Electrodes

In the lamp, the transformation of electrical energy into a light emitting plasma takes place at the electrodes. For the electrode design to be considered effective, this transfer must be efficient, and the resultant arc must be reliably controlled for maximum lamp life and system performance. With this in mind, the importance of the electrode should not be overlooked.

The anode

The simplest of the electrodes is the anode, made of high purity Tungsten doped with a rare earth oxide. The dopant aids the machining of the electrode which would otherwise be difficult (pure Tungsten is very brittle). The anode's primary purpose is to receive the charge emitted by the cathode and hence complete the electrical circuit.

Care should be taken when considering shape. The anode must have a large tip area that is in proportion to the power it receives. It should also have a shape that holds the arc in the centre of the lamp's bore at all times. Where the arc is allowed to drift close to the quartz, an excessive thermal loading is caused which rapidly ages the quartz and consequently reduces the lamp's life.

The cathode

Like the anode, the main body of the cathode is manufactured from doped Tungsten, however a separate tip is brazed onto the main body of the electrode. While this tip only forms a small part of the lamp's construction, it is arguably one of the most important features of the lamp.

The tip of the cathode is made of porous Tungsten. This porosity is tightly controlled during the manufacturing process, when the loose powder is compressed, under massive pressures, to form the tip.

At the time of writing, Heraeus Noblelight is the only laser lamp manufacturer to carry out this process in-house, where it is controlled to a precise degree. The porous Tungsten matrix is then impregnated with a dopant, again to a defined level.

The dopant is a proprietary powder having a low work function, to ease the emission of electrons and reduce the temperature for an extended cathode lifetime. Depending on the lamp's application, the level of doping used needs careful consideration - Engineers at Heraeus Noblelight can advise on this. For instance, in the case of a continuous wave (CW) lamp, there is a high concentration of dopant on the surface of the cathode to aid the lamp's operation. Yet in the case of pulse lamps where there is a high peak current and a long pulse, the amount of emissive material on the surface of the cathode should be limited.

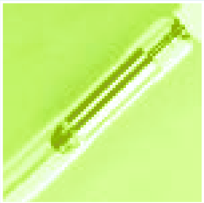
Providing consideration is given to the above, cathode break-up is reduced, thus increasing the lamps' life.

Cathode types

The Hi-Charge™ cathode

Heraeus Noblelight's patented High Charge Transfer design (figure 6) represents an exclusive development in cathode technology that today remains unrivalled in the lamp industry.

This innovative technology allows Heraeus Noblelight Design Engineers to fine-tune the temperature of the emitting surface of a cathode for optimum performance. Figure 4 demonstrates the increased lifetime over competitors' lamps in relation to charge transfer.



Electrodes continued

Lamps which are operated using a square wave pulsed power supply can be prone to premature ageing because of thermal cycling in the cathode tip. This occurs due to the relatively long time periods between the high power pulses. The Hi-Charge™ design developed by Heraeus Noblelight limits thermal cycling and the associated ageing by incorporating a thermal choke in the neck of the cathode. This restricts thermal energy flow out of the cathode between pulses and stabilises the operating temperature.

By varying the width of the cathode neck, the operating temperature of the cathode can be moved through a range until an optimum is achieved. Figures 4 and 5 demonstrate the difference between a Heraeus Noblelight lamp and the industry standard when a square wave pulse is applied.

Figure 5 illustrates the lower fluctuation in temperature of the Heraeus cathode. The operating temperature of the Hi-Charge™ cathode can be raised or lowered by manufacturing the cathode neck with different diameters.

The Standard Pulse cathode

In simple terms the Standard Pulse cathode is a Hi-Charge™ cathode without the thermal choke (figure 7). In practice however, the manufacturing processes are slightly different to optimise performance.

This cathode has been developed specifically for use in systems using a Pulse Forming Network (PFN) power supply. The design of this supply differs from that of a square wave unit. Instead of using high power electronics to manipulate the power waveform, a bank of capacitors and inductors is charged and then discharged through the lamp to form the pulse.

PFN power supplies generally deliver pulses of a lower power than those in a square wave unit, the pulses having a curved waveform (half sinusoidal) rather than a square shape. The exact shape of the pulse depends upon the damping ($\propto$) of the circuit as detailed in the Pulse section (see page 21).

As well as having lower power, the pulses generated by a PFN network tend to be shorter, with pulse widths measured in the microsecond range rather than in milliseconds. Where lower power, high frequency, short pulses are applied to the lamp, the thermal loading per pulse is considerably less than would be seen in a Hi-Charge™ application, thus the change in cathode temperature between pulses is much less.

The strain on the cathode material caused by temperature oscillation is thus considerably reduced and the use of a thermal choke is unnecessary.

Fig.4 Lamp lifespans

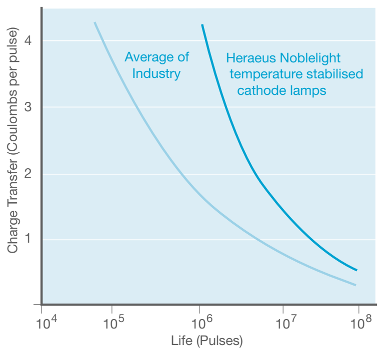
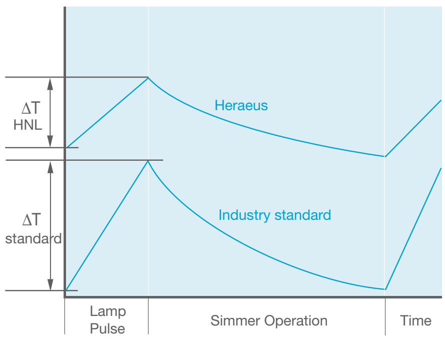


Fig.5 Temperature fluctuation



The Air-Cooled cathode

This cathode (figure 8) is a derivative of the Standard Pulse cathode. Lamps used in low power applications, where the rise in temperature of the lamp during operation remains minimal, require little or no cooling other than local airflow. The use of a large Tungsten mount to provide a sink transferring heat away from the cathode tip is therefore unnecessary, as normal thermal radiation through the quartz body will keep the electrode temperature at an acceptable level.

Put simply, in the case of an air-cooled lamp, the mount is completely omitted and the tip is brazed onto the Tungsten wire.

The Continuous Wave (CW) cathode

Until recently the term ‘CW’ referred to lamps operating at pre-set current values with either no, or very low frequency changes to that value. It is hardly surprising therefore, that just one type of cathode was used.

More recently this situation has changed. Now a number of different running parameters exist which fall under the label of CW operation (see page 18). Heraeus Noblelight has risen to the challenge of these new operating parameters by developing a number of different cathodes in response to market demands. The cathode in figure 9 is the standard CW design for applications where the lamp current trace remains flat, with little or no change during operation.

This design effectively retains the arc in the centre of the lamp bore during operation. The angle of the cathode has also been specifically engineered so that, during operation, the tip remains at the optimum temperature for efficient emission and maximum life.

A variation on this cathode is illustrated in figure 10. This has been developed for quasi-CW operation as described on page 19. The key difference between the two cathodes is the quasi-CW cathode’s rounded end.

The rounded end design was developed in response to a tendency for the tip end to form a ball of molten metal and detach when a standard CW cathode was used in quasi operation. The rounded tip design spreads the heat load during operation, and thus prevents a ball of molten metal forming.

In the case of modulated CW operation, as described on page 19 the cathode design is significantly different to the models outlined overleaf. This cathode, (figure 11) is the result of considerable research and development by Heraeus Noblelight and leads to a significant increase in lamp lifetime.

One major problem with modulated CW operation is the tendency of the arc to wander around the tip circumference when the lamp is in the low current section of its operation cycle. This results in the quartz immediately next to the electrode suffering very high thermal loading, causing rapid ageing.

This cathode design largely prevents this happening. The shape prevents the arc from wandering and because the tip is relatively far away from the quartz, it dramatically reduces any possibility of damage.

Fig.6 Hi-Charge™ cathode

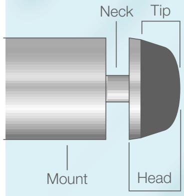


Fig.7 Standard Pulse cathode

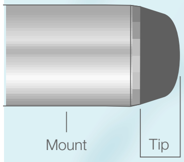


Fig.8 Air-Cooled cathode

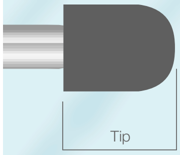


Fig.9 Continuous Wave (CW) cathode

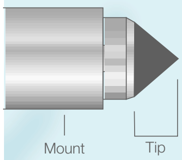


Fig.10 Quasi-CW cathode

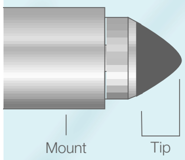


Fig.11 Modulated CW cathode