Near-infrared up-conversion photoluminescence imaging of carbon nanotubes in mice tissues

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1. Introduction

Single-walled carbon nanotubes (SWNTs) have been considered as promising luminescent probes for deep-tissue bioimaging because of their intrinsic photoluminescence in the near infrared wavelength range of ~1000-1300 nm called NIR-II [1, 2]. The near infrared light readily penetrates into highly scattering media such as biological tissues; this enables photoluminescence imaging of deep inside of them. However, it is necessary to use Stokes photoluminscence (here after, referred to as PL) at longer wavelengths than ~1100 nm to avoid autofluorescence from the biological tissues, and standard Si-based detectors cannot be used in this wavelength range. Recently, efficient up-conversion photoluminescence (UCPL) of SWNTs has been discovered [3]. The UCPL phenomena enable SWNTs excited at wavelengths longer than ~1050-1200 nm to emit PL shorter than 1000 nm in which standard Si-based detectors have finite sensitivity. The availability of the UCPL thus drastically enhances the usefulness of SWNTs as luminescent probes in their bioimaging applications.

2. Experimental

The samples that have been used for the experiment were sectioned liver tissues of mice into which SWNTs were intravenously injected. In optical measurements, we used 1064 nm or 658 nm lasers for the excitation in order to compare UCPL and PL images. The images were captured using EMCCD camera and the spectra were measured using a Si-CCD and an InGaAs photodiode array detectors.

3. Results and Discussion

We observed microscopic PL and UCPL images of sectioned liver tissues of mice. Figures 1(a) and 1(b) show PL (excited at 658 nm) and UCPL (excited at 1064 nm) images, respectively. In the case of the PL image in Fig. 1(a), PL of both SWNTs (bright spots) and the tissue itself (autofluorescence, bright back ground) were observed. In contrast, only the UCPL of SWNTs (bright spots) was clearly observed in Fig. 1(b). Figs. 1(c) and 1(d) show PL and UCPL spectra of SWNTs in the sectioned liver tissue. The circles in Fig. 1(a) and 1(b) indicate the position at which the PL and UCPL spectra shown in Fig. 1(c) and 1(d) were measured. In the PL spectrum, distinct peak feature of SWNTs could be hardly observed because of the strong autofluorescence from the biological tissues, whereas the UCPL spectrum showed a clear peak feature at about 1010 nm. Similar UCPL peak was also observed for the SWNTs before the injection; this confirms that the UCPL feature originates from the injected SWNTs.

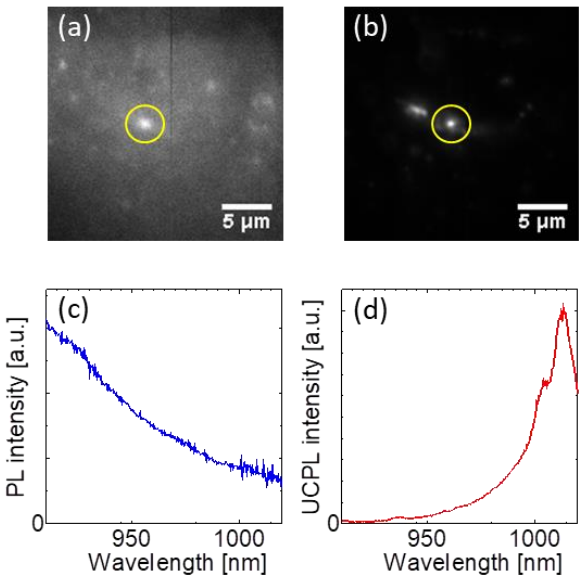

Fig. 1(a) PL image excited at 658 nm and (b) UCPL image excited at 1064 nm of the sectioned tissue of a mouse liver with the infused SWNTs. The images were taken at the same position of the sample. (c) PL spectrum taken at the position indicated by a circle in (a). (d) UCPL spectrum taken at the position indicated by a circle in (b).

4. Conclusions

We demonstrated the UCPL imaging of SWNTs in sectioned liver tissues of mice with negligible autofluorescence. We also confirmed that the bright spots observed in the UCPL images originate from the UCPL of the SWNTs by spectral measurements.

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