ALEC TECHNICAL EXPRESS
Feb, 2008
No. 11

New type Optical high accuracy DO sensor, RINKO Scheduled to be released in April

Alec Electronics Co., Ltd. has been developing a new optical DO sensor with fast response and high accuracy. The development on incredible fast response function (<1sec.) is in the final stage. Aiming to show at OCEANS'08 MTS/IEEE KOBE-TECHNO-OCEAN '08 in this April, we are going on working for commercial products. Here, we introduce the instrument in an overview.

Development

In the field measurements of DO, the galvanic electrode sensors have usually been used for several decades. Recently, various *in-situ* optical DO sensors were developed and have been commercialized. But both type sensors have late response time, such as 20~50 seconds. Moreover the sensors are sometimes unstable in the field measurements. Therefore, many users waited for someone to develop a new-technology sensor with fast response time, high stability and good accuracy. We have collaborated with Nara Women's University since March 2007 to develop the reactive chemical material with suitable characteristics for DO sensor, based on existing PSP (Pressure Sensitive Paint) technology. Although the development is extremely difficult because of our ultimate target to make sensor to be fast response (1sec), seawater resistance, high stability, good accuracy, low price and so on, we have reached our final goal and now are making our effort toward the commercial products. The prototype sensor was named "*RINKO". We already did some tests in deep-ocean with depth of 2000m to 6000m and obtained many valuable data. The tests show RINKO's great potential application on relative research.

(*Rinko means phosphorescence in Japanese.)

Fig. 1 *RINKO I* (Data logger model).

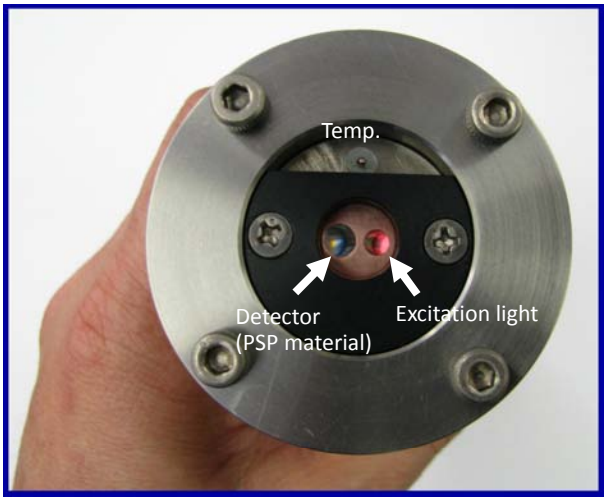


Fig.2 Optical window and temperature sensor.

Principle and Futures

We applied phosphorescent material to the sensing foil of RINKO. When a pulse-excitation light is emitted from the inside to its material, it radiates the red colored phosphorescence. Its intensity varies in a negative correlation with oxygen partial pressure [Fig.3]. Thus, the phosphorescent intensity is the highest at anoxic environment. Moreover, the lifetime of the phosphorescence is varied, as well as its intensity. During the reaction, the oxygen molecules are not consumed. RINKO measures the phosphorescent lifetime by a phase differential detection to estimate DO [Fig.4]. This optical method provides two advantages; one is very stable without the influence of bio-fouling, the other, the sensor does not need water mixing like the galvanic electrode sensors.

The optical DO sensor presently being used over the world has a similar principle as RINKO. But their sensing foils are too weak to the ambient light from the outside, so they must need a layer, like black silicones, to shade it. It is known well that the sensor's response time gets extremely delayed by this layer. According to our new technology, RINKO's sensing foil does not need a layer to shade it. This technology is greatly improved by our technology, which makes us successful to develop a new type DO sensor with high response and long-term stability [Fig.5].

We are planning to provide 4 models for RINKO instrument based on its special characteristic. To coincide with the release of RINKO, we will discontinue manufacturing COMPACT-OPTODE and COMPACT-DOW.

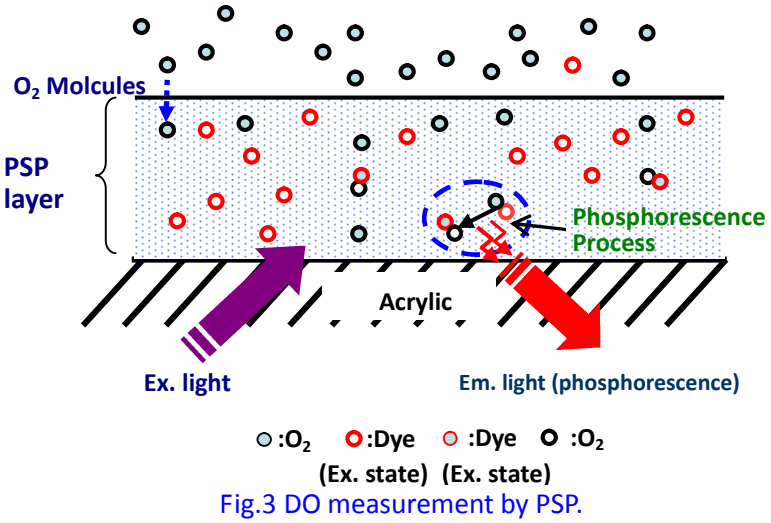


Fig.3 DO measurement by PSP.

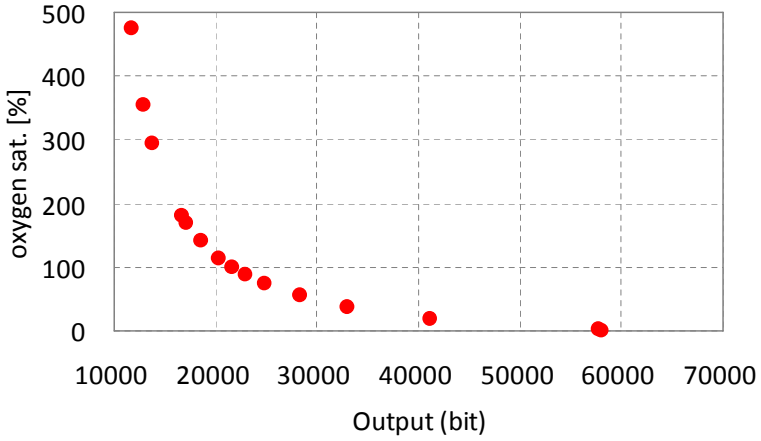


Fig.4 A relationship between the oxygen partial pressure (concentration) and the ***RINKO***'s output [the lifetime of phosphprescence].

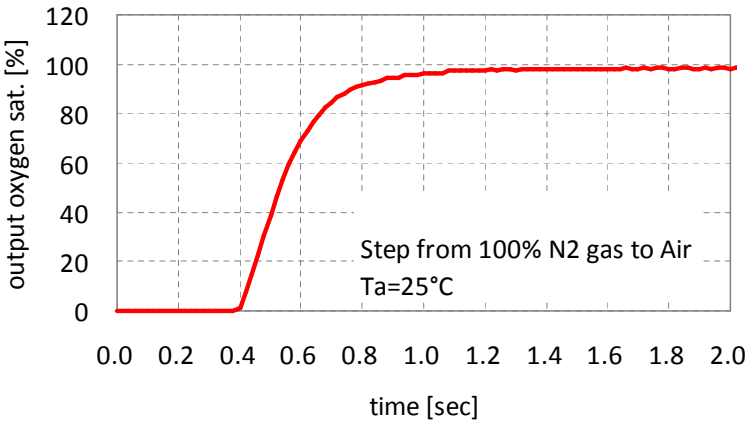


Fig.5 The response time of ***RINKO***. This figure shows that the response time which reaches to 90% value of oxygen in air is within 1second.

Luminescence - Fluorescence and Phosphorescence -

Phosphorescence is a photo-luminescence including fluorescence. Fig.6 shows the energy diagram and the interaction between PSP and the oxygen molecules. The luminescence molecules absorb lights and are excited from its ground state S_0 to excited state S_1. According to the spin angular momentum (spin) of their excited molecules, their excited states are called as singlet or triplet state. Both excited states are relaxed to the ground state via non-radiative transition and radiative transition, where some of energies are lost as heats and lights. If the radiative transition occurs between the singlet excited state and the ground state (S_1 to S_0), the emission light (photon) is called as fluorescenscence. If the radiative transition occurs between the triplet state and the ground state (From T_1 to S_0), this process is called as phosphorescence. Phosphorescence has a feature where its lifetime is longer than that of fluorescence.

RINKO's PSP emits the luminescence. But PSP is categorized as a phosphorescence material, because the contribution of the fluorescence to PSP's luminescence is very little. The intensity and the lifetime of its phosphorescence vary in a negative correlation with oxygen partial pressure, because the PSP's molecules, at the triplet state, lose some of the excitation energies by the transmitted oxygen molecules into the PSP layer. A relationship between the phosphorescence and the partial pressure of oxygen defines as Stern-Volmer equation. The measurement of DO by RINKO applies this equation.

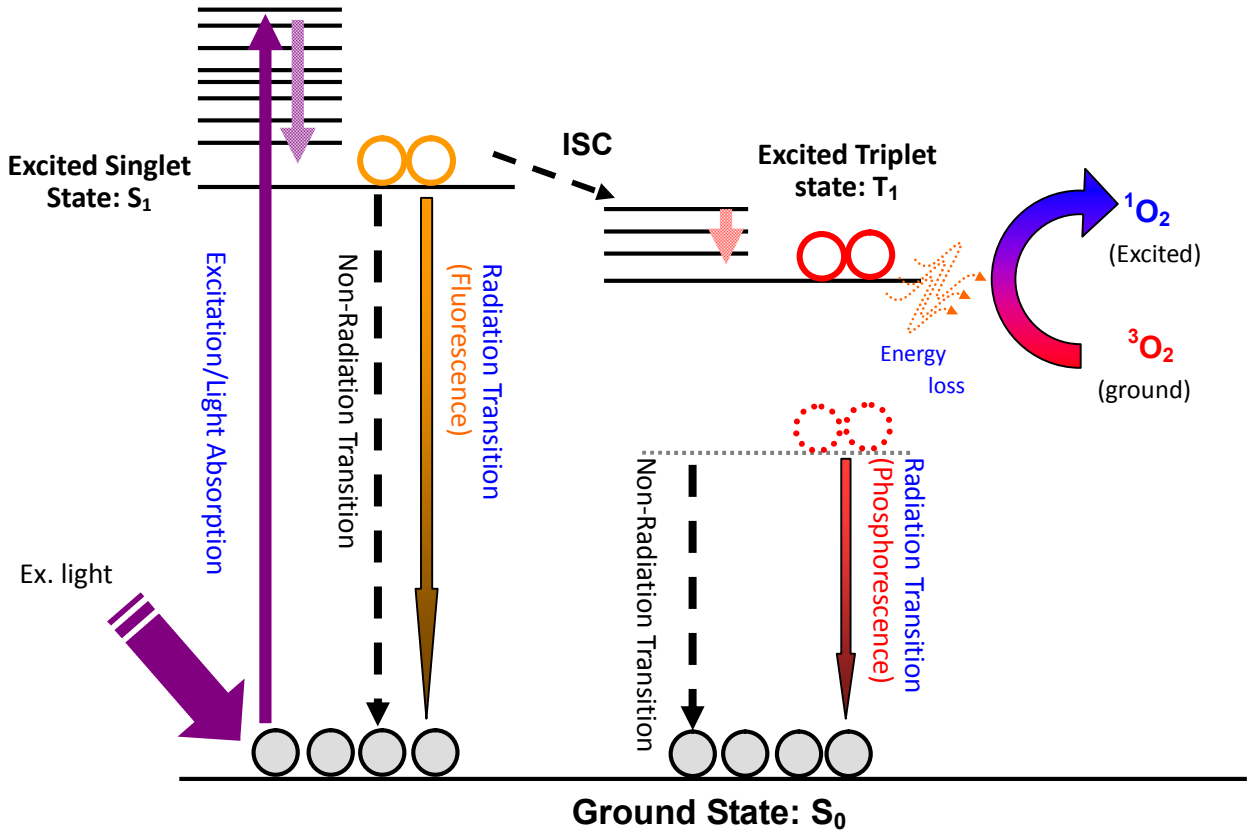


Fig.6 The luminescence mechanism (Perrin-Jabloski Diagram) in PSP and the quenching process of PSP's phosphorescence.

Our Plan for lineup

- *RINKO-I* (Data Logger Model)

RINKO is equipped with Alec's data logger which is used in current COMPACT series or next-generation INFINITY series. We provide two sonde types; the first is of titanium for deep-water (≤ 7000m), the second is of resin for shallow-water (≤ 200m).

- Application : Long term self-mooring.

- *RINKO-II* (Digital Output, Real-Time Model)

RINKO-II is a real-time model with digital sensor (DO, Temperature, Depth), 50m cable and a portable display.

- Application : Water quality measurements in surface water, automatic observation systems.

- *RINKO-III* (Analogue output Model)

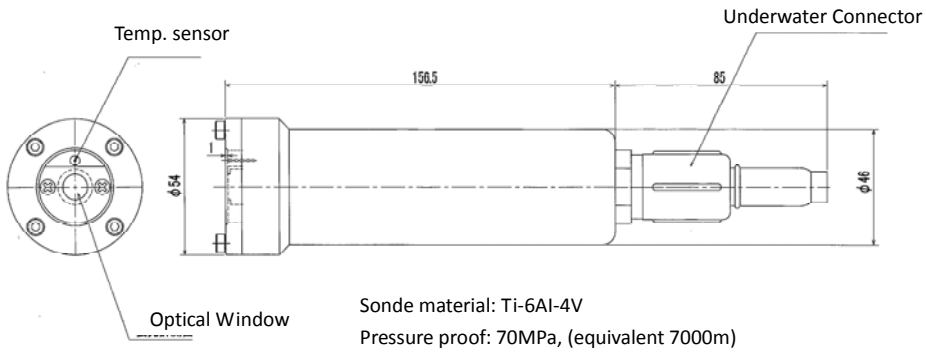
This is a model to be integrated in CTD-RMS and operated by DC12V. Both signals of DO and temperature are output by analog voltages (0~5V). There is no difference in DO profiles of upward cast and downward cast in the normal winch speed, because RINKO has fast response time within 1 sec.

- *RINKO-IV°* (OEM Model)

We plan to supply the OEM model of only the optical sensor part (without the sonde). We will design the sensor part depending on the requirements from various customers, including the manufactures of industry, medicine and institutions.

Specification (*RINKO*-III)

Parameter	DO	Temerature
Type	Phosphorescent life time	Thermistor
Range	0 ~200%	-5 ~ 40 C°
Accuracy	< ± 2%	± 0.05 C°
Resolution	0.4%	0.01 C°
Response time	≤ 1 second	
Output	Analogue voltage (0 ~ 5V)	
Sonde Materials	Ti-6Al-4V	
Pressure proof	70 MPa (equivalent 7000m)	
Size	Length: 157mm (Sensor only), dia: 54mmϕ	
Weight	Air: 1000g, Water: 600g	
Power	DC 12V	
Power consumption	50mA	
Underwater connector	AG306-HP (Impulse Enterprise, Inc.)	



Sonde material: Ti-6Al-4V

Pressure proof: 70MPa, (equivalent 7000m)

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