Two-dimensional imaging of oxygen concentrations at sediment-water interface using an optode system.

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Marine organic materials produced in euphotic zone descend with decomposing down to sediment-water interface (SWI). There, almost organic materials are degradated or decomposed by benthic and microbial activities. During decomposition, oxygen dissolved in benthic boundary layer and pore water are consumed. Thus typical oxygen concentration decreased rapidly and reached to be zero within only a few millimeters to centimeters from the sediment surface. This profile is formed by interactions between diffusion, organic carbon flux, carbon assimilation ratio and mixing process by benthic organisms.

A study to understand such processes has been attempted from a viewpoint to know a nature of interactions between sediments and organisms or to obtain knowledge of environmental changes. However, conventional methods for profiling oxygen concentration had been restricted to one-dimensional manner such as measurement with electrode or qualitative descriptions to measure oxidized layer seen in brownish part at the top part of sediments.

Recently, a new method to obtain two-dimensional images of oxygen concentrations has been developing. This is based on relationships between oxygen concentration and luminescence lifetime from excited state of oxygen-sensitive molecular sensor, such as Ruthenium (II)-tris(4,7-diphenyl-1,10-phenanthroline) dichloride (Ru(dpp)3Cl2). It emits orange phosphorescence (613 nm in wavelength) when excited by blue light (455 nm in wavelength), and both lifetime and intensity of the phosphorescence have inversely proportion to the surrounding oxygen concentration. Thus if these molecules are doped into oxygen-transparent binder and make a thin film, they can be an optical 2D-oxygen sensor. We made 2D-optode foil to bind Ru(dpp)3Cl2 into thin polystyrene film on the transparent PET film, and evaluated the specifications of the films. For a phosphorescence imaging, we used blue LED array as an excitation light source and recorded the phosphorescence by multigate CCD camera made by Hamamatsu Photonics Co. LTD. These equipments were set on optics system. For actual optics constructed in a dark box, blue excitation light was diffracted to 90 degree by dichroic mirror in order to introduce in front of sample chamber. Phosphorescence from the film in the chamber was pass through the mirror and red bandpass filter set on the lens. To obtain concentration images, we used a method so-called luminescence lifetime imaging. Single lifetime image was calculated from three images taken 0.5, 3.5 and 6.5 microseconds after cut off the excitation light, respectively. Image size was 512x672 pixels and was stored in PC. Then, lifetime images were converted into concentration images following with the Stern-Volmer equation, known as transition trend from excitation state: tau/tau0=a+(1-a)*(1/(1+Ksv*[O2])), where tau/tau0=ratio of lifetime in actual oxygen concentration/absent in oxygen, [O2]=actual oxygen concentration, Ksv=Stern-Volmer constant and a=constant (Glud et al., 1996). We calibrated the film at 0%, 50% and 100% in oxygen concentration and obtained Ksv image. Using these images, we calculated actual images taken SWI in an aquarium. We report these results and time-series images from the experiments.

Acknowledgements

To conduct this study, I have advised many useful comments and suggestions from many peoples. Especially, I would like to thank gratefully to Drs. Frank Wenzhoefer, Anders Tengberg, Lars Rickelt and Michael Kuehl, University of Copenhagen.