Hollow Cathode Lamps

HAMAMATSU

PHOTON IS OUR BUSINESS

Overview

Atomic absorption spectroscopy (or AAS) in its modern form came from principles developed by Australian physicist Dr. A. Walsh in 1955. Atomic absorption spectroscopy is ideal for analyzing minute quantities of metallic elements because its operating principle and analysis method offer relatively simple measurement with high accuracy.
Hamamatsu provides a full line of hollow cathode lamps developed by our discharge tube manufacturing technology accumulated over long years of experience. These lamps provide the sharp, high-purity spectral lines essential for high accuracy measurement.

■Type of hollow cathode lamps

Hollow cathode lamps consist of single-element lamps and multi-element lamps. Single-element lamps are usually superior to multi-element lamps in absorption sensitivity and analytical line radiant intensity. Although multi-element lamps offer the advantage of simultaneous determination of multiple elements, their cathode composition must be determined by taking the properties of the metals to combine fully into account, so fabricating cathodes from an optional combination of elements is not possible.

■Applications

- **Atomic absorption spectrophotometers**
- **Atomic fluorescence spectrophotometers**
- **Multi-element analyzers**
- **Environmental analytical instruments**

Construction

As shown in Figure 1, a hollow cathode lamp is constructed with a bulb having a window (④ in Figure 1) made of quartz or UV-transmitting glass or borosilicate glass for spectral line emission, and into which a hollow cylindrical cathode (② in Figure 1) and a ring-shaped anode (① in Figure 1) are assembled. Noble gas is also sealed inside at a pressure of several hundred pascals. The cathode is made of a single element or alloy of the element to be analyzed to ensure sharp analytical spectral lines with an absolute minimum of interfering spectral components.

Figure 1: Construction of hollow cathode lamp

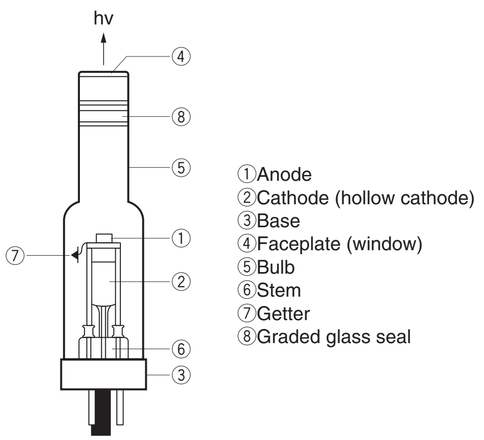
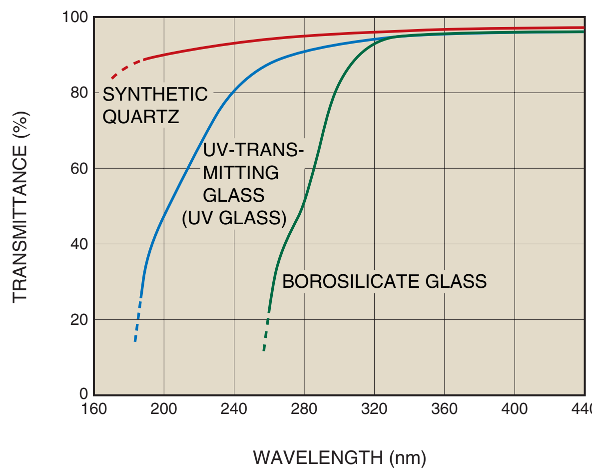


Figure 2: Transmittance of window glass materials



Operating Principle

The hollow cathode lamp is a type of glow discharge tube that uses a hollow cathode to enhance the emission intensity. Compared to parallel plate electrodes, using a hollow cathode increases the current density by more than 10 times and this is accompanied by a significant increase in light intensity and a lower voltage drop in the lamp. This is known as the hollow cathode effect (or hollow effect).
When a voltage is applied across the electrodes of a hollow cathode lamp to cause a discharge in the lamp, electrons pass from the interior of the cathode to the cathode-fall region and flow through the negative glow region toward the anode. This causes ionization of the gas within the lamp through inelastic collisions with the gas atoms. Positive ions generated by the gas ionization are accelerated by the electric field and collide with the cathode surface. The kinetic energy of ion impact causes the cathode materials to sputter (or fly) away from the cathode surface in the form of an atomic vapor. This metallic vapor consists primarily of single atoms in the ground state and they are thermally dispersed within the hollow cathode.
Meanwhile an electron bunch or cluster is accelerated by the electric field toward the anode. The accelerated electrons collide with the ground-state metallic atoms being diffused and excite the metallic atoms. The excited metallic atoms return to the ground state again in an extremely short transition time of about 10-8 seconds. At this point, monochromatic light characteristic of those atoms is emitted at an energy corresponding to the energy difference between the excited state and the ground state.
This transition of electrons occurs not only in the target element for quantitative analysis but also in other elements of the cathode materials, causing a variety of energy transitions to occur. So, in a wide spectral range, many spectral lines of those elements and the filler gas can be observed. Transition metal elements such as Ni, Co and Fe in particular result in an extremely large number of spectral lines.

For conventional atomic absorption spectroscopy

Lineup of Hollow Cathode Lamps

●L233 series (38 mm diameter): Single-element hollow cathode lamps (66 lamps) ①

Element		Atomic Number	Type No. (suffix)	Analytical Line (nm)	Operating Current (mA)	Maximum Current (mA)
Ag	Silver	47	-47NB	328.07 * 338.28	10	20
Al	Aluminium	13	-13NB	309.27 * 396.15	10	20
As	Arsenic	33	-33NQ	193.70 * 197.20	10	12
Au	Gold	79	-79NQ	242.80 * 267.59	10	16
B	Boron	5	-5NQ	249.68 * 249.77	10	20
Ba	Barium	56	-56NB	553.55 *	10	20
Be	Beryllium	4	-4NQ	234.86 *	10	20
Bi	Bismuth	83	-83NQ	223.06 * 306.77	10	12
Ca	Calcium	20	-20NU	422.67 *	10	18
Cd	Cadmium	48	-48NQ	228.80 *	5	12
Co	Cobalt	27	-27NU	240.73 * 346.58	10	20
Cr	Chromium	24	-24NB	357.87 * 425.44	10	20
Cs	Caesium	55	-55NB	852.11 *	10	20
Cu	Copper	29	-29NB	324.75 * 327.40	10	20
Dy	Dysprosium	66	-66NB	404.59 * 421.17	15	15
Er	Erbium	68	-68NB	400.79 * 415.11	15	15
Eu	Europium	63	-63NB	459.40 * 462.72	15	15
Fe	Iron	26	-26NU	248.33 * 371.99	10	20
Ga	Gallium	31	-31NU	287.42 294.36 *	4	6
Gd	Gadolinium	64	-64NB	407.87 422.58 *	12	12
Ge	Germanium	32	-32NU	265.16 *	10	20
Hf	Hafnium	72	-72NU	286.64 * 307.29	20	25
Hg	Mercury	80	-80NU	253.65 *	4	6
Ho	Holmium	67	-67NB	410.38 * 416.30	15	20
In	Indium	49	-49NB	303.94 * 325.61	10	15
Ir	Iridium	77	-77NQ	208.88 * 266.47	20	20
K	Potassium	19	-19NB	766.49 * 769.90	10	15
La	Lanthanum	57	-57NB	357.44 550.13 *	10	20
Li	Lithium	3	-3NB	610.36 670.78 *	10	20
Lu	Lutetium	71	-71NB	328.17 331.21 *	15	15
Mg	Magnesium	12	-12NU	285.21 *	10	18
Mn	Manganese	25	-25NU	279.48 * 403.08	10	20
Mo	Molybdenum	42	-42NB	313.26 * 320.88	10	20
Na	Sodium	11	-11NB	589.00 * 589.59	10	15
Nb	Niobium	41	-41NB	334.91 * 405.89	20	30
Nd	Neodymium	60	-60NB	463.42 492.45 *	15	15
Ni	Nickel	28	-28NQ	232.00 * 341.48	10	20
Os	Osmium	76	-76NU	290.90 * 305.86	15	15
Pb	Lead	82	-82NQ	217.00 * 283.30	10	15
Pd	Palladium	46	-46NQ	244.79 * 247.64	10	20
Pr	Praseodymium	59	-59NB	495.13 * 513.34	15	15
Pt	Platinum	78	-78NU	265.95 * 299.80	10	20
Rb	Rubidium	37	-37NB	780.02 * 794.76	10	20
Re	Rhenium	75	-75NB	346.05 * 346.47	20	25
Rh	Rhodium	45	-45NB	343.49 *	10	20
Ru	Ruthenium	44	-44NB	349.89 *	20	25
Sb	Antimony	51	-51NQ	217.58 * 231.15	10	15
Sc	Scandium	21	-21NB	390.74 391.18 *	10	15
Se	Selenium	34	-34NQ	196.03 *	20	25
Si	Silicon	14	-14NU	251.61 * 288.16	10	20
Sm	Samarium	62	-62NB	429.67 * 484.17	15	20
Sn	Tin	50	-50NQ	224.61 * 286.33	20	20
Sr	Strontium	38	-38NB	460.73 *	10	20
Ta	Tantalum	73	-73NU	271.47 * 275.83	10	20
Tb	Terbium	65	-65NB	431.88 432.64 *	15	15
Te	Tellurium	52	-52NQ	214.27 *	10	15
Ti	Titanium	22	-22NB	364.27 * 365.35	10	20
Tl	Thallium	81	-81NU	276.78 * 377.57	7	10
Tm	Thulium	69	-69NB	371.79 * 410.58	10	15
V	Vanadium	23	-23NB	306.64 318.40 *	10	20
W	Tungsten	74	-74NU	255.14 * 400.87	10	25
Y	Yttrium	39	-39NB	410.23 * 412.83	15	15
Yb	Ytterbium	70	-70NB	346.43 398.79 *	10	10
Zn	Zinc	30	-30NQ	213.86 * 307.59	7	15
Zr	Zirconium	40	-40NB	360.12 * 468.78	20	20
D_2	Hydrogen	1	-1DQ	240.00 (peak value)	30	35

●L733 series (38 mm diameter): Multi-element hollow cathode lamps (11 lamps) ①

Element		Atomic Number	Type No. (suffix)	Analytical Line (nm)	Operating Current (mA)	Maximum Current (mA)
Na-K	Sodium Potassium	11 19	-201NB	Na 589.00 * K 766.49 *	10	15
Ca-Mg	Calcium Magnesium	20 12	-202NU	Ca 422.67 * Mg 285.21 *	10	18
Si-Al	Silicon Aluminium	14 13	-203NU	Si 251.61 * Al 309.27 *	10	20
Fe-Ni	Iron Nickel	26 28	-204NQ	Fe 248.33 * Ni 232.00 *	10	20
Sr-Ba	Strontium Barium	38 56	-205NB	Sr 460.73 * Ba 553.55 *	10	20
Al-Ca-Mg	Aluminium Calcium Magnesium	13 20 12	-321NU	Al 309.27 * Ca 422.67 * Mg 285.21 *	10	18
Ca-Mg-Zn	Calcium Magnesium Zinc	20 12 30	-322NQ	Ca 422.67 * Mg 285.21 * Zn 213.86 *	10	15
Cu-Mo-Co-Zn	Copper Molybdenum Cobalt Zinc	29 42 27 30	-401NQ	Cu 324.75 * Mo 313.26 * Co 240.73 * Zn 213.86 *	10	15
Cd-Cu-Pb-Zn	Cadmium Copper Lead Zinc	48 29 82 30	-402NQ	Cd 228.80 * Cu 324.75 * Pb 217.00 * Zn 213.86 *	10	15
Cu-Fe-Mn-Zn	Copper Iron Manganese Zinc	29 26 25 30	-405NQ	Cu 324.75 * Fe 248.33 * Mn 279.48 * Zn 213.86 *	8	15
Co-Cr-Cu-Fe-Mn-Ni	Cobalt Chromium Copper Iron Manganese Nickel	27 24 29 26 25 28	-601NQ	Co 240.73 * Cr 357.87 * Cu 324.75 * Fe 248.33 * Mn 279.48 * Ni 232.00 *	10	20

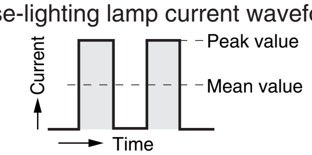
Analytical lines marked with an asterisk (*) indicate the maximum absorption wavelength of each element. Since each element has two or more spectral emission lines, select the spectral line that best suits the sample concentration.

NOTE: ①The guaranteed lifetime is defined by the product of the operating current and the accumulated operating time and is specified as 5000 mA·hrs except for the guaranteed lifetimes of As, Ga and Hg which are specified as 3000 mA·hrs.

Note on the L233 and L733 series current values

The operating current and maximum current values listed above are specified as a peak current value. However, instruments using a pulse lighting system may indicate the lamp current value as the mean value. So, when using such an instrument, verify which current value (mean or peak) it indicates and use the specified current value to operate lamps correctly.

Pulse-lighting lamp current waveform



For atomic absorption spectroscopy using the S-H method background correction

Lineup of Giant-pulse Hollow Cathode Lamps

●L2433 series (38 mm diameter): Single-element hollow cathode lamps (46 lamps)

Element		Atomic Number	Type No. (suffix)	Analytical Line (nm)	Low ① Current (mA)	High ① Current (mA)	Accumulated ② Lifetime (mA·ms·h)	Operating ② Lifetime (h)
Ag	Silver	47	-47NB	328.07 * 338.28	10	400	20 000	500
Al	Aluminium	13	-13NB	309.27 * 396.15	10	600	30 000	500
As	Arsenic	33	-33NQ	193.70 * 197.20	12	500	7500	150
Au	Gold	79	-79NQ	242.80 * 267.59	10	400	20 000	500
B	Boron	5	-5NQ	249.68 * 249.77	10	500	5000	100
Ba	Barium	56	-56NB	553.55 *	15	600	30 000	500
Be	Beryllium	4	-4NQ	234.86 *	10	600	6000	100
Bi	Bismuth	83	-83NQ	223.06 * 306.77	10	300	6000	200
Ca	Calcium	20	-20NU	422.67 *	15	600	30 000	500
Cd	Cadmium	48	-48NQ	228.80 *	8	100	5000	500
Co	Cobalt	27	-27NU	240.73 * 346.58	15	400	20 000	500
Cr	Chromium	24	-24NB	357.87 * 425.44	10	600	12 000	200
Cu	Copper	29	-29NB	324.75 * 327.40	10	500	25 000	500
Dy	Dysprosium	66	-66NB	404.59 * 421.17	15	600	6000	100
Er	Erbium	68	-68NB	400.79 * 415.11	15	500	5000	100
Eu	Europium	63	-63NB	459.40 * 462.72	10	600	6000	100
Fe	Iron	26	-26NU ②	248.33 * 371.99	12	400	20 000	500
Ga	Gallium	31	-31NU	287.42 294.36 *	4	400	4000	100
Ge	Germanium	32	-32NU	265.16 *	20	500	5000	100
Hf	Hafnium	72	-72NU	286.64 * 307.29	20	600	6000	100
Hg	Mercury	80	-80NU	253.65 *	12	400	4000	100
Ho	Holmium	67	-67NB	410.38 * 416.30	10	600	6000	100
K	Potassium	19	-19NB	766.49 * 769.90	10	600	30 000	500
La	Lanthanum	57	-57NB	357.44 550.13 *	20	600	9000	150
Li	Lithium	3	-3NB	610.36 670.78 *	15	500	25 000	500
Mg	Magnesium	12	-12NU	285.21 *	10	500	25 000	500
Mn	Manganese	25	-25NU	279.48 * 403.08	10	600	30 000	500
Mo	Molybdenum	42	-42NB	313.26 * 320.88	10	600	9000	150
Na	Sodium	11	-11NB	589.00 * 589.59	10	600	12 000	200
Ni	Nickel	28	-28NQ	232.00 * 341.48	10	400	20 000	500
Pb	Lead	82	-82NQ	217.00 * 283.30	10	300	15 000	500
Pd	Palladium	46	-46NQ	244.79 * 247.64	10	300	3000	100
Pt	Platinum	78	-78NU	265.95 * 299.80	10	300	3000	100
Ru	Ruthenium	44	-44NB	349.89 *	20	600	6000	100
Sb	Antimony	51	-51NQ	217.58 * 231.15	15	500	7500	150
Se	Selenium	34	-34NQ	196.03 *	15	300	4500	150
Si	Silicon	14	-14NU	251.61 * 288.16	10	500	10 000	200
Sm	Samarium	62	-62NB	429.67 * 484.17	15	600	6000	100
Sn	Tin	50	-50NQ	224.61 * 286.33	20	500	25 000	500
Sr	Strontium	38	-38NB	460.73 *	10	500	25 000	500
Te	Tellurium	52	-52NQ	214.27 *	15	400	4000	100
Ti	Titanium	22	-22NB	364.27 * 365.35	10	600	12 000	200
V	Vanadium	23	-23NB	306.64 318.40 *	10	700	7000	100
Y	Yttrium	39	-39NB	410.23 * 412.83	15	600	6000	100
Yb	Ytterbium	70	-70NB	346.43 398.79 *	5	200	2000	100
Zn	Zinc	30	-30NQ	213.86 * 307.59	10	300	15 000	500

Analytical lines marked with an asterisk (*) indicate the maximum absorption wavelength of each element. Since each element has two or more spectral emission lines, select the spectral line that best suits the sample concentration.

NOTE:

① Maximum discharge current: Peak current (See the current waveform charts for the low current and high current waveform specifications.)

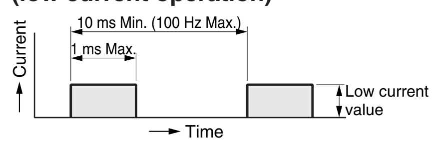
② · When lamps are operated at a current less than the maximum discharge current specified for each element:
The accumulated lifetime(mA·ms·h) is defined by the operating time including the lamp preheat time multiplied by the product of the low current and its time width or the product of the high current and its time width, whichever is larger.
· When lamps are operated at the maximum discharge current specified for each element:
The guaranteed lifetime (operating lifetime) is defined by the accumulated operating time including the lamp preheat time.
The guaranteed lifetime is specified by either of the above definitions.

Note on L2433 series current values

●Low current operation

Absorption of the target element occurs when a lamp is operated at a low current. While making sure not to exceed the low current value listed for the lamp, set the current at which the best analytical sensitivity is obtained.

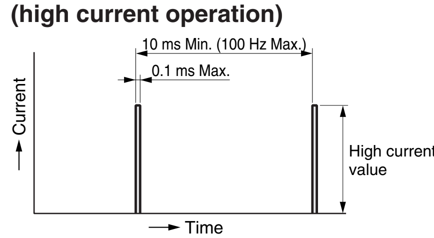
Current waveform chart (low current operation)



●High current operation

When a lamp is operated at a high current, a self-reversal effect occurs in the lamp to absorb the background. As in low current operation, set the current while making sure not to exceed the high current value listed for the lamp.

Current waveform chart (high current operation)



●Time width

Do not operate the lamps in a state where the time width of the discharge current waveform exceeds the maximum time width shown in the above charts.

Lamp Current and Absorption Sensitivity

The ideal analytical line profile of the light emitted by a hollow cathode lamp should exhibit no spectral line broadening other than natural broadening. In actual operation, however, the spectral lines are emitted along with a certain broadening. The causes of such broadening include Doppler broadening, self-absorption line width distortion, Lorentz broadening (pressure broadening), Holtzmark broadening (resonance broadening), Zeeman effect broadening, and Stark effect broadening. Among these, Doppler broadening and self-absorption line width distortion are major factors in broadening so that broadening related to other causes is usually small enough to be ignored.

Doppler broadening depends on the random thermal motion of the light-emitting atoms, which is affected by the temperature of the gas. Spectral line broadening does not occur as long as the thermal motion of the atoms is within a plane perpendicular to a line connecting the observation point and the light source. However, if the thermal motion of the atoms is parallel to that line (forward and back motion as seen from the observation point), the frequency at the emitted light observation point will increase (shift to shorter wavelength side) during motion toward the observation point and decrease (shift to longer wavelength side) during motion away from the observation point. This phenomenon is the so-called Doppler effect. Light-emitting atoms in a hollow cathode have a random thermal motion that causes the spectral lines to broaden. The width λ_0 of this Doppler broadening can be expressed by the following equation:

$$\Delta\lambda_D = 1.67 \times \frac{\lambda_0}{c}\sqrt{\frac{2RT}{Ma}}$$

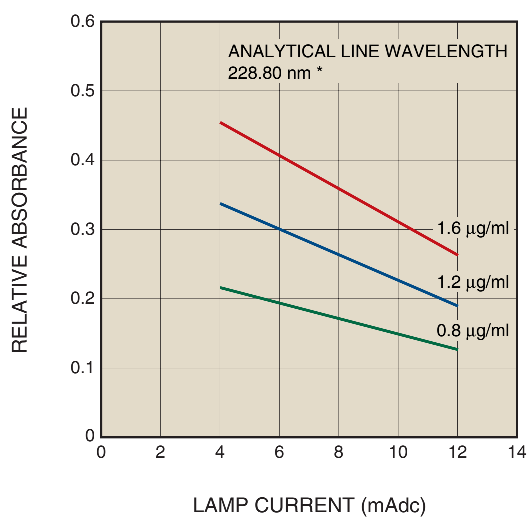
where c is the velocity of light, R is the gas constant, T is the absolute temperature of the gas, and Ma is the atomic weight.

Self-absorption occurs when there is a temperature gradient within the atomic vapor layer inside the cathode hollow, in other words, it occurs when the atomic vapor within the cathode hollow is flowing out of the hollow. In this state, atoms in the higher-temperature atomic vapor layer within the hollow are more excited than those in the lower-temperature atomic vapor layer outside the hollow, and so cause light emission. When the emitted light passes through the relatively low temperature atomic vapor layer outside the hollow, it is absorbed by the atoms in the ground state. This phenomenon is termed self-absorption and just as with the Doppler effect results in broadening of analytical line width and a loss of absorption sensitivity.

As stated above, deterioration in the analytical line profile depends on the lamp current, so care must be taken since increasing the lamp current may cause an excessive increase in atomic vapor. In actual measurement, it is essential to operate the lamp at an optimal current that takes into account both the analytical line output intensity and absorption sensitivity.
The self-absorption effect is large for high-vaporization-pressure elements such as Cd (Cadmium) and small for low-vaporization-pressure elements such as Mo (Molybdenum). The typical operating current for the former is usually specified as a low value.

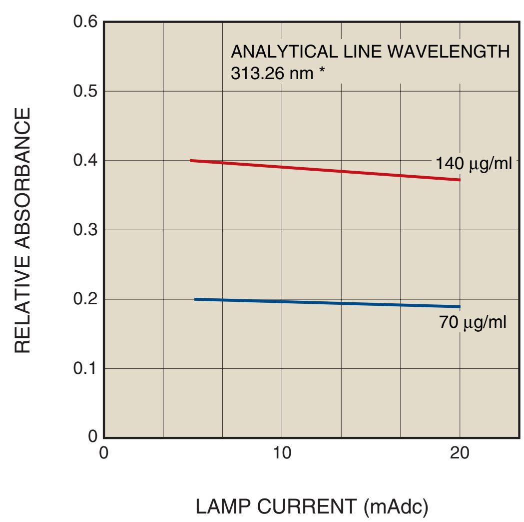
Figure 3: Lamp current vs. absorption sensitivity (typical example)

●L233-48NQ (Cd)



* Maximum absorption wavelength

●L233-42NB (Mo)

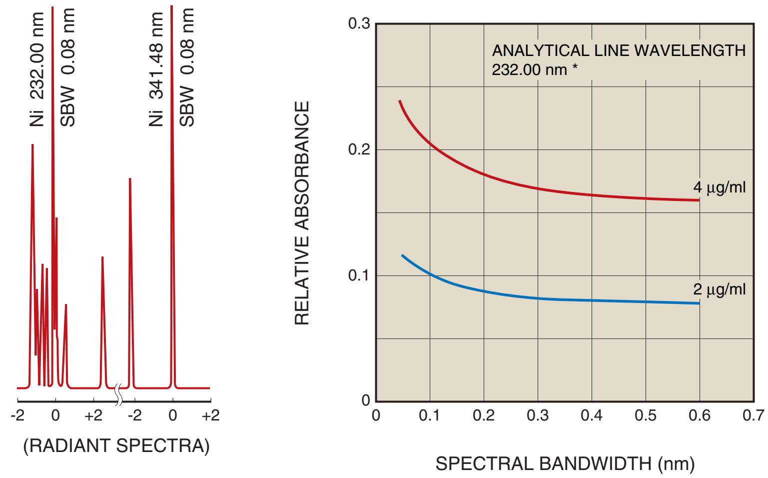


Spectral Bandwidth (S.B.W.) and Absorption Sensitivity

In the vicinity of an analytical line, the presence of other spectral lines from the same element or a different element will cause the absorption sensitivity to drop. (These spectral lines in the vicinity of the analytical line are known as proximity lines.) When these proximity lines are present, the spectral bandwidth (SBW) should be narrowed to reduce the effect of proximity lines by narrowing the slit width of the spectrophotometer.

Figure 4: Spectral bandwidth and absorption sensitivity (typical example)

●L233-28NQ (Ni)



* Maximum absorption wavelength

Time Stability of Analytical Line Radiant Intensity

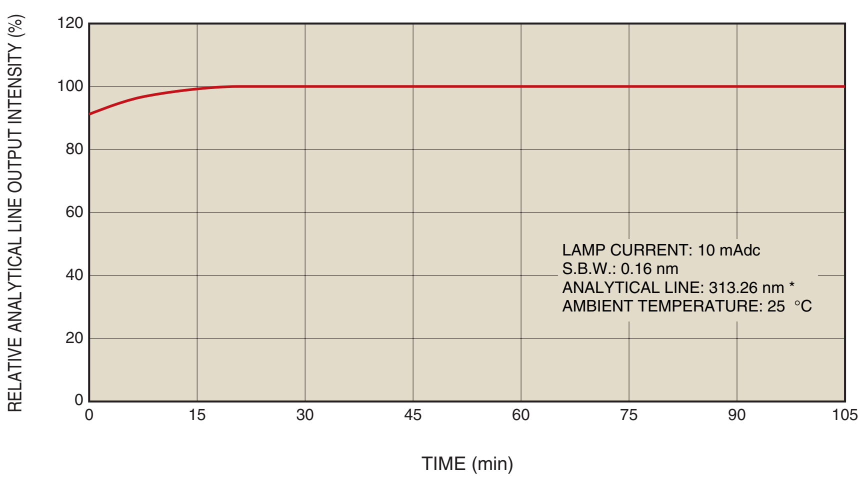
As described in the section dealing with the emission process of spectral lines, sputtered metal atoms are thermally diffused during repeated inelastic collisions with electrons. In this process, during the period required for the metal atom density to reach equilibrium, the radiant intensity of the analytical lines varies. This variation usually occurs in the direction of increased intensity for 10 to 20 minutes after the lamp has started, although it will vary depending on the element and operating current. After reaching equilibrium, the radiant output intensity at the analytical line wavelength is extremely stable.

In high-vapor-pressure element lamps, operation at excessive current levels causes excessively vaporized metal atoms to flow out of the hollow cathode space in the direction of the optical axis. This causes a temperature gradient to occur and might lower the analytical line output intensity due to phenomena such as self-absorption.

After a lamp has been left unused for a long period of time, some amount of time may be required for analytical line output intensity to reach initial stabilization, which results from changes in the cathode surface over time and depends on the element (especially alkaline element). Even in such cases, once the lamp is operated, it will light up normally from the next time.

Figure 5: Time stability of analytical line output intensity (typical example)

●L233-42NB (Mo)



* Maximum absorption wavelength

Life

The life of a hollow cathode lamp is greatly affected by the operating current. This is due to the increase in the energy of positive ions colliding with the cathode surface which causes violent sputtering. During pulse operation as well, there is no change in the energy of the ions colliding with the cathode surface at each pulse, so lamp life is determined by the peak current and the pulse width (time width).

The following phenomena may be observed when a lamp has reached its life end:

(1) Discharge does not occur at the hollow cathode and the current does not vary even if the current control knob is changed. The analytical line output is not detectable.

(2) Extreme variations occur in analytical line intensity and the lamp current may also vary in some cases.

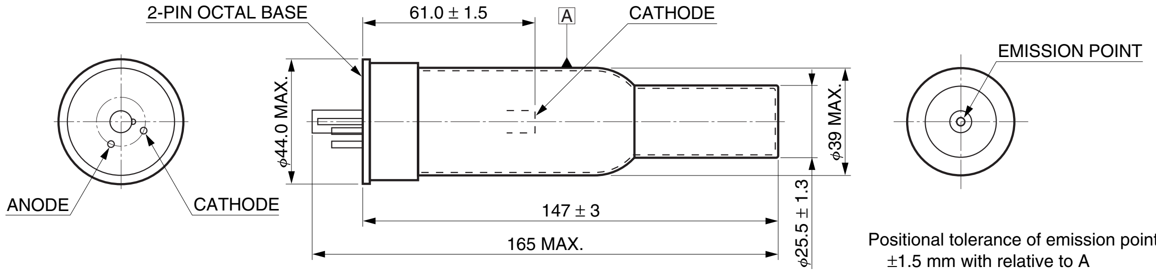
(3) The analytical line intensity weakens significantly and the signal-to-noise ratio deteriorates.

The major cause of these phenomena is a drop in gas pressure within the lamp. This drop in gas pressure is caused by the "gas clean-up" phenomenon in which cathode metal atoms sputtered during discharging attracts gases while being scattered and these adhere together to the bulb wall and electrodes at a lower temperature.

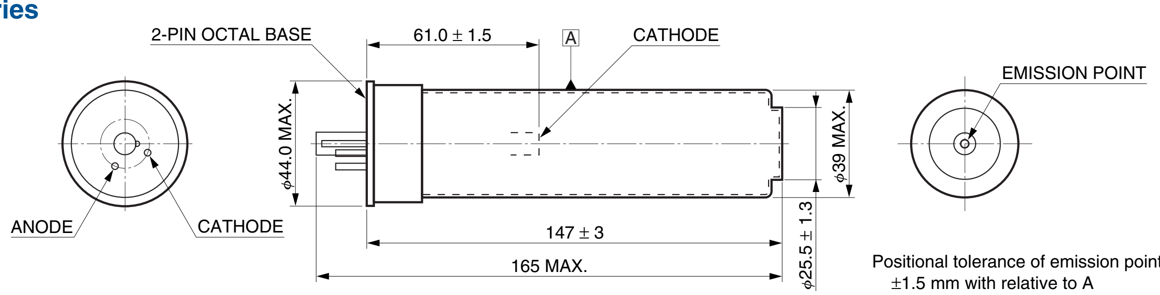
As the lamp is used, the cathode hollow shape is gradually worn away and deformed by sputtering from the discharge. These characteristics will vary depending upon the element and will exhibit small differences even for lamps of the same element.

Dimensional Outlines (Unit: mm)

●L233 / L733 series



●L2433 series



Related Products

Deuterium lamps (L2D2 lamps)

L2D2 lamps are deuterium lamps developed for spectrophotometry for chemical analysis.

These L2D2 lamps offer long service life, high stability, and the high output needed for light sources used in spectrophotometry. L2D2 lamps can also be used for background correction in atomic absorption spectrophotometers.

Photomultiplier tubes

Among the many light sensors currently available, photomultiplier tubes are the most sensitive and photodetectors with high speed response.

Photomultiplier tubes are designed and manufactured to provide stable operation even when detecting changes in weak light or its on/off, or even when the supply voltage is varied. These features make photomultiplier tubes useful as a photodetectors that ensure accurate measurements in atomic absorption spectroscopy.

Precautions and Warranty

■Precautions

1. Long-term storage

Please note that the lamps should be used shortly after delivery. If the lamps are left unused for a long period of 6 months or more, take the following precautions:

· Store the lamps in low humidity and at room temperature in locations where no corrosive gases are present and temperature fluctuations are minimal.

· We recommend operating the lamp for approximately 3 hours once every 3 months at half the normal operating current specified for the lamp in order to stabilize the lamp characteristics.

2. Handling

· High voltage is supplied to the lamp to start operation. Take precautions to avoid electrical shock.

· Ultraviolet rays harmful to the eyes and skin are emitted from the lamp faceplate (window) during operation. Do not look directly at the operating lamp.

· Disposal of hollow cathode lamps

The cathode of some hollow cathode lamps contains elements that are defined as hazardous substances under waste disposal laws. When disposing of the lamps using such as the cathode, entrust proper disposal to an industrial waste disposal company licensed to perform intermediate treatment and final disposal of hazardous substances. Lamps using a cathode that does not contain the following elements may be disposed of as normal industrial waste (like glass and ceramic waste). Even in such cases, be sure to comply with local regulations to ensure correct disposal.

Elements of hazardous substance: As, Be, Cd, Cr, Cs, Cu, Hg, In, K, Na, Ni, Pb, Rb, Se, V, Zn, Na-K

· Do not touch the lamp faceplate window with bare hands. Grime from the hands adhering to the faceplate will cause a drop in the analytical line output intensity. If there is grime, wipe the faceplate using gauze or oil-free cotton moistened with high-purity alcohol and wrung out thoroughly. Note that the volatile vaporization of organic solvents will absorb analytical lines of As, Se, etc. So use caution when handling such solvents near the measurement site.

· The bulb wall or electrodes of some lamps might appear in a blackened state when delivered. This is caused by the spattering of cathode materials and this condition will differ depending on the particular element. This condition is especially noticeable on lamps with high vapor pressure elements such as As, Se, Cd, Zn, Na and K. This condition occurs during the manufacturing process and does not affect the lamp operating characteristics.

· The major analytical lines used in atomic absorption spectroscopy are present in the UV wavelength range from 200 nm to 300 nm. Since mirrors, lenses and other optical components generally have low reflection or transmission efficiency in this wavelength region, alternately fine-adjust the spectrophotometer wavelength dial and the lamp position so that the output meter indicates the maximum while checking the wavelength dial scale to achieve the correct analytical line wavelength. Failure to make this analytical line wavelength adjustment correctly may prevent obtaining high measurement accuracy.

· If a high current is passed through the lamp suddenly at the beginning of discharge or the power supply is cut off suddenly during discharge, surge currents or other abnormal currents will flow in the lamp, causing unnecessary lamp deterioration. When lighting the lamp, gradually increase the lamp current to the specified value and when turning off the lamp, also gradually decrease the current to ensure a long lamp life with stable operation.

· The maximum current shown on the lamp is the absolute maximum value (which is broadly viewed as the guaranteed current at which no damage is caused to the lamp). In lamps based on elements having high vapor pressure (e.g., Hg, Cd and Zn), the maximum current shown on the lamp is set to a low current value. If this type of lamp is operated at a current higher than this value, the resulting Joule heat might melt the cathode.

■Warranty

Warranty period

Hamamatsu hollow cathode lamps are warranted for a period of one year after the date of delivery.

Warranty coverage

The warranty is limited to repair or replacement of defective lamps free of charge.

Cases not covered by warranty

The warrant shall not apply to the following cases even if within the warranty period.

· Lamp operation has exceeded the guaranteed life time.

· Lamp failure was caused by incorrect usage that did not meet the product specifications or by careless handling or modifications made by the user.

· Lamp failure was caused or induced by unavoidable accidents such as natural disasters.

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