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# Raman investigation of single-walled carbon nanotubes in liquid by tip-enhanced Raman spectroscopy

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## 1. Introduction

Tip-enhanced Raman spectroscopy (TERS) is a powerful tool that enables to measure Raman scattering from samples with nano-scale spatial resolution. Owing to the combination of near field light and localized surface plasmon generated at a metallized tip apex, which is utilized in TERS, high spatial resolution and high efficiency of Raman scattering light are achieved[1].

Taking advantages of high resolution and high efficiency of Raman signals, TERS is utilized for various samples and nowadays the need for the investigating for samples in liquid environment is increasing[2]. This is because some samples, especially in biological and medical fields, show an intrinsic behavior only when they are in liquids. In this study, we introduced the TERS system that can measure Raman scattering light from samples in liquid and succeeded in taking TERS images taken in liquid condition.

## 2. Experimental

Our TERS experiment setup is based on an inverted optical microscopy and an atomic force microscopy (AFM) capable of investigating samples in liquid, as shown in Fig.1. A high numerical aperture objective lens (NA = 1.4 × 60) was used to make efficient evanescent light on the surface of substrate. An AFM tip was coated with a 80-nm-thick layer of evaporated silver for creating strong near-filed. The Raman scattering was excited with a CW laser of wavelength 488 nm and collected through the objective, then passed through a beam splitter and was navigated to the Raman spectrometer. The samples were single-walled carbon nanotubes(SWNTs), which are widely used for TERS study because of their strong resonance Raman effect[3, 4, 5].

The comparison of the TERS spectrum and the ordinal Raman spectrum of SWNTs in G-band spatial region is shown in Fig.2. From this figure, it is clear that G band peak intensity was enhanced, indicating that localized surface plasmon polariton effect could be utilized even for the samples in water environment. We also succeeded in taking TERS image constructed by the Raman intensity of samples in water.

## 3. Conclusions

In this study, we constructed the TERS system for measurement of samples in liquid and succeeded in TERS measurement of SWNTs in water. Our study will contribute to TERS study especially in biological, chemical and medical fields.

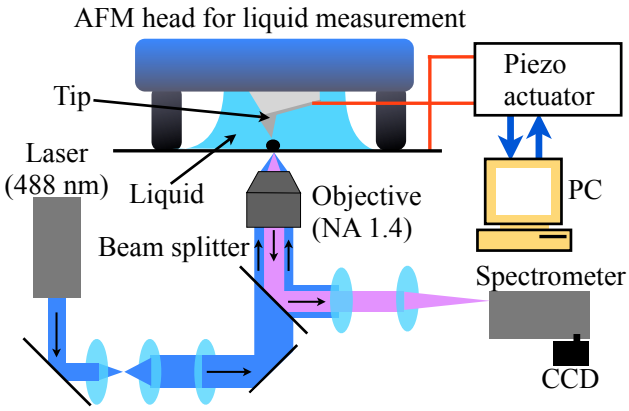


**Fig.1** : Schematic image of TERS setup for measurement in liquid

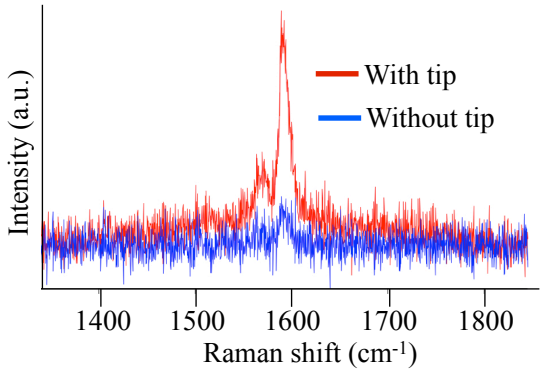


**Fig.2 :** TERS and normal Raman spectrum of SWNTS detected in water

## Reference

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