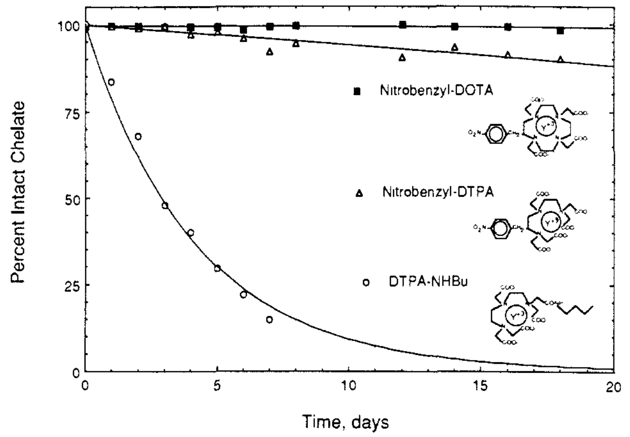

Figure 2. Loss of yttrium from metal chelates in serum. Data shown are the average of two independent experiments. In each case, the total ligand concentration was 10^{-7} M, while the total yttrium concentration was approximately 10^{-11} M. Serum was maintained sterile at 37 °C, pH 7.4, in an air/CO_2 atmosphere (approximately 95/5 by volume).

desired cyclization is a common problem; our efforts to form a 12-membered macrocycle with a *p*-nitrobenzyl sidechain by bimolecular cyclizations[10c,k] gave unsatisfactory yields.

We have developed a new synthetic route to these macrocycles via peptide synthesis and *intra*molecular tosylamide ring closure. For polyazamacrocycles with nitrogens separated by two-carbon chains, peptides made from α-amino acids are readily accessible starting materials.[11] Treatment with borane converts peptides to linear polyamino alcohols, in which the original peptide backbone has been converted to a C-terminal alcohol, an N-terminal primary amine, and internal secondary amines (Figure 1, step a).[12] Treatment with *p*-toluenesulfonyl chloride produces a C-terminal tosyl ester, an N-terminal secondary tosylamide, and internal tertiary tosylamides (Figure 1, step b). Treatment with mild base converts the N-terminal tosylamide to a nucleophile, which displaces the C-terminal tosyl ester and thus forms a macrocyclic ring in high yield (Figure 1, step c). This intramolecular cyclization may be performed in very dilute solution, eliminating concerns about polymer formation.

The inclusion of peptide synthesis allows one to vary sidechains on the ring conveniently by selecting the appropriate amino acids as building blocks. Loss of entantiomeric purity is unlikely under the reaction conditions involved.[10g] Amino acids such as glycine, β-alanine, and γ-aminobutyric acid are potential sources of 2-, 3-, and 4-carbon chains between the nitrogens in the macrocycle.

Synthesis of the title compound **1** is illustrated in Figure 1. The ^{88}Y(III) complex of octadentate ligand **1** (7 mM) forms in a few hours at room temperature in 0.1 M ammonium acetate, pH 5. Under the same conditions, the ^{88}Y(III) complexes of 14-membered nitrobenzyl-TETA or 16-membered nitrobenzyl-HETA[13] do not form in significant yields.

The stability of a metal complex under physiological conditions may be assessed by dissolving the complex at high dilution in sterile human serum at 37 °C, pH 7.4, and measuring the rate of transfer of the metal from the complex to serum proteins over the course of several days.[14] A comparison of Y(III) complexes of **1** and other ligands which have recently been reported to form complexes with Y(III) or In(III) appropriate for use in living systems[15,16] is shown in Figure 2. At 10^{-7} M, the noncyclic octadentate ligand 1-(*p*-nitrobenzyl)diethylenetriaminepentaacetate loses Y(III) with a pseudo-first-order rate constant $k = 0.006$ day^{-1}. An analogue of the ligand formed by reaction of DTPA cyclic anhydride with a lysine residue, ^{88}yttrium diethylenetriaminepentaacetate–monobutylamide, loses Y(III) 45 times faster, having $k = 0.27$ day^{-1}. Incubation of the ^{88}Y(III) complex of **1** for 18 days results in loss of so little Y(III) from the complex—less than 0.5%—that the rate of loss cannot be measured under these conditions. This remarkable stability appears to be superior to a number of metal chelates now being tested in living systems.[14-17] Further progress in this area depends on such stability.

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Supplementary Material Available: Experimental details for the synthesis of the title compound **1** and yttrium complex studies in serum (3 pages). Ordering information is given on any current masthead page.

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Highly Sensitive Flash Photolysis with Optical Waveguides: Photodeposition of Ag onto Particulate TiO_2 from Solution

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Typical difficulties in the optical monitoring of photoreactions taking place at semiconductor surfaces are as follows: small optical density changes at flat surfaces and large light scattering in opaque particulate systems. In order to overcome these difficulties, we introduced optical waveguides (OWG's) and carried out flash photolysis measurements on OWG systems for the first time.[1]

It is well known that Ag^+ ions deposit onto TiO_2 surfaces in a metal form under UV illumination.[2] Since the deposited metallic Ag absorbs visible light, the deposition process can be monitored optically. Thus, photodeposition of Ag^+ from aqueous solution onto particulate TiO_2 was used here as a model system.

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(1) A part of this work was presented at the 195th American Chemical Society Meeting at Toronto, Canada, 1988.

(2) For example: Nishimoto, S.; Ohtani, B.; Kajiwara, H.; Kagiya, T. *J. Chem. Soc., Faraday Trans. 1* **1983**, *79*, 2685. Baba, R.; Konda, R.; Fujishima, A.; Honda, K. *Chem. Lett.* **1986**, 1307.

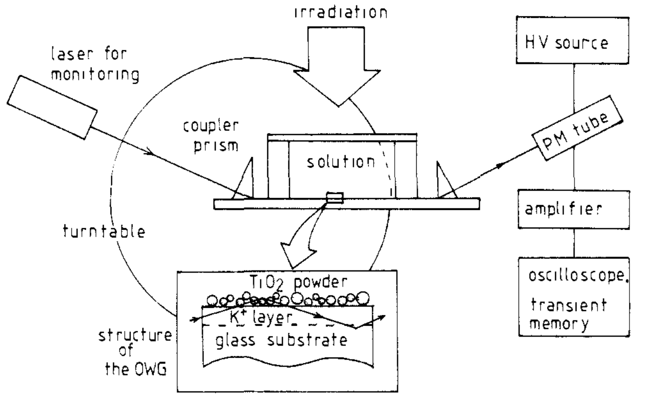

Figure 1. A glass OWG covered with particulate TiO_2 and a schematic drawing of the measurement system.

A wave of light is confined in such a small region of OWG surfaces that surface chemical species located at the surface of the OWG experience extremely high electric field. Thus, the OWG's significantly enhance the sensitivity of the optical measurement. For instance, Swalen et al.,[3] measured optical absorbances of Langmuir–Blodgett films sandwiched by a glass substrate and a polymer waveguide layer. They have shown that the sensitivity of the OWG method in this configuration may increase to 10^4 times that of conventional absorption measurements.[3] Ho et al.,[4] observed coherent anti-Stokes Raman scattering of oxygen adsorbed onto ZnO waveguides. Although well-established OWG systems were employed in these studies, we constructed special types of OWG's for our surface photochemical measurements.

We have prepared OWG's with a structure shown in Figure 1. A glass OWG was made by immersing a glass plate into molten KNO_3 for 0.5–4 h. Its surface was made in contact with a suspension of TiO_2 (Japan Aerosil p-25), then the suspension was removed after several minutes, and finally the OWG surface was washed with water. Thus, only adsorbed TiO_2 remained on the OWG surface. Incoupling and outcouplng of a monitoring laser beam (He–Ne laser, wavelength = 633 nm) with the OWG were made by using two glass prisms and a matching liquid. Basic characteristics of the OWG, e.g., the number of modes and relative mode intensity, were not affected by the adsorption of the TiO_2 powder, but the monitoring beam was considerably scattered by the adsorbed TiO_2 powder. As a result, a trace of the monitoring beam was clearly seen at the OWG surface. However, the magnitude of attenuation of the monitoring beam was small enough (< 2 dB/cm) when the OWG was in contact with a solution. The sensitivity of this OWG system was estimated by using the adsorption of a dye (methylene-blue). The sensitivity was found >100 times that of conventional absorption spectral measurements.

The OWG was mounted on a turntable as shown in Figure 1 and was made in contact with an aqueous solution of $AgNO_3$ in a solution reservoir (optical path length = 3 cm). The TiO_2 powder on the OWG was irradiated with a N_2 laser (wavelength = 337 nm, pulse width = 5 ns) or a high pressure Hg lamp (100 W) from the rear side. Irradiation with the Hg lamp for 1 s gave a large decrease in the intensity of the guided light (I_{OWG}) as shown in Figure 2. I_{OWG} decreased to almost zero after an irradiation period of 10 s, and the surface of the OWG became brown. The surface of the glass OWG itself was not colored; this was confirmed by removing the colored TiO_2 powder from the glass OWG with tissue paper. It should be noted that I_{OWG} decreased but slowly (40% in 1 min) under continuous irradiation when the solution did not contain Ag^+. Moreover, in this case, I_{OWG} slowly increased and recovered the initial value after the irradiation was stopped. Thus, the attenuation of I_{OWG} appeared to be due to the photodeposition of Ag onto the surface of the TiO_2 powder. It is interesting that I_{OWG} considerably increased when the irradiation was stopped. This is probably because the deposited Ag was partly desolved again into the solution. The slow changes in I_{OWG} observed with no Ag^+ in the solution is presumably due to accumulation and disappearance of Ti^{3+} in the particles.[5]

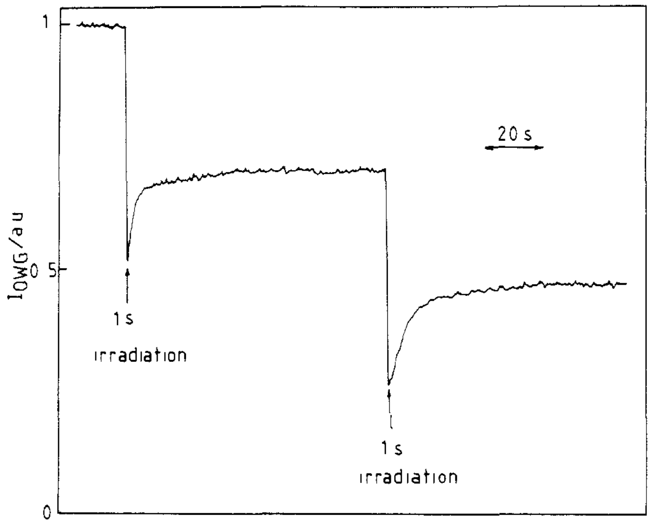

Figure 2. Changes in the intensity of the guided light (I_{OWG}) associated with irradiation: high pressure Hg lamp 1 s, 1 mmol/dm^3 $AgNO_3$ aqueous solution.

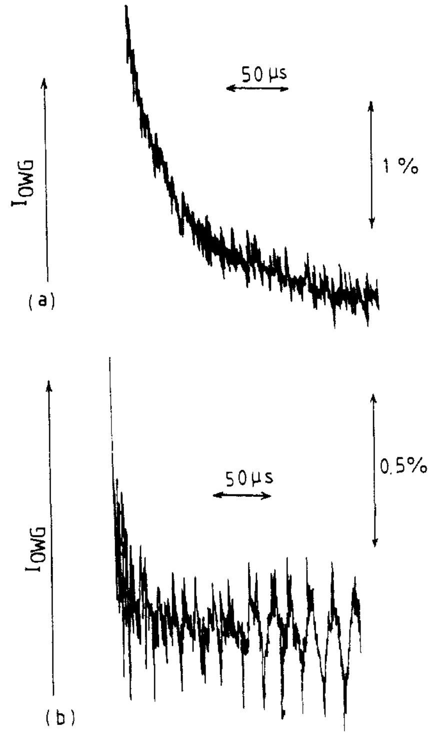

Figure 3. Changes in the intensity of the guided light (I_{OWG}) associated with irradiation: N_2 pulsed laser, 1 mmol/dm^3 $AgNO_3$ aqueous solution (a) and 10 mmol/dm^3 $AgNO_3$ aqueous solution (b).

Figure 3 shows typical I_{OWG} changes due to pulsed irradiation. The decay time constant was ca. 50 μs for 1 mmol/dm^3 $AgNO_3$ and ca. 10 μs for 10 mmol/dm^3. Such a slow change of I_{OWG} is surprising because Ag^+ ions are good electron traps[2] and the solution contained no sacrificial reagents. In addition, 10% ethanol in the solution changed only the magnitude of the I_{OWG} changes. We also observed that the magnitude of the I_{OWG} change, associated with each pulse, increased during the first several pulses.

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This probably shows that either the deposited Ag functions as a catalyst for the succeeding Ag deposition or very small Ag clusters do not absorb 633 nm monitoring light. A detailed study is now under way.

The I_{OWG} change in Figure 3a was ca. 0.01 in optical density (OD). This means that OD will only be ca. 10^{-4} when the monitoring beam is incident vertically over the OWG. Thus, the OWG method proved to be very effective for monitoring surface photoreactions. We are now also testing OWG's having semiconductor films including conductive SnO_2 and photoactive TiO_2.

Observation of a Local Minimum on the S_1 Surface of *cis*-Stilbene Solvated in Inert Gas Clusters

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Contrary to previously accepted view, this work presents strong evidence for a minimum on the S_1 surface of *cis*-stilbene in which the molecule lives on a nanosecond time scale. *Cis*- and *trans*-stilbene have been extensively studied as model systems for photochemical cis–trans isomerization in gas phase under isolated conditions and in solution where solvent viscosity opposes large amplitude geometrical changes.[1-8] In *trans*-stilbene, isomerization is inhibited by a 1200-cm^{-1} barrier.[2] By contrast, at ~300 K in gas[3] and solution,[4,7] *cis*-stilbene is nonemissive presumably because the S_1 state decays by barrierless isomerization on an ~1 ps time scale. In viscous solutions, a marked increase in *cis*-stilbene fluorescence quantum yield has been ascribed to retardation of isomerization by solvent-dependent viscosity barrier.[5,8] In this work, some of these ideas are challenged by observation of the same emission spectrum from inert-gas *cis*-stilbene clusters formed by supersonic expansion. Namely, the macroscopic viscosity of inert gas clusters (e.g., Ar)[9] is more than 10^6 times smaller than in viscous solutions;[5] therefore, viscosity may not be the controlling factor, rather it is proposed that *cis*-stilbene in a cluster vibrationally relaxes into an inherent minimum on the S_1 surface, from where it decays with the observed 20 ns lifetime. Fluorescence excitation and emission spectra of *cis*-stilbene seeded in several gases support these conclusions.

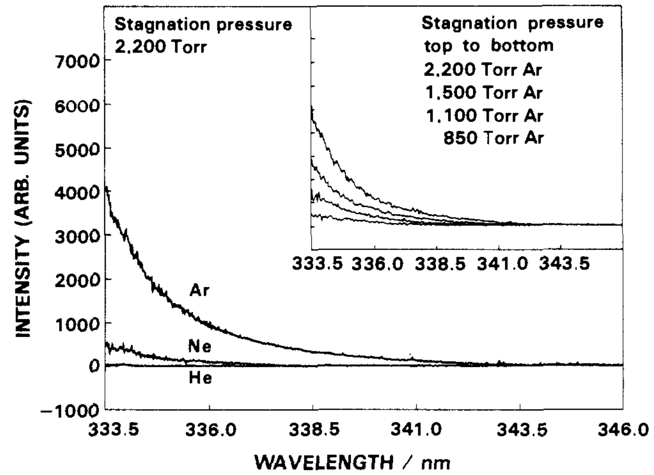

Figure 1. The fluorescence excitation spectra of *cis*-stilbene in He, Ne, and Ar expansions. Argon stagnation pressure dependence of the emission intensity is shown in the insert.

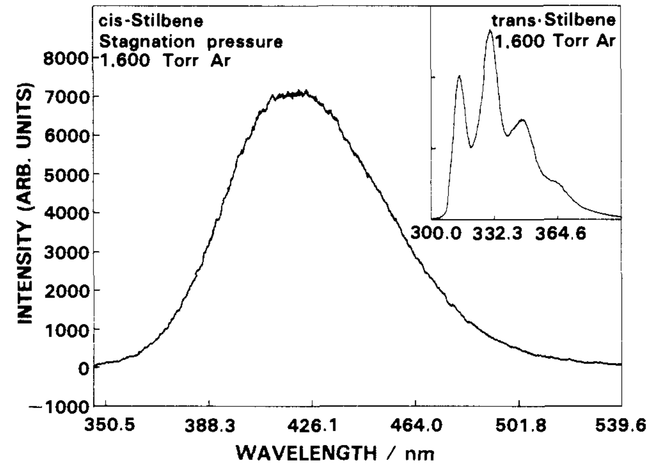

Figure 2. The emission spectra of *cis*- and *trans*-stilbene (insert) in Ar clusters generated by supersonic expansion. Excitation wavelength is 266 nm.

The supersonic beam of *cis*-stilbene (at 80 °C) seeded in He, Ne, Ar, Kr, N_2, or C_2H_4 is formed by expansion through a 0.2 mm diameter pulsed nozzle. *cis*-Stilbene fluorescence is excited by an excimer-pumped dye laser between 354 and 308 nm. Emission spectra are excited by the same laser or by fourth (266 nm) or fifth (213 nm) harmonics of a Nd:YAG laser, dispersed with a 25 cm monochromator, and detected by an OMA. The signal is measured to be linear with laser power.

cis-Stilbene fluorescence excitation spectra in Figure 1 show extraordinary dependence of emission intensity on the seeding gas and its pressure (insert). The spectrum between 308 and 333.5 nm (not shown) is featureless and monotonically rising. The displacement of the Franck–Condon maximum from the origin is due to large changes in the geometry between ground and excited states. Since the density of *cis*-stilbene in the supersonic beam is determined by *cis*-stilbene density before expansion, the observed effects suggest unexpected increase in *cis*-stilbene fluorescence quantum yield for higher stagnation pressures and for heavier noble gases.

The emission spectrum of *cis*-stilbene (Figure 2) closely resembles the previously observed spectra in viscous solutions.[5] The spectral profile is independent of seeding gas, stagnation pressure, excitation wavelength, and laser power. The relative emission intensity with 266-nm excitation and 1600 Torr stagnation pressure has the following dependence on seeding gas: Kr; Ar; N_2; Ne; C_2H_4; He/1.0; 0.5; 0.09; 0.0086; 0.0067; 0.0058. The same

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[§] Permanent address: Optics Laboratory, Korea Standards Research Institute, Taedok Science Town, Chungnam 300-31, Korea.

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0002-7863/88/1510-6269$01.50/0