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for the preparation of γ-ketoesters as an alternative to the method of Wacker oxidation,[7] since this new isomerization reaction of epoxides to methyl ketones is highly regioselective[4] and simple in experimental procedure.[8]

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4. No aldehydes isomeric to the isolated methyl ketones was detected in the crude reaction products by ^{1}H NMR spectroscopy.
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8. The presence of potassium hydrogen difluoride (KHF$_2$) is essential for the isomerization. When the reaction was carried out in the absence of KHF$_2$, no reaction occured.

Synthesis of Partially Deuterated Porphyrins

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The convenience of functionalization and the wealth of available meso-substituents make the meso-porphyrins ideally suited for use in various model systems.[1,2] Although porphyrin is easily obtainable in a facile manner from pyrroles

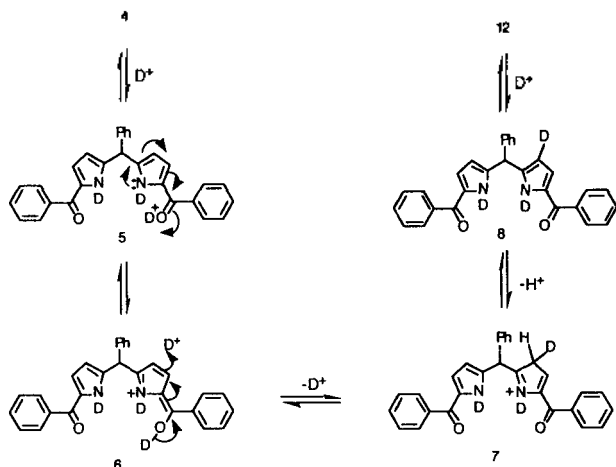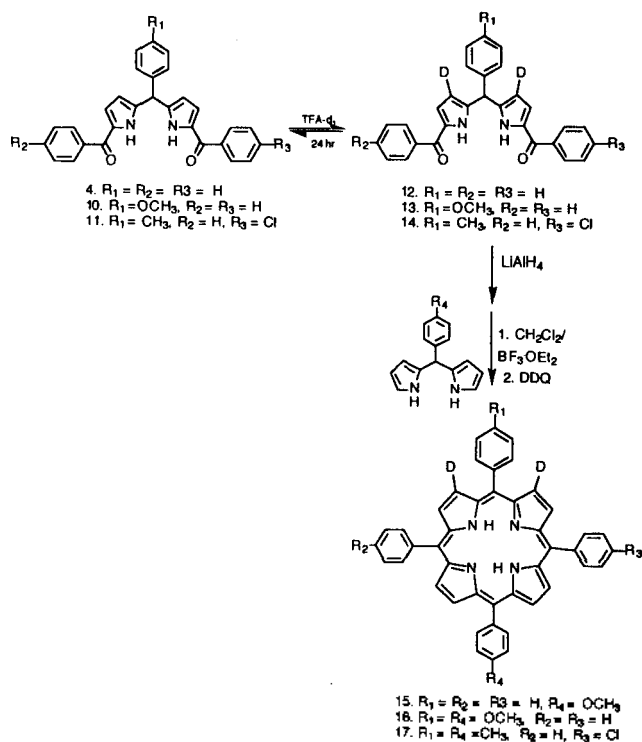R$_1$ = H, CH$_3$, OMe,   R$_2$ = H, Cl, CH$_3$
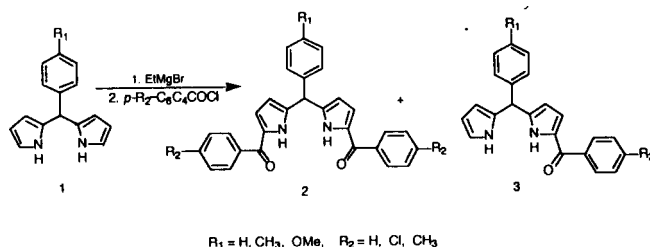
Scheme 1.

and aldehydes, generic methods are still limited to symmetric porphyrins because of the isomeric porphyrin formation and consequent difficulties in separation and identification. A major limitation in the synthesis of isotopically labeled porphyrins is the construction of building subunits affording porphyrins by condensation. Thus methods for the synthesis of those subunit still leave much to be desired at least in creating sophisticated models of porphyrin-based enzymes. The existing synthetic routes are mainly the condensation of an aldehyde with pyrrole or pyrromethanes.[3,4] In the case of the porphyrins bearing two different types of meso-substituents, the synthesis can be achieved by a binary mixed aldehyde condensation and separation of mixture resulting from the condensation.[6]

A synthesis of porphyrins bearing deuterium specifically at β-pyrrolic position has not investigated well. Major difficulties in the synthesis are the problems associated with construction of the dipyrromethane components with partial deuteration. The great potentials of deuterated porphyrins in various model system led us to pursue an efficient synthesis of partially deuterated porphyrins.[7] Spectroscopic studies of porphyrins usually require deuterated porphyrins.[8] Simple meso-tetraarylporphyrins with β-pyrrolic deuteration are readily available from the condensation of aldehydes and pyrrole-d$_5$. But this method is not applicable to porphyrins with partial deuteration at β-pyrrolic position. Our current studies, we report an efficient synthesis of partially deuterated porphyrins by 2+2 condensation.

As shown in Scheme 1, the success of the synthesis solely relys on the facile construction of dipyrromethanes **1** and their acylation to 1,9-substituted dipyrromethanes **2**. Pyrrole generally undergoes electrophilic aromatic substitution easily, but α,α'-functionalization with acyl units cannot be achieved in a direct manner. But an α-substituted pyrrole can be acylated at the α'-position as long as the α-substituent is not electron-withdrawing. We recently reported one-flask synthesis of 1,9-unsubstituted, meso-substituted dipyrromethanes. The BF$_3$ or trifluoroacetic acid-catalyzed condensation of an aldehyde dissolved in 40 times excess pyrrole affords the meso-substituted dipyrromethanes in high yields depending on the nature of aldehydes. The selective introduction of acyl group at 1,9-position of dipyrromethanes was possible by utilizing ethyl magnesium bromide and acid chlorides.[9,10] Meso-aryldipyrromethanes **2** were treated with 2.2 equivalent of ethyl magnesium bromide in THF at room temperature and resulting dipyrromethane-Grignard reagent was treated with 1.4 equivalent of appropriate acyl chlorides. The reaction gave a mixture of the mono-acylated **3** in 21-34% and bis-acylated **2** in 18-48% after chromatographic separation. Another key step in this synthesis is the regioselective pro-

Scheme 2.

4. R₁ = R₂ = R3 = H
10. R₁ =OCH₃, R₂= R₃ = H
11. R₁ = CH₃, R₂ = H, R₃ = Cl

12. R₁ = R₂ = R3 = H
13. R₁ =OCH₃, R₂= R₃ = H
14. R₁ = CH₃, R₂= H, R₃ = Cl

15. R₁ = R₂ = R3 = H, R₄ = OCH₃
16. R₁ = R₄ = OCH₃, R₂= R₃ = H
17. R₁ = R₄ =CH₃, R₂ = H, R₃ = Cl

Scheme 3.

ton-deuterium exchange of compounds **4, 10** or **11** upon exposure to acidic condition. Treatment of **4, 10** or **11** with 15-20 equivalent of CF_3COOD in CD_2Cl_2 (or $CDCl_3$) led to exchange of the 3,7-protons and N-H protons selectively over 24 hr period. We found that 85% of protons are exchanged with deuterium in 24 hr period. This observation is based on the proton NMR spectra. The selective exchange is easily identified by proton NMR. Both β-positions in pyrrole are equally reactive toward exchange, but in the 1,9-bisacylated dipyrromethane the presence of acyl groups causes exchange to occur exclusively at the 3,7-positions. A proposed exchange mechanism is shown in Scheme 2.

The exchange process can be explained involving protonation and enolization (**5→6**). The γ to the carbonyl is deutera-

ted first and α,β-unsaturated carbonyls lead to net exchange at the γ-position. The deuterated **12** can be isolated and re-protonated upon exposure to CF_3COOH. The positional regiochemistry of exchange also was verified by NOE experiment.[9]

The dueterated porphyrin was synthesized by employing Lindsey condition.[11] as shown in Scheme 3. 3,7-Deuterated bisacyl compounds **12-14** were quantitatively reduced to corresponding diols with $LiAlH_4$ in THF and the condensation of 12-diol, 13-diol or 14-diol with 1,9-unsubstituted dipyrromethanes afforded porphyrins **15-17**. The yields of each porphyrins were; 5.3% (**15**), 5.1% (**16**) and 3.6% (**17**). The reaction were not optimized. The proton NMR spectrum of the porphyrins **15-17** clearly show exchange in the β-pyrrolic region. The integration of the β-pyrrolic region was 75-80% of the unexchanged. Mass spectral analysis also showed molecular ion peak corresponding to two deuterium substitution.[11]

In conclusion, partially deuterated porphyrins at β-pyrrolic carbon with two or three different meso-substituents have been synthesized regioselectively. The synthesis utilizes the condensation of 3,7-dideuterated-1,9-bisacylated dipyrromethanes and 1,9-unsubstituted dipyrromethanes. This synthetic methodology will have variety of utilities in conjunction with a synthetic method toward isotopically labeled porphyrins. In order to establish their generality and exploit them for the preparation of deuterated porphyrin building blocks, wide applicable approaches are under investigation.

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11. ¹H NMR (CDCl₃) 15; δ 8.87 (m, 6H, β-pyrrolic-H), 8.22 (m, 4H, ArH), 7.75 (m, 15H, ArH), 4.11 (s, 3H, -OCH₃),

−2.77 (s, 2H, N-H), LD-MS Calcd. for $C_{45}H_{29}N_4OD_2$ 645. 75, Found 645.8 (M⁺). 16; δ 8.90-8.82 (m, 7H, β-pyrrolic-H), 8.24-8.20 (m, 4H, Ph(o)-H), 7.78-7.74 (m, 6H, Ph(m,p)-H), 8.21 and 7.27 (AA'BB', 4H, Ar-H), 4.10 (s, 6H, -OCH₃). LD-MS Calcd for $C_{46}H_{32}N_4O_2D_2$ 676.79, Found 676.8 (M⁺). 17; δ 8.90-8.79 (m, 6H, β-pyrrolic-H), 8.23-8.08, 7.78-7.55 (m, 17H, Ar-H), 2.71 (s, 6H, -CH₃). LD-MS calcd for $C_{46}H_{31}N_4ClD_2$ 678.26, Found 678.37 (M⁻).

Electric Field Dependence of Thermal and Mass Diffusion of Methyl Red Doped in MBBA Studied by Transient Grating Method

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Properties of rod-shaped molecules forming liquid crystalline phases are greatly affected by electric field due to relatively large polarizabilities.[1] A lot of theoretical and experimental studies have been carried out to investigate deformations of liquid crystal structures occurring above a critical electric field, so called Freedericksz effect. Detailed understanding of the electric field effect on the dynamics of liquid crystalline molecules is important in both basic scientific and practical views since most liquid crystal devices are operated under electric field. Thermal diffusivity and diffusion coefficient are relevant parameters in studies of liquid crystalline molecules. When two coherent laser pulses are overlapped spatially and temporally, spatial modulation of refractive index formed by the interference of electric field can diffract a probe beam like a transmission grating.[2] As the interference pattern disappears rapidly through various relaxation mechanisms, it is called transient grating (TG). The fringe spacing, d depends on the wavelength of the excitation laser, λ and the crossing angle of the excitation beams, θ by the relation, $d=(\lambda/2)\sin(\theta/2)$. Since the fringe spacing is in the range of 10^0-10^1 μm, TG method can be used to study many dynamic phenomena in microscopic scale including the dynamics of liquid crystalline molecules.[3]

We report preliminary results of the electric field effect on the TG decay for methyl red (MR) doped in N-(4-methoxybenzylidene)-4-butylaniline (MBBA). The reagents from Aldrich are used without further purification. MBBA forms nematic phase between 22 and 42 ℃. The full description of the setup for TG experiment will be given in a shortly-coming paper.[4] Briefly, the second harmonic (532 nm) of Q-switched Nd : Yag laser, operated at 0.2-1 Hz, is used as
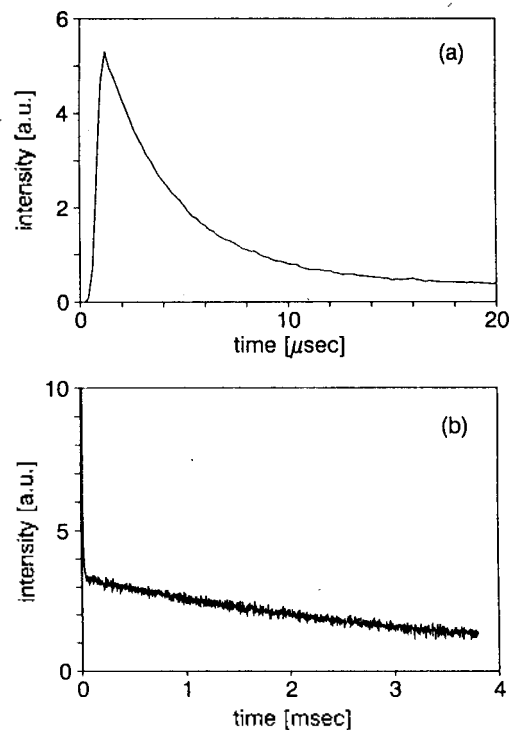

Figure 1. Decay of TG signal of MR in MBBA at 45 ℃. The fringe spacing is 4.17 μm. Biexponential decay of largely different time constants is observed. The repetition rate of the laser pulse is 1 Hz and the average of 100 data is plotted. (a) Fast component of decay due to thermal diffusion, $\tau=7.1$ μsec. (b) Slow component of decay due to mass diffusion, $\tau=6.6$ μsec. Figure 1(a) corresponds to the early part of Figure 1(b).

the excitation pulse and the decay of TG is probed by 5 mW cw He-Ne laser. For the studies of liquid crystal molecules which have no absorption in the visible region, dye molecules are usually doped for the application of optical methods.[5] The sample cell made of sandwiched ITO glass has a thickness of 200 μm when a teflon tape is used as a spacer. The optical density of MR is about one when the concentration of the sample is about 10^{-4} M. Cell temperature is maintained by keeping the cell in a water circulating copper block.

Figure 1 shows the TG decay at 45 ℃ when the electric field is not applied. As the sample temperature is higher than transition temperature (nematic to isotropic) of MBBA, anisotropy of the matrix is not considered here. Biexponential decay of largely different time constants is observed and time constants of fast and slow components are 7.1 μsec and 6.6 msec, respectively. Photophysics and photochemistry of MR, which have been investigated in various media,[6] suggest that main relaxation mechanisms of TG induced by nsec laser pulses are thermal relaxation and mass diffusion of photoactivated MR.[7] Non-radiative decay of MR and intermolecular energy transfer to give local heating along the fringe pattern are very fast compared with the width of the employed laser pulse (~10 nsec). The fast component of the decay is due to relaxation of temperature gradient of the MBBA matrix. As the time constant for the isomerization of the photoexcited cis-MR into trans form in MBBA[8] is very