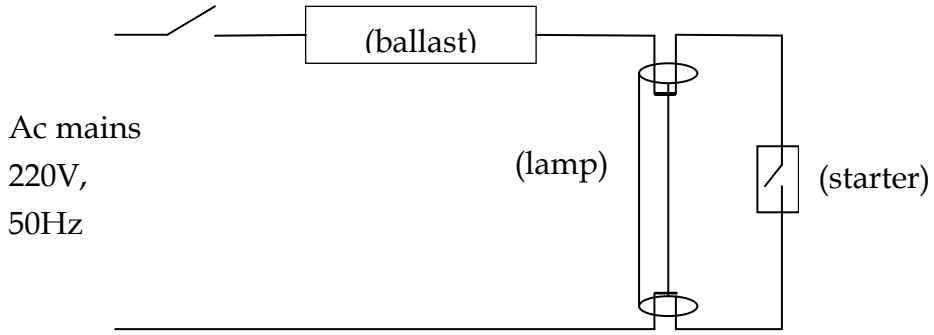
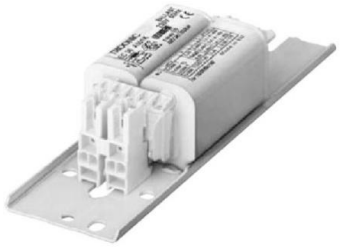
Research background

Since their invention in mid 1940's, fluorescent lamps have been used as a major light source in society。 Fluorescent lamps are discharge lamps that need a device called "ballast" to limit their current and thus their power. (Fig.1)

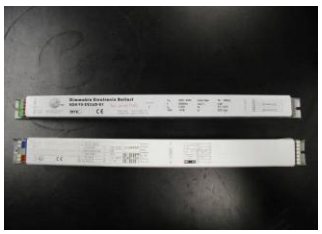


(Fig.1)

Nowadays, ballasts can be classified as "magnetic" and "electronic" types. Magnetic ballasts have been used since 1940's. Their structures are very simple. Each unit consists of a magnetic core and a copper winding. Its typical lifetime exceeds 20 years. The core and the winding can be recycled. (Fig.2)



(Fig.2)



(Fig.3)

Since early 1980, electronic ballasts have emerged as a more energy efficient solution to replace magnetic ballasts. Electronic ballasts are electronic circuits, each comprising thirty or more electronic components. They operate the fluorescent lamps at a high frequency. (Fig.3)

Compared with traditional magnetic ballasts, electronic ballasts have the advantages of a high energy efficiency and the elimination of flickering effects in the lamps. In the last 20 years, it has been thought that replacing magnetic ballasts with electronic ones can save about 17% electric power for traditional fluorescent lamps. When the T5 lamps were promoted as a new generation of high energy-efficiency lamps in mid 2000s, the lighting industry recommended electronic ballasts only for T5 lamps. Magnetic ballasts were not even included in the Class-A classification of the energy efficiency rating of ballasts.

However, the electronic waste issue increases with the increasing popularity of electronic ballasts. According to market survey, over 200 million units of electronic ballasts were made in 2005. Limited by the lifetime of a component called "electrolytic capacitor", electronic ballasts have typical lifetime of 3 to 5 years. Electronic ballasts cannot be recycled and therefore their disposal could lead to serious environmental problems.

In summary, traditional magnetic ballasts have the advantages of (1) long lifetime and (2) recyclability, and the disadvantage of (a) a lower energy efficiency than electronic counterparts. Electronic ballasts have the advantage of (1) energy saving, and disadvantages of (a) short lifetime and (b) not recyclable.

Novel Sustainable Lighting Technology – Ultra-low-loss Magnetic Ballasts

The researchers at the Department of Electrical & Electronic Engineering, HKU promote a new concept of "Sustainable Lighting". Different from the Energy Labeling Scheme which includes only energy efficiency, the new concept covers 3 important factors:

(1) High energy efficiency
(2) Long product lifetime (>10 years)
(3) Recyclability (>80% materials recyclable)

Based on these factors, the HKU research team led by Professor Ron Hui has successfully developed the "Ultra-low-loss magnetic ballasts" to meet the 3 criteria for sustainability.
The Ultra-low-loss magnetic ballasts are suitable for T5 fluorescent lamps. It consists of 3 components (Fig.4):

(1) Inductor L - A magnetic core and a copper winding (lifetime exceeding 20 years; recyclable)
(2) CapacitorC - Non-electrolytic type (typical lifetime exceeding 10 years)
(3) Starter- amount of electronic components less than 10% of electronic ballasts (only used in the ignition time – less than 1 second; expected lifetime 10 years)

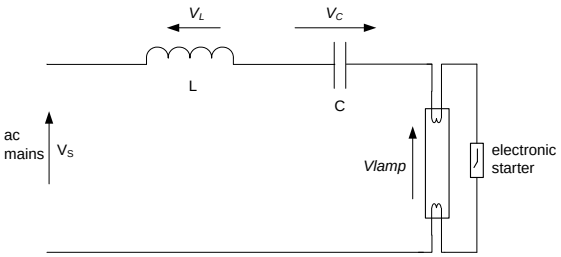


Fig.4

The new invention has been peer-reviewed by independent professionals and its results have been published in the IEEE Transactions on Power Electronics in 2011. Comparative summaries of their technical performance and sustainability are listed in Table 1 and Table 2, respectively.

TABLE 1

Model T5-28W lamp	Input Power (W)	Lamp Power (W)	Ballast Loss (W)	Luminous Flux (Lumen)	Energy Efficiency (%)	System Luminous Efficacy (Lumen/Watt)
Ultra-low-loss Magnetic ballast	31.2	28.7	2.5	2423	92.0	77.66
Electronic Ballast	31.6	26.9	4.76	2411	85.1	76.30

TABLE 2

Sustainability Criteria	Electronic ballasts		Ultra-low-loss magnetic ballasts	
(1) Energy Saving	√		√	
(2) Lifetime	**X**	(3 - 5 years)	√	**(>10 years)**
(3) Recyclability	**X**		√	**(>80%)**

Advantages of the new invention

1. It has the potential of changing the current pattern of using electronic ballasts in public lighting, and consequently may drastically reduce electronic wastes arising from lighting industry.
2. Because the expected product lifetime exceeds 10 years, it is envisaged that property management companies can save lots of efforts and costs in maintenance, and also the economic losses arising from the closure of shops and venues for such maintenance.
3. The product design can cope with wide temperature range. They are particularly suitable for general public lighting applications such as car parks, corridors, stair, hallways and general public areas.
4. Over 80-% of the product materials can be recycled. The iron core and copper winding can be sold as waste metals. This is not only environmentally friendly, but also cost saving.
5. The invention has been adopted by lighting industry and commercialized. The new products have passed IEC test requirements by certified laboratory. It energy efficiency rating has been classed as “A-Class”, same as the best electronic ballasts in the market.

Note 1:
Taking the traditional T8-36W lamp as an example and using the same light output as reference, the total system power consumption of an electronic ballast system is 36W, whilst that of a magnetic ballast system is 42W. This is why lighting industry has been replacing magnetic ballasts with electronic ones in the two decades.

T5 fluorescent lamps are a new generation of high energy-efficiency lamps. Its luminous efficacy is amongst the highest. Its system luminous efficacy exceeds 70 lumens per Watt and is comparable with that of high-quality LED products. T5 lamps are high-voltage and low-current lamps, while T8 lamps are low-voltage and high-current lamps. Their major difference is that T5 lamps have much lower current rating. (Table 3). It is important to note that the copper conduction loss is proportional to the square of the current, and the magnetic core loss is roughly proportional to the current. From Table 3, it can be seen that, when applied to T5 lamps, the magnetic ballast will have its conduction loss reduced by 84% and core loss by 60%.

TABLE 3

Lamp Type	T8 36W Traditional	T5 28W New energy-efficient lamps
Rated voltage (V)	103	167
Rated current (A)	0.44	0.175
Conduction loss (i^2R)	100%	16% (less 84%)
Core loss ($\propto I$ *or* ϕ)	100%	40% (less 60%)