Tomalia, D. A.; Naylor, A. M.; Goddard, W. A. *Angew. Chem., Int. Ed. Engl.* **1990**, *29*, 138–175; (b) Ghosh, S.; Banthia, A. K. *Tetrahedron Lett.* **2001**, *501*–, 503.
5. Pistolis, G.; Malliaris, A.; Tsiouravas, D.; Paleos, C. *Chem. Eur. J.* **1999**, *5*, 1440–1444.
6. Selected data for dendrimer **1**: Purified through column chromatography (eluent, $CHCl_3$: MeOH (5:1)). FT-IR (KBr): 3387 (-NH), 2940, 2861 (-CH_2-, -CH_3), 1734 (ester C=O), 1657 (amide-I, aryl C=C, aryl CH), 1550 (amide-II), 1544, 1209 (CO-O-C), 1051 (CO-O-C), 900 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$) δ: 7.75 (d, $J = 8$ Hz, 2H), 7.45 (t, $J = 8$ Hz, 2H), 7.27 (d, $J = 8$ Hz, 2H), 3.66 (bs, 52H, -$CO_2C\underline{H}_3$, -$COOC\underline{H}_2CH_2N$-), 3.29 (bs, 24H, -$CONHC\underline{H}_2$-), 2.29–2.74 (bm, all other dendritic CH_2, -$OCOC\underline{H}_2(CH_2)_6$-$C\underline{H}_2COO$- of sebacoic acid, 148H), 1.6 (bm, 8H, naph-$OCOCH_2C\underline{H}_2(CH_2)_4C\underline{H}_2CH_2COO$-), 1.24–1.29 (bm, 16H, naph-$OCO(CH_2)_2(C\underline{H}_2)_4$-); ^{13}C NMR (50 MHz, $CDCl_3$) δ: 173.0, 172.0 (-$\underline{C}OOCH_3$, -$\underline{C}OOCH_2$-, naph-O$\underline{C}OCH_2$), 146.6, 128.1, 125.9, 119.0, 118.6, 52.8, 51.6, 51.3, 50.2–49.1 (broad and unresolved), 37.0, 34.3, 34.0, 33.0–32.6 (unresolved), 29.0, 24.9, 24.8. Anal. calcd for $C_{158}H_{266}N_{26}O_{52}$; C, 56.46; H, 7.92; N, 10.83; Found: C, 56.24; H, 7.64; N, 9.07%.
7. Caminati, G.; Turro, N. J.; Tomalia, D. A. *J. Am. Chem. Soc.* **1990**, *112*, 8515–8522.