An Introduction to Green Oxygen Luminescence Detector and Spectrometer (GOLDS)

Application to surface chemistry through adsorbed oxygen

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1. Introduction

This guide book introduces a newly invented spectroscopic equipment and procedures based on green oxygen luminescence emitted from adsorbed oxygen molecules on the surface of materials when they are illuminated with a radiation sources including a near ultraviolet (NUV)-LED. We named this new instrument as GOLDS (Green Oxygen Luminescence Detector and Spectrometer).

Luminous intensity from the adsorbed oxygen could be proportional to the amount of oxygen containing compounds such as alcohol, acid, metal oxides. Amount of oxygen containing functional groups in organic compounds increases with aging; thus, the GOLDS can detect global degree of autoxidation including carbonyl compound, carboxylic acids, and hydroperoxides. Moreover, the GOLDS can detect the amount of adsorbed oxygen on metal oxides formed on the surface of metallic materials and various metal oxide catalysts. For example, titanium oxides exhibited green oxygen luminescence and other emission when being illuminated with NUV lamp and fluorescent tube, whose emission spectra were different from those for other metal oxides. The GOLDS would be a noble diagnostic instrument to elucidate the mechanism of photo-catalyst and surface analysis of pure metals and metal alloys.

2. What is Green Oxygen Luminescence?

Continuous emission spectra ranging from 400nm to 600nm with a peak wavelength of 500nm have been observed in chemiluminescence studies of a variety test samples. Notably, stainless steel and polytetrafluoroethylene (PTFE) emitted green light when it was heated above 100°C in an inert atmosphere and when being illuminated with black light (365nm) at room temperature in both air and inert atmosphere. Note that continuous radiation is produced by molecular oscillations excited in the condensed solid by the thermal energy (called black-body radiation). Molecules and atoms in the gas phase emit discrete line spectra when they are excited by light or by heat.

Careful investigation of the green luminescence has led us to conclude that it is originated from the light emission from adsorbed oxygen molecules on the surface of materials based on the following experimental facts: (1) intensities of the green luminescence increased with aging in air, (2) intensities of the luminescence increased with decreasing temperature for a constant time period, (3) detailed analysis of the spectra for the green luminescence from a cellulose filter exhibited double peaks in the spectra; one peak was 480nm and the other was 520nm. The former peak is close to a line spectrum of singlet oxygen, (4) two different activation energies were obtained from heat-excited luminescence measurements. the lower value was 6.8 kcal/mol and the higher one was 12 kcal/mol. these vales fall in the range of well-known hydrogen bonding,

(5) ultra high sensitive color CCD camera took a green photograph(see **Figure 1**) of a filter paper which was exposed to near ultraviolet (365 nm) radiation.

Based on these new experimental findings we have postulated "oxygen bonding" between molecular oxygen and oxygen atoms in materials. Oxygen bonded oxygen molecules have unique roles: (1) they absorb the energy of ultra violet light and emit a broad visible light with a color of green, (2) energetic oxygen molecules (like steam) and electronically excited singlet oxygen molecules are generated from surface of oxygen adsorbed materials. The hot and singlet oxygen may cause oxidation on the surface or above



Figure 1 Color photograph of a filter paper taken with ultra high sensitive CCD camera immediately after being irradiated with NUV lamp (365nm) in air.

organic materials. The bond-strength of the oxygen bonding on the the surface of organic materials was estimated to be approximately 5 kcal/mol, in another word, activation energy for the oxygen bonding might be a order of 10 kcal/mol, which is almost one third of the bond dissociation energy of O-O bonds in hydroperoxides. Hydroperoxides have been known as an important intermediate in the process of autoxidation. Most people has believed that the hydroperoxides initiate autoxidation. The importance of the adsorbed oxygen on the surface of the materials has never been neglected so far. Molecular orbital calculations indicated that the adsorbed oxygen will form oxygen bonding through -bonds; oxygen molecules form oxygen bonds between two oxygen atoms in materials. Oxygen molecules could be aligned perpendicular to the plane of the two oxygen atoms in materials. Activation energies of green oxygen luminescence for metal oxides were as high as twice compared to those for organic materials and glasses. This fact may indicate that d-orbital in heavy atoms also form oxygen-bonds with oxygen molecules. Models for the oxygen-bonding are postulated in Figure 2 in the case of oxides (MO2) by the author.

Temperature dependence of thermally excited luminescence can provide activation energy (Ea) for green luminescence. Bond energy for weakly bonded oxygen bonding was calculated to be the half of Ea + RT, where R is gas constant. Bond energy for weak oxygen bonding was 3.8 kcal mol⁻¹ for cellulose. Bond energy for strong oxygen bonding for cellulose was 6.4 kcal mol⁻¹. Bond energy for hydrogen bonding of H2O is known to be 5.5 kcal mol⁻¹. Bond strength of oxygen bonding formed on organic compounds seems to be close to that of hydrogen bonding.



Figure 2Some postulated oxygen-bonding structure from Kimura (2003).Estimated bond energy for various oxygen-bonds:

For metal oxides: 14.4 kcal/mol (TiO2), 14.9 kcal/mol (18-8 stainless steel). For organic materials: 6.4 kcal/mol (cellulose), 6.4 kcal/mol (PTFE). For weak O-bond: 3.1 kcal/mol (cellulose diacetate), 3.8 kcal/mol (cellulose).

3 How to measure Green Oxygen Luminescence?

Figure 3 illustrate the GOLDS and a special sample chamber equipped with NUV-LED and gas purge ports. The GOLDS system is basically a chemiluminescence spectrometer. This apparatus has two interchangeable sample chambers. One is thermal chamber and the other is photoirradiation chamber. Thermal camber equipped with electric heater can heat up sample to 160°C. The photoirradiation chamber has two ports for light source. One can use UV-LED or blue-LED. Inner wall of the photo irradiation chamber is gold-plated to reduce the background emission from the chamber wall. Luminescence spectra can be measured with cutoff filters.



Figure 3 Schematic diagram of GOLDS (Green Oxygen Luminescence Detector and Spectrometer) and specially designed sample chamber.

4. Examples of GOLDS Measurement

Several samples were examined with a prototype GOLDS apparatus. Figure 4 shows example of luminous intensity (count s⁻¹ abb. cps) decay curves obtained after irradiation with NUV(375nm)-LED in air. Analysis of the decay curves and the spectra could reveal the light-emitting species. Conventional thermally excited luminescence in an active (air, oxygen) and inert atmosphere could bring kinetic information. Comparison of photo- and thermo-excited luminescence data would provide a deep insight into surface chemistry.

Example 1 Filter paper and Cellulose Powder

Cellulose is a linear polymer containing only D-glucose units, all in the 1-4 linkage. Cellulose is the most abundant molecule in living tissues.

A cellulose-repeating unit contains six hydroxyl groups and three ether bonds. This implies that cellulose could adsorb oxygen to a considerable extent. According to an expectation, a cellulose filter continued to emit relatively strong light for more than one week when it was heated at 120°C in flowing nitrogen atmosphere.

Two cellulose powders were kept in air for two weeks at two different temperatures (ca. 10°C and 20°C). Figure 5 show the luminescence curves for these celluloses heated to 70°C. Surprisingly the luminous intensity increased with decreasing storage temperature. This result



Figure 4 Luminescence decay curves for photo-illuminated samples in air.



Figure 5 Aging temperature effect on luminous intensity for cellulose powder, measured at 70°C in flowing nitrogen.

strongly implies that the increase in luminous intensity could be due to adsorption of oxygen. It should be remembered that solid and liquid adsorb gases easier at lower temperatures. The authors have found strange flow rate effect on luminescence of filter cellulose as can be seen in Figure 6. Luminous intensity increased with decreasing flow rate of nitrogen gas. Quite similar phenomena appeared also in luminescence for liquid These experimental facts may alcohols. suggest that chemiluminescent (oxidation) reactions might occur in the gas phase, where oxygen and fuel react together. When gas flow rate were increased, nitrogen gas would dilute the concentration of oxygen and fuel resulting in decrease in luminous intensity.

Anomalous initial peak appeared in the luminescence curve of cellulose has been known but the reason for the initial peak was unknown (see Figure 7). The initial peak disappears when it was heated again after being cooled down to room temperature. One will probably point out that the peak could be due to the decomposition of hydroperoxides formed during storage in air. Kinetic analysis of the initial peaks was conducted as follows: Decay curves after the peak were plotted in logarhysmic fashion against time. Straight lines having different slopes were obtained in this plotting. The slope of the straight lines were plotted in Arrehenius plot (Figure 8). The activation energy for initial peak decay estimated to be $6.8 \text{ kcal mol}^{-1}$. was Steady-state activation energy for filters paper



Figure 6 Flow rate effect on luminous intensity of filter cellulose heated in N2.



Figure 7 Anomalous initial peak in luminescence curves of cellulose filter heated in nitrogen at the first time.



the initial decay rate in Figure 7

and cellulose powder heated in nitrogen was 12 kcal mol⁻¹. These values are too low for the activation energies of hydroperoxides decomposition which are in the range from 23 kcal/mol to 35 kcal/mol.

Luminescence spectrum for filter paper heated in nitrogen was obtained with a CL spectrometer as depicted in Figure 9. Luminescence peak in the spectrum can be assigned to aldehyde (360 nm) and singlet oxygen (480, 530, 570, 630, and 690 nm). These assignment may imply that the predominant reaction for the luminescence will be the termination reaction of some peroxy radicals (ROO) by disproportionation as below:

2ROO · \rightarrow **R'CHO*** + **R'OH** + ¹**O2***

A complex set of emission peaks can be seen in the wavelength range from 400 nm to go For more detailed ≥ 600nm in Figure 9. analysis of the emission spectrum in this spectrum ගු wavelength range, another measurement of the filter paper was conducted at 160°C in flowing nitrogen of 60 ml/min. With a plot of logarithm of luminous intensity in Figure 10, two groups of emission can be clearly identified. One group is comprised of a series of discreate emission bands for singlet The other group exhibited a oxygen. characteristic triangle with the apex of 500 nm



Figure 9 Luminescence spectrum of cellulose filter heated in nitrogen at 90°C.

(Russel Mechanism)



Figure 10 Luminescence spectrum of filter paper heated in nitrogen at 160°C. Continuous green emission and ¹O2 discrete emission band appeared.

which is green oxygen luminescence (see the photo in Figure 1). The spectrum was measured with cutoff filters from 400 nm to 600 nm at an interval of 20nm. Thus the characteristic triangle spectrum is an continuous spectrum like black-body radiation. This radiation might be generated by UV emission (360nm) on the adsorbed oxygen molecules because the chemiluminescent reaction of filter paper seems to occur in the gas phase as discussed above .

In order to demonstrate the green oxygen luminescence, a filter paper was irradiated with NUV (365nm) lamp for 10 seconds in nitrogen atmosphere at room temperature. With a plot of logarithm of luminous intensity against wavelength in Figure 11, emission spectrum seems to be consisted of two characteristic triangles with the apex of 480 nm and 520 nm. Emission bands of both singlet oxygen and carbonyl compounds has never been observed. This result may implys

that irradiation of cellulose with NUV lamp under this experimental conditions could not cause photochemical reactions. The short wavelength (480 nm) of the peak correspond to the shortest band (480 nm) of singlet oxygen molecules in visible region and the long wavelength (520 nm) seems to shift to longer wavelength by 40 nm. This red-shift is probably due to the formation of strong oxygen bonding between two hydroxyl groups in cellulose and adsorbed oxygen molecules.



Figure 10 Luminescence spectrum of cellulose filter measured after irradiation with UV lamp (365 nm) in nitrogen.

As described before two different values of activation energy were observed for paper filter heated in inert atmosphere. These experimental facts strongly suggest that there are two different types of oxygen bondings: weak oxygen bonding will be O2---O2 bond above monomolecular layer and strong oxygen bondong will be O2---hydroxyl group bond on the surface of cellulose (see the model for oxygen bonding in Figure 2). When filter paper was heated in an inert atmospher, oxygen could be initially generated from weakly bonded oxygen molecules and secondly from strongly bonded oxygen molecules. It is noteworthy that generation of oxygen molecules from the surface of filter paper will be the rate-controlling step of chemiluminescent reaction in nitrogen. Put another way, once energetic oxygen molecules areevolved from the surface of cellulose, subsequent autoxidation reactions would come to an end immediately.

Example 2 Effect of deoxygenating agent on milk powder

A fresh milk powder was exposed to NUV (365 nm) for 5 seconds in emission nitrogen and then measurement started after 5 second. The glass bottle of the milk powder was closed with a deoxygenation agent and kept in a refregirator for 2 weeks. The 2-weeks-aged milk powder was also treated with NUV lamp in the same way as fresh milk poder described above. Two emission decay curves for a fresh milk powder and the milk powder deoxygenated were plotted in Figure 11. The initial luminus intensity for fresh



Figure 11 Photo-induced emission curves for fresh milk powder and 2-weeks-stored milk powder with a deoxygenation agent.

milk was almost 50 times higher than that for deoxigenated fresh milk. The two emission curves overlap each other above 80 seconds. The emission decay curve for fresh milk powder is comprised of two straight lines with different slopes. The slope for the deoxigenated milk powder agrees with a gentle slope for fresh milk powder. Difference in the two emission curves may suggest that the curve with a steep slope originated from generation of weak oxygen-bonded

oxygen and that the curve with a gentle slope originated from strong oxygen-bonded oxygen. This may imply that deoxigenation agents could absorb multilayer oxygen molecules on milk powder but not the monomolecular oxygen.

Figure 12 depicts a color photograph of milk powder after exposure to NUV (365 nm) radiation. Bluish green colored surface of milk powder resembles the color photograph of a filter paper shown in Figure 1. This color photograph will be an another direct evidence for the presence of oxygen molecules on the surface of milk powder.



Figure 12 Color photograph of a milk powder taken with ultra high sensitive CCD camera immediately after exposure to NUV lamp (365nm) in air.

Example 3 Effect of color lamps on GOLD

Filter paper was irradiated with different color lamps in nitrogen atmospher. Figure 13 shows the luminescence curves of filter paper for blue, green, and red lamp. Luminous intensity for blue lamp was the highest and that for red lamp was the lowest. The former is several hundred times higher than the latter. Similar results were obtained for 18-8 stainless steel and glass cell. This result suggests that we can use blue light if a test sample is inadequate for irradiation of UV light.



Figure 13 Effect of color lamps (40 W) on the emission curves of filter paper in

Example 4 Aging of powdered manganese

Powdered manganese samples with an average diameter of 30 µm were stored in polyethylene bottle containing silica gel for different period of time from 5 months to 45 months. Five grams of mnganese powders aged 5, 15, and 45 months were put into a sample cell with a diameter of 5 cm. These samples were irradiated with a NUV (365 nm) lamp for 5 seconds in nitrogen and then luminescence measurement started after 5 seconds.



Figure 14 Aging effect on the luminescence curves for of powdered manganese in nitrogen.

Luminescence curves from the samples were obtained as seen in Figure 14. In this figure, starting points of the luminescence curves are shifted intensionally for easiness of reading. It was found that the peak height of their luminescence was exponentially increased with aging period. This result agrees well with that from other chemical analysis. It should be noted that no difference was observed in the luminescence measurements in air.

Example 5 Analysis of photo-induced luminescence of a glass

A glass vial with a diameter of 5 cm was set into the sample chamber and irradiated with a NUV (365 nm) lamp for 5 seconds and the luminescence measurement started after 5 seconds in air. Figure 15 shows the plots of the luminescence peak decay curves in two different ways to clarify the two-step luminescence; in the left figure normal intensity was plotted against logharism of time: in the right figure logarhysm of luminescence intensity was plotted against time. The fist-stage decay exhibited very fast until 10 seconds having the half-life time of about 3 seconds. The second-stage decay was slow having the half-life time of about 500 seconds, which has been known as after-glow.



Figure 15 Different plotting of the luminescence decay curves for glass vial irradiated with NUV (365 nm) in air.

Luminescence spectrum measurements were conducted for each stages. Left figure in Figure 16 is the spectrum for the second stage having the peak wavelength of 360 nm. This continuous spectrum is similar to the spectrum of quartz (SiO2). Unknown first stage spectrum was obtained by using four color filters as shown in the right figure of Figure 16.



Figure 16 Photo-irradiated luminescence spectra for glass vial. (left) spectrum for the second stage, (right) spectrum for the first stage.

By plotting the logarhysm of luminous intensity against wavelength, the peak wavelength of the first-stage luminescence was about 520 nm (green). Thus the first-stage luminescence could be originated from the green luminescence probably due to adsorbed oxygen.

Example 6 Photo- and thermal luminescence from 18-8 stainless steel

Stainless steel cell was irradiated with NUV (365 nm) lamp for 5 seconds luminescence and the measurement started after 5 seconds. Measured luminescence curves are plotted in Figure 17. Initial luminous intensity of the curves measured in nitrogen was almost one order of magnitude higher than those in air. Decrease in the intensity in air could be due to quenting effect of oxygen on the luminescence.



Figure 17 Luminescence decay curves for 18-8 stainless steel cell irradiated with NUV (365 nm) in air and nitrogen.

The photo-excited luminescence spectra of the stainless steel cell were measured in nitrogen atmosphere. Figure 18 is the overwiting of five spectra measured repeatedly. It should be pointed out that very weak luminescence spectra are not always the same because various noises such as thermal noise of photo-detector and cosmic rays could affect the luminous intensities. This figure shows that spectrum peaks ranges from 440 nm to 550 nm.

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Figure 18 NUV –irradiated luminescence spectrum for 18-8 stainless steel cell.

Figure 19 Luminescence spectrum for 18-8 stainless steel cell heated at 160°C in nitrogen.

Luminescence spectrum for the stainless steel cell heated in nitrogen at 160°C was depicts in Figure 19. The spectrum peak is tottally dofferent from the photo-excited spectrum. A series of band spectrum for singlet oxygen was clearly identified. It is noteworthy that adsorbed oxygen on stainless steel can be liberated by heaing but not by photo-irradiation. A luminescence peak at 370 nm migh be caused by emission of free electrons corresponding to the band gap of



Figure 20 Analysis of another luminescence spectrum for 18-8 stainless steel cell heated at 160°C in nitrogen.

chromium oxides on the surface of stainless steel. Green luminescence could not clearly identified in Figure 19. Another spectrum (Figure 20) exhibited both the characteristic triangle peak at 480 nm for green luminescence as well as a series of singlet oxygen luminescence bands.

Example 7 Application to a photo catalyst (TiO2)

Titanium oxides have been widely used as a photo-catalyst. Behavior of adsorbed oxygen on the surface of anataze titanium oxides (TiO2) were examined with GOLDS techniques. Figure 21 shows the luminescence curves irradiated with NUV (365 nm) lamp in both nitrogen and oxygen. Contrary to the results for the other test samples, initial luminous intensity was higher in oxygen than that in nitrogen.

Anataze TiO2 was heated in nitrogen



Figure 21 Luminescence curves for TiO2 irradiated with NUV lamp in O2 and in N2.

in the temperature range from 100°C to 160°C. Figure 22 shows the luminescence curves for the step heating of anataze TiO2. The steady state luminous intensities at different temperatures were plotted in Arrhenius plot (Figure 23). Activation energy for the thermo-excited luminescence of anataze TiO2 was calculated to be 22 kcal mol⁻¹, which is almost twice as high as those for cellulose, PTFE and glasses. Activation energy for the thermaly-excited luminescence was obtained to be 28 kcal mol⁻¹.



Figure 22 Luminescence curves for TiO2 heated in nitrogen from 100°C to 160°C.



Figure 23 Arrhenius plot of the luminous intensity against reciprocal temperature for TiO2 heated in nitrogen from 100°C to 160°C.

Photo-excited luminescences of anataze titanium oxide were strong and continued for long time compared to those for 18-8 stainless steel cell. All the light such as NUV (365 nm) lamp, NUV (375 nm)–LED, and fluorescence light were used to irrradiate anataze TiO2.

Luminescence spectra obtained by using the different light sources provided principally the same results. A typical luminescence spectrum for anataze TiO2 irradiated with fluorescence light under nitrogen atmosphere is shown in Figure 24 and that under oxygen in Figure 25. Both spectra are bascically the same. Spectrum bands originated from singlet oxygen can be seen in the wavelength range above 500 nm. A luminescence peak at 360 nm corresponds approximately with the band gap energy of anataze TiO2.



Figure 24 Luminescence spectra for TiO2 irradiated with fluorescent light in both oxygen (left spectrum) and nitrogen (right spectrum).

Simultaneous photo- and thermoexcited luminescence measurements of anatarze titanium oxide were conducted by using fluorescent loght in nitrogen. Figure 25 shows the luminescence curves at different temperatures from 25°C to 100°C. The luminescence decay curves were replotted against logarhysm of time in Figure 26, where one can see the initial slope of the curve decreases with increasing temperature. Activation energy for photoand thermo-excited luminescence for anatarze titanium oxide was obtained to be negative 9.3 kcal mol⁻¹. The apparent negative activation energy may suggest that adsorption of oxygen to the surface of TiO2 predominates photoin the and thermo-luminescence. Activation energy for the thermally excited luminescence of TiO2 was obtained to be 22 kcal mol⁻¹ (Figure 23). It should be remembered that cellulose gave two activation energies: 6.8 kcal mol⁻¹ for initial luminescence peaks and 12 kcal mol⁻¹ for steady-state thermoluminescence. The low activation energy was attributed to weak oxygen binding above second layer on cellulose. The higher activation energy could agree with



Figure 25 Luminescence curves for simultaneous photo- and thermal excited TiO2 irradiated with fluorescent light and heated to 100°C in nitrogen



Figure 26 Replotting of the luminescence curves in Fig. 25 and Arrehenius plot of the initial luminous intensity.

the bond energy for an oxygen bonding between hydroxyl groups of cellulose and oxygen molecules. By analogy with cellulose, the higher activation energy (22 kcal mol⁻¹) would corrspond to the oxygen bonding between the two oxygen atoms in TiO2 and O2 molecule. The lower value (9.3 kcal mol⁻¹) could be attributed to weak oxygen bonding between oxygen molecules (see model for oxygen bonding in Figure 2).

The real meaning of singlet oxygen emission from photo-irradiated TiO2 will be explained as below. Stainless steel did exhibit green luminescence but not singlet oxygen when it was irradiated with NUV lamp. Generation of singlet oxygens indicates that a huge number of energetic oxygen could be evolved. The ratio of singlet oxygen to energetic oxygen is unknown at this time. Combination of singlet oxygens and energetic oxygen must be the power to kill germs. In addition to this effect, liberation of oxygen from the surface of TiO2 may increase the hydrophilicity of TiO2. The surface of untreated TiO2 must be completely covered with oxygen molecules by forming coovalent bonds which are originally lipophilic. Photo-irradiation of TiO2 could evolve oxygen and the vacant sites of oxygen could be occupied with H2O resulting in increase of hydrophilicity.

5. Merits of GOLDS

Green oxygen luminescence detection and spectroscopy (GOLDS) technique is very new and promissing daignaustic technique for the surface chemistry and autoxidation studies. In other word, GOLDS exploits adsorbed oxygen as a probe to investigate the surface of almost all materials. GOLDS measurement is very fast, quantitative, and reproducible. Luminescence spectrum can provide us a good clue to reveal the mechanism of unsolved questions on the surface of materials.

Specifications

Type of CL Analyzer	CLA-GOLDS (Green Oxygen Luminescence Detector and Spectrometer)
Photo Detection	Single photon counting with photomultiplier tube (PMT)
PMT Detection Range	300 nm ~ 850 nm (Center wavelength: 420 nm)
Cut Filters	330 nm ~ 700 nm (20 filters with an interval of 20 nm)
Filter Exchange Device	Rotating table having 20 filters is controlled by a computer software named CLA-DASH
PMT Cooling Method	Primary cooling: Pertier Electronic Cooling Secondary cooling: Water Chiller
Temperature Control	Electronic Heater embedded in sample chamber Temperature controller is on the front panel. (Temp. control can be done by manually and with computer.)
Temperature Range	R.T. ~ 100 (CLS-OL)
Monitoring of CL count	Indicated on the front panel by LED indicator
Output Signal	Recorder Output: 1.0 V/F.S Integrator Output: 1.0 V/F.S RS-232 Interface (com1, com2)
Additional Functions	Gain Control, Attenuation Switching, Auto-zero function Marker signal generator, Alarm display
Power Source	AC 100V, 50/60Hz, 6A
Size and Weight	520(W) x 420(D) x 547(H) mm, Approx. 50 kg

Software

CLA Data Acquisition Software (CLA-DASH) (runs on Windows 98/Xp)

CL measurement: Measuring conditions, shutter control, Temp. control, data monitoring, Start, Stop, Pause

CL data Analysis: File, Graph-processing, Overlay, Print, Calculation

* CLA-DASH does not include the function of chromatograph analysis.

Sample Chamber

Product Model	Model CLS-OL
Sample Dish	A stainless steel sample dish is put in this holder(50mm)
Injection Port	1(one) port on the front panel (a TEIC needle is necessary)
Electrical Heater	Fixed under the holder and maximum temperature is 100°C or less
Functions	IN (inlet) & OUT (outlet) on the front panel
	Magnetic sheet is built-in under the sample dish holder
Size Weights	221(W) x 357(D) x 121(H) mm approx 4kg
LED Controller	radiation sources : near ultraviolet (NUV)-LED <375nm>

The contents described in this document are subject to change without notice



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