SIMPLE EXTRINSIC FIBER OPTIC METHOD TO EVALUATE ABSORBANCE IN AQUEOUS NANOPARTICLE

Nguyen Thi Kieu Hanh[a,*], Atul Kulkarni[b], and T. Kim[a,b]

[a] SKKU Advanced Institute of Nanotechnology, Sungkyunkwan University
300 Cheongcheon-dong, Jangan-gu, Suwon, Gyeonggi-do, 440-746, South Korea
[b] School of Mechanical Engineering, Sungkyunkwan University
300 Cheongcheon-dong, Jangan-gu, Suwon, Gyeonggi-do, 440-746, South Korea
tkim@skku.edu (email address of corresponding author)

Abstract
In recent years, there has been a remarkable progress in the development of the fiber optic sensors for the detection of various chemicals. Fiber optic sensors have the advantages of very small size, flexibility and low cost. The fiber optic sensors employing different optical or spectroscopic phenomena have been reported such as bulk absorption, optical reflectance, fluoresces and energy transfer.
In this study, the effect of nanoparticle concentration in liquid upon light absorption and scattering was studied using extrinsic fiber optic method. For the evaluation, we used Red (650 nm) and Blue (430 nm) light sources which are coupled through the standard cuvette using optical fiber to detector. The experiments are carried out with Polystyrene latex (400 – 800 nm), and Silicon (35 – 110 nm) nanoparticles suspended in Isopropanol. Differences in light absorption and scattering depending on nanoparticle concentration and type are discussed. This method may be useful to study nanoparticles properties for various application and research.
Key words: nanoparticles, light absorption, light scattering, optical fiber, nanoparticle concentration.

INTRODUCTION
In recent years, the optical properties of the systems of reduced dimensions have attracted growing interest in both the basic and the applied sciences. Like many other characteristics of nanoparticles, interaction with electromagnetic radiation depends on the dimensions of the particles and thus allows one, for example, to fabricate tailor-made materials for novel optical components [1].

Most of the known analytical determinations are based on an absorbance measurement. In nanoparticle science, this is not a simple task: light which is impinging on the particle may be absorbed but is also producing scattering light. Since the first use some 30 years ago [2, 3], light transmission measurements on particles retained on glass fiber filters have been the most common technique. The light-transmission measurements are usually performed by dual-beam spectrophotometers where the light transmitted through the particle retaining filter is compared with the light transmitted through an unused "reference" filter. The spectral range in these measurements covers the visible region and it often extends to the ultraviolet and near infrared [4]. The spectral absorption coefficient of aquatic particles can be determined from measurements with laboratory Spectrophotometers and in situ instruments. Although in recent years considerable progress has been achieved, a general consensus on the most effective methodology for measuring particulate absorption has not been reached [5].

The incorporation of optical fibers imparts a number of advantages in measurements such as miniature device application, geometrical flexibility and ruggedness, small sample volumes, remote signal detection, multi-sensing capabilities and low cost.

This paper presents simple extrinsic optical fiber based method to evaluate light transmission i.e. absorption and scattering in nanoparticles in solutions phase. To investigate these effects in visible spectrum we used Red and Blue light sources. The system relies on monitoring the light intensity from the aqueous nanoparticle solution as the solution subjected for theses light sources. Different types of aqueous nanoparticle (PSL, Si) solutions with different nanoparticle concentration were investigated for the same. Obtained results were compared with visible spectroscopy observations and found in good agreement.

EXPERIMENTAL
To evaluate the aqueous nanoparticle absorption and scattering, a simple experimental setup was prepared and is illustrated in the figure 1.

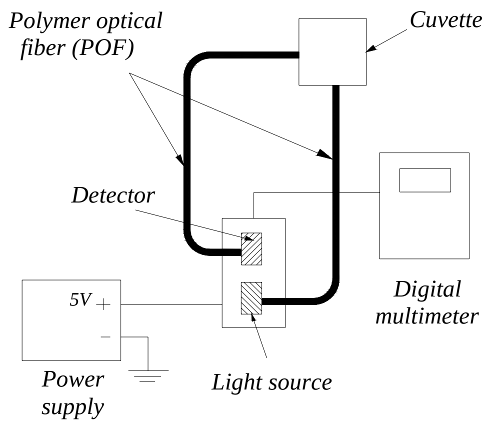

Figure 1 – Schematic of experimental setup for aqueous nanoparticle absorption measurement

The setup consists of polymer optical fiber (POF), standard cuvette, photodiode as a light source, phototransitor as a detector and a digital multimeter. The POF used (SH 4100, Super Eska Fiber, Mitsubishi Rayon Co., Ltd., Japan) has a core diameter of 980 µm and a cladding diameter of 20 µm. Two segments of POF of 30 cm of length with polishing ends were placed right angle and close to the cuvette faces. We carried out experiments using two types of photodiode light sources viz. SFH-756 (650 nm, Infineon Technologies) and IF E92A (430 nm, Industrial Fiber Optics, Inc.). The phototransitor detector SFH 350 (Infineon Technologies) has a spectral range of 200 nm to 1100 nm was used as detector. The photodiode and phototransitor were supplied 5 Volt DC from DC Power supply DRP – 303D. The standard digital multimeter (Sanwa) was used to measure the detector output in mini-volts.

Two samples of nanoparticles: Polystyrene latex (PSL) (Duke Scientific Corporation) and Silicon (35 nm – 110 nm, denoted as Si) (production of our lab) were used for studying the absorption. Two different mean diameters of PSL particles of 500 nm and 700 nm (denoted as PSL – 500 and PSL – 700) were used. We prepared PSL – 500, PSL – 700 and Si solution by dispersing particles of each type in Isopropyl alcohol with different solution concentrations as illustrated in the table 1. We verified the particle size distributions and number concentrations of these solutions using TSI Scanning Mobility Particle Sizer (SMPS) spectrometer and Condensation Particle Counter (CPC) model 3080 and 3025, respectively. Obliviously for all solutions, the number concentration of particle is direct proportion with the solution concentration.

Table 1. Total surface area concentration and size range of PSL-500, PSL-700 and Si

Particle type	Diameter range (nm)	Total surface area concentration (nm^2/cm^3)			
		0.01%	0.02%	0.05%	0.10%
PSL-500	400 – 600	5.00E+07	1.00E+08	2.20E+08	4.00E+08
PSL-700	600 – 800	8.00E+07	1.13E+08	3.05E+08	1.49E+09
Si	35 – 110	6.98E+10	7.93E+10	8.47E+10	1.03E+11

The experiments were carried out in the dark room at ambient temperature (24 ± 2) ˚C under normal atmospheric pressure conditions. The experiment was carried with each solution with Red and Blue light sources, respectively. For every transmission measurement, air reading (empty cuvette) was recorded to enhance the measurement accuracy. The ratio of detector voltage in air and in solution is equivalent to the absorption due to particle size and its concentration. After each measurement care was taken to clean the cuvette to avoid the contamination. To verify the experimental results, we carried out visible spectrometry by using spectrophotometer (UV-3600, Shimadzu).

RESULTS AND DISCUSSION

UV/visible absorptiometry in its various forms are probably the most popular method in conventional analytical chemistry. It is based on the absorption of light by the analyte. According to Beer and Lambert, the following linear relation exists between absorbance A and the concentrations C of an absorbing analyze [6].

$$A_{\lambda} = -\log_{10}\left(V_{sol}/V_{air}\right) = \varepsilon . c . d \quad (1)$$

Where, A_{λ} = Absorbance at particular wavelength (λ), V_{sol} = detector output voltage through the solution under test, V_{air} = detector output voltage in air (without solution). Absorbance is sometimes also referred to as optical density (OD) or extinction. "ε" is the decadic molar absorption coefficient and "d" is the path length of the light in the cuvette. It is obvious that when "ε" is high and "d" is large, absorptiometry can be very sensitive.

Polystyrene latex particles are used for a variety of procedures requiring uniform particle sizes in the colloidal size range. Particles of this size are of special interest for research in light scattering, microporous filter checking or aerosol particle generation. The polystyrene microspheres have a density of 1.05 g/cm³ and a refractive index of 1.59 @ 589 nm. They are useful for applications such as filter evaluation and testing, fluid mechanics research, dispersion studies and many other research and development projects. Also these particles can be easily suspended in DI water or IPA. Hence we selected the PSL aqueous nanoparticles for this study.

The experimental results were evaluated using above said theory for PSL particle at Red (650nm) and Blue (430nm) wavelength and the results are summarized in the table 2 and plotted in figure 2.

Table 2: Absorbance of light by PSL solutions

Solutions / Absorbance at	PSL_500				PSL_700			
	0.01%	0.02%	0.05%	0.10%	0.01%	0.02%	0.05%	0.10%
λ=650 nm	0.557	0.517	0.451	0.384	0.516	0.519	0.429	0.382
λ=430 nm	0.135	0.105	0.067	0.067	0.146	0.105	0.073	0.035

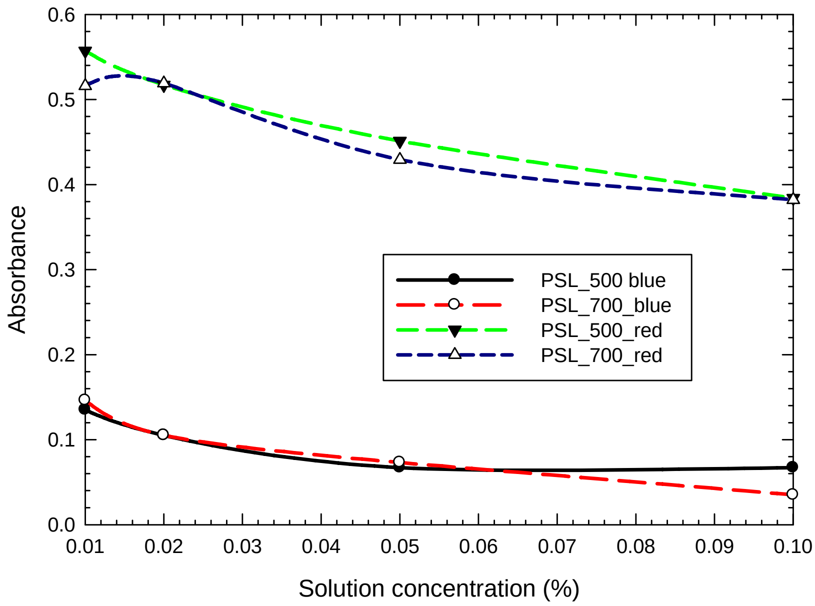

Figure 2. Absorbance of light by PSL (PSL-500, PSL-700) solutions

It is clearly seen from the results that for both PSL 500 and 700nm solution the absorbance is high at λ = 650 nm (Red source) as compared with the λ = 430 nm (Blue source). This indicates that PSL particles are more sensitive to Red than Bule light. Also for selected concentration there is very less effect of particle size on absorbance. It is also clearly seen that the change in absorbance due to particle concentration in solution has less influence for the Blue light source as compared with Red light source.

Unlike PSL, amorphous silicon (a-Si) is the non-crystalline allotropic form of silicon. These particles have wide applications in the field of solar cell and thin transparent films. Several studies are found in the scientific literature, mainly investigating the effects of deposition parameters on electronic quality, but optical properties are still not explored. Hence we selected the Si nanoparticles. In order to evaluate the absorbance, we carried out similar experiments with amorphous silicon and the results are depicted in the Table 3 and plotted in figure 3.

Table 3: Absorbance of light through Si solutions

Absorbance at \ Solutions	Si			
	0.01%	0.02%	0.05%	0.10%
Red (650 nm)	-0.157	-0.374	-0.472	-0.555
Blue (430 nm)	-0.035	-0.067	-0.125	-0.151

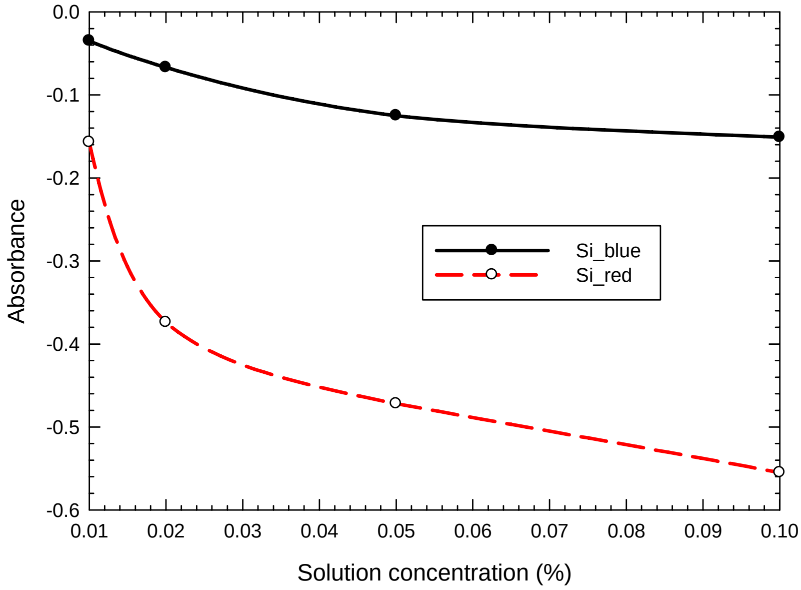

Figure 3. Absorbance of light by Si solutions

As expected we observed the absorbance value "A "as negative in case of Silicon particles for all concentrations. Which means that in absorption is less dominant than scattering and it can be treated as transmittance due to silicon particles. As silicon particles has semi-conducting properties in nature unlike PSL particles. We observed that there is more scattering in case of red light source as compared to Blue light source. The light transmission due to number concentration of Si particles is found higher to red than blue.

CONCLUSION

In this study, the effect of nanoparticle type and concentration in liquid upon absorbance was successfully studied. This method may be useful to study nanoparticles properties for various application and research. The effects of visible light on to types of aquous nanoparticle solutions were studied. In case of PSL we observed that the absorption due to particles is dominant, where as in case of Silicon transmittance due to light scattering is dominant. We found that the proposed method is simple, low cost and easy to implement in the laboratory scale to evaluate the aqueous nanoparticle studies. More experiments were under evaluation for various aqueous nanoparticle solutions and we hope that this technique will be useful for nanoparticles properties for various application and research.

REFERENCES

[1] Villa-Sanchez, G., Mendoza-Anaya, D., Gutierrez-Wing, R., Perez-Hernandez, R., Gonzalez-Martmez, P. R., Angeles-Chavez, C., "Ag nanoparticle effects on the thermoluminescent properties of monoclinic ZrO_2 exposed to ultraviolet and gamma radiation" Optical properties of nanoparticles", Nanotech., **18**, (2007).

[2] Yentsch, C. S., "Measurement of visible light absorption by particulate matter in the ocean", Limnol. Oceanogr., **7**, 202-217 (1962).

[3] Truper, H. G., Yentch, C. S. "Use of glass fiber filters for rapid preparation of in vivo absorption spectra of photosynthetic bacteria", J. Bacteria, **94**, 1255-1256 (1967).

[4] Tassan, S., Karima, A. "Proposal for simultaneous measurement of light absorption and backscattering by aquatic particulates", J. Plankton Research, **24**, 471-479

[5] Tassan, S., Mitchell, B. G., Bricaud, A." Light absorption measurements of aquatic particles: status and prospects", Pro. Symp. Igarss'97, **II**, 657-661 (1997).

[6] http://www.chemguide.co.uk/analysis/uvvisible/beerlambert.html