

## Characterisation of Aromatic Polyester Dendrimers by Matrix-assisted Laser Desorption Ionisation Mass Spectrometry

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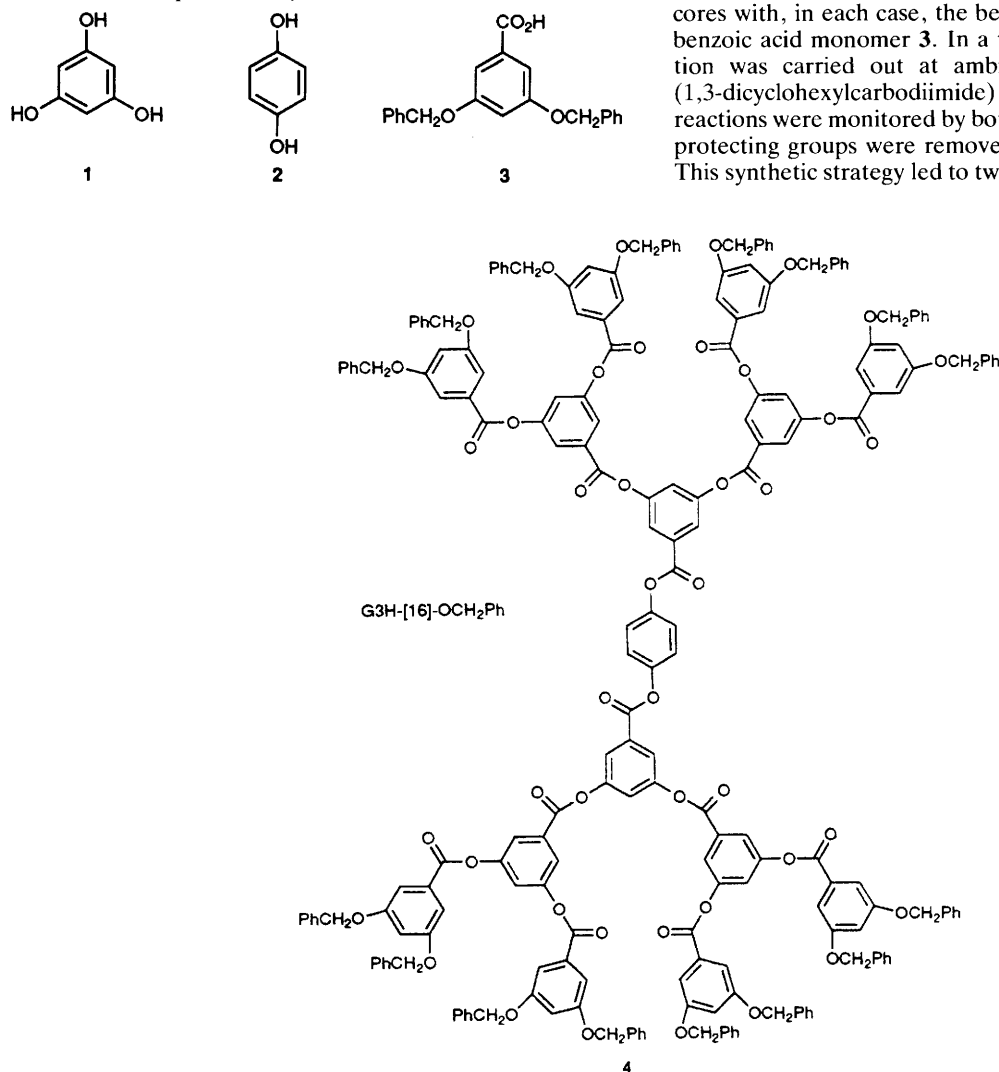
The relative molecular masses of aromatic polyester dendrimers are measured by matrix-assisted laser desorption ionisation (MALDI) mass spectrometry.

The synthesis of dendrimers is receiving world-wide attention in both academic and industrial laboratories.<sup>1</sup> Synthetic strategies using both convergent and divergent methodology are becoming increasingly sophisticated, producing an impressive variety of molecular structures.<sup>2</sup> The synthetic chemist requires a rigorous analytical method to test his skills. The unusual nature of dendritic macromolecules has, however, presented difficulties, especially with regards to accurate mass determination.

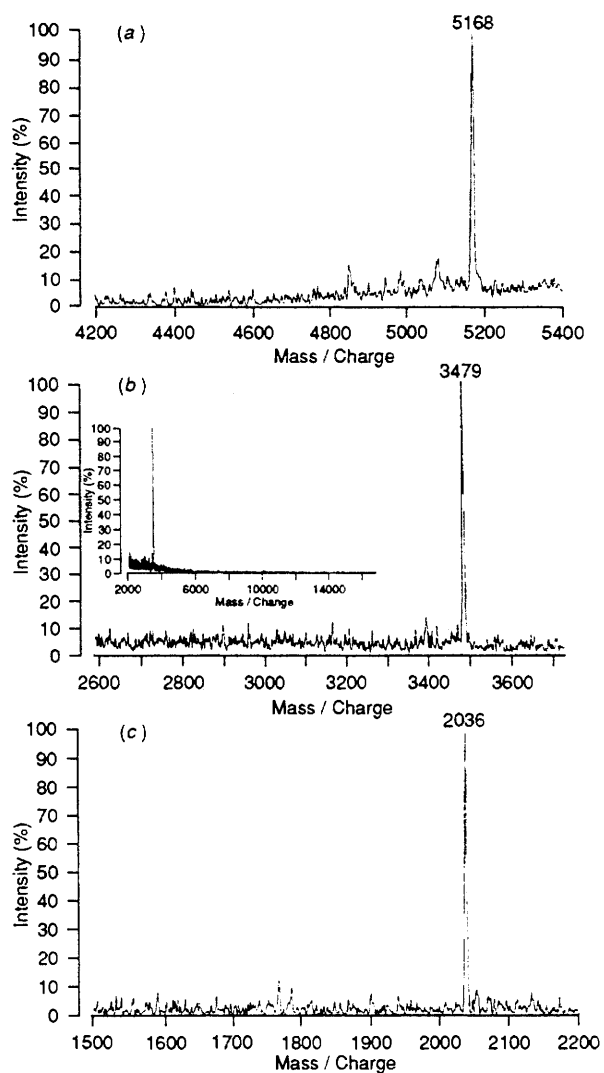
It is often difficult to distinguish by NMR between perfect dendrimers and those possessing a small degree of defects, and the molecular masses of all but the lowest generations are too high for conventional mass spectrometry. Gel permeation chromatography (GPC) is routinely used but it has been demonstrated that, even with the application of the universal calibration principle or LALLS (low angle laser light scattering), detection errors as much as 30% can arise.<sup>3</sup> Electrospray ionisation mass spectrometry has been utilised to achieve

excellent values for molecular ions, but the nature of the technique produces a multi-lined spectrum which cannot easily be used for analytical purposes.<sup>4</sup> Moore, Wilkins *et al.* have recently reported the use of both Fourier transform laser desorption and MALDI time-of-flight mass spectrometry for the characterisation of phenylacetylene dendrimers.<sup>5</sup> The presence of dendrimer dimer and trimer species in the MALDI spectra was, however, a problem, and the spectrum presented has a relatively very poor signal-to-noise ratio. Here we report on the use of matrix-assisted laser desorption ionisation time-of-flight mass spectroscopy (MALDI-TOF-MS), a technique which is becoming of increasing importance for synthetic polymer chemistry,<sup>6</sup> for the mass determination of aromatic polyester dendrimers as a routine rigorous test of synthetic methodology.

Two series of aromatic polyester dendrimers were synthesised by the divergent strategy from one or the other of the trifunctional phloroglucinol **1** and hydroquinone **2** central cores with, in each case, the benzyl protected 3,5-dihydroxybenzoic acid monomer **3**. In a typical experiment, esterification was carried out at ambient temperature with DCC (1,3-dicyclohexylcarbodiimide) as an esterification agent. The reactions were monitored by both NMR and GPC. The benzyl protecting groups were removed by catalytic hydrogenation. This synthetic strategy led to two families of dendrimers, both



containing two different surface functionalities benzylic ether (as in **4**) and hydroxy. Our nomenclature gives the dendrimer generation (G1, G2, etc.) followed by a letter denoting the nature of the core (P = phloroglucinol; H = hydroquinone), a number in square brackets giving the number of surface



**Fig. 1** MALDI-MS of selected dendrimers: (a) G3P-[24]-OCH<sub>2</sub>Ph, (b) G3H-[16]-OCH<sub>2</sub>Ph, inset shows the high mass region with absence of dimer, trimer, etc., and (c) G3H-[16]-OH

**Table 1** Molecular mass data for dendrimers<sup>a</sup>

Dendrimer	Calc. RMM	MALDI-MS	Mn (GPC)	PDI (GPC)
G1P-[6]-OCH <sub>2</sub> Ph	1074	1075	1200	1.001
G1P-[6]-OH	534	533	900	1.007
G2P-[12]-OCH <sub>2</sub> Ph	2433	2431	2600	1.006
G2P-[12]-OH	1350	1351	2400	1.007
G3P-[24]-OCH <sub>2</sub> Ph	5147	5147	4400	1.008
G3P-[24]-OH	2984	2983	2700	1.017
G1H-[4]-OCH <sub>2</sub> Ph	742	742	900	1.009
G1H-[4]-OH	382	382	700	1.013
G2H-[8]-OCH <sub>2</sub> Ph	1646	1647	2300	1.005
G2H-[8]-OH	926	926	1900	1.006
G3H-[16]-CH <sub>2</sub> Ph	3455	3455	4300	1.005
G3H-[16]-OH	2014	2015		

<sup>a</sup> GPC relative to P(MMA) narrow molecular mass standards in thf at 1 ml min<sup>-1</sup>, using one Polymer Labs mixed E column and refractive index detection. Calculated and MS molecular masses to the nearest amu.

functional groups and finally the nature of the surface functionality. Generation three from **2** G3H-[16]-OCH<sub>2</sub>Ph with benzylic functionality is shown as **4**.

The molecular masses of the dendrimers have been measured by GPC relative to poly(methylmethacrylate) (PMMA) narrow molecular mass standards (Table 1). Although we observe quite good agreement with the calculated mass for the benzylic ether dendrimers, we observed large deviations for the hydroxy functional dendrimers. MALDI-MS was carried out on a Kratos Kompact III spectrometer in the reflection mode, operating with irradiation from a nitrogen laser at 337 nm. Samples were prepared by first laying down 0.5 μl of a 10<sup>-1</sup> mol dm<sup>-3</sup> solution of 2,5-dihydroxybenzoic acid in 50% water-50% acetone, followed by 0.5 μl of a 10<sup>-3</sup> mol dm<sup>-3</sup> solution of analyte in either a water-acetone or chloroform solvent. Spectra were averaged over 200 laser pulses whilst scanning across the sample. Samples were doped with sufficient sodium chloride so as to simplify the spectra by suppression of other residual cations, e.g. K<sup>+</sup>, and hence molecular ions were observed at 23 mass units above the molecular mass of the analyte due to the addition of Na<sup>+</sup>.

Molecular mass data for all dendrimers synthesised is reported in Table 1. GPC is extremely useful for monitoring the reaction, but is prone to significant errors. This is especially true for hydroxy functional dendrimers and is ascribed to interactions between these polar molecules and the column. The polydispersity index (PDI) is indicative of a monodisperse product, and any imperfections in the synthesis would be easily seen. In all cases MALDI-MS gives the molecular mass to within one amu of that calculated, with peak half-widths of between 4 and 8 amu. Figs. 1(a)-(c) show the quality of the spectra achieved with excellent signal-to-noise ratios. The spectra show that the synthetic method has been successful for both series of dendrimers reported.

In conclusion, we have demonstrated that accurate mass data for a series of both hydrophilic and hydrophobic dendrimers can be easily obtained by MALDI-MS. We see no evidence for dimer and trimer formation either in the synthesis or within the mass spectrometer. This is the only method to date that can be used to routinely test synthetic methodology for these unusual geometry, monodisperse high molecular mass compounds.

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