FILM CAPACITORS FOR HIGH-INTENSITY DISCHARGE (HID) AUTOMOTIVE LAMPS

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GENERAL

Up to now, the automotive industry has mainly been using tungsten-halogen lamps for headlights. New and compact HID lamps feature higher luminous efficacy and improved visibility under adverse weather conditions like rain, snow or fog. Their energy consumption is roughly 50% lower than that of conventional lamps, and the service life of the lamp and associated components is longer. HID lamps are therefore being used on a large scale in Europe and Japan, and the total number of lamp units used worldwide per year is estimated to exceed three million at the turn of the millenium. Intensive research is currently being conducted to develop an HID lamp with integrated igniter circuit for standardization of the headlight unit. The MKT, MFT and MKN film capacitors specially developed by EPCOS for advanced automotive lighting face bright prospects.

1. IGNITER CIRCUIT AND CAPACITOR REQUIREMENTS

HID lamps must be properly ignited. Normally, a high voltage pulse produced by an igniter circuit (**Fig. 1**) is superimposed on the operating voltage in order to ignite the lamp on the first strike. If this fails, the pulse is repeated until either the lamp is ignited or the circuit goes into a failure protection mode of operation. The energy contained in one pulse must be high enough to cover the variation of lamp properties and switching spark gap (SSG) voltage with temperature and lifetime respectively. Since the first-time effect of the SSG has to be taken into account, the open circuit voltage V_o is chosen approximately 30% higher than the rated voltage of the SSG. Typically, the level of the energy stored in the capacitor ranges from 20 to 50 mJ and is limited by a drastic reduction of lifetime for the SSG occurring at higher energy levels. Thus, only certain capacitances and film capacitor designs will match a given SSG voltage rating (**Table 1**). Thanks to EPCOSs' outstanding position as a supplier of highly reliable switching spark gaps for this application, designers at EPCOS were able to optimize the film capacitor based on test results for the whole circuit.

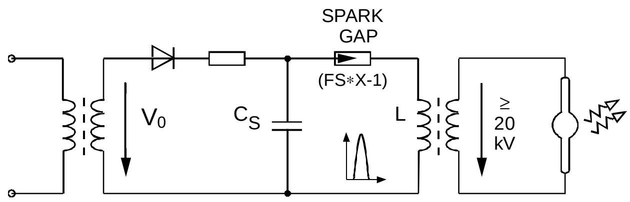

Fig. 1 Basic igniter circuit

Taking 0.5 to 1 µH for the primary inductance of the transformer, a capacitor peak current of several hundred amperes can be calculated corresponding to the dv/dt values given in **Table 1**.

$V_{R,SSG}$ (V)	C_S (nF)	dv/dt (V/µs)	Design
400	330	1000	MKT stacked film
800	120	3000	MKT stacked/MFT
1000	60	6000	MFT

Table 1 Typical film capacitor ratings and designs

In addition, the wide temperature range from –40 to 130 °C (or even 150 °C) and strong vibrational loads underline the severe requirements imposed on film capacitors by this automotive application.

2. CAPACITOR DIELECTRIC

In view of these extreme requirements and the need to minimize size and costs, polyester is the obvious choice of material for the dielectric of capacitors used in the igniter circuits of HID lamps. Since there is no continuous ac load, the comparably high dissipation factor (i.e. self-heating) of polyester can be tolerated. The significant variation of its electrical characteristics with temperature does not affect operation of the circuit thanks to the margins already provided to compensate the effect of temperature on the other components used.

As already discussed elsewhere[1], one critical point in using film capacitors at elevated temperatures is the corrosive influence of the sealing material of boxed capacitors. The capacitance loss found at low dc voltages and high operating temperatures can be reduced drastically by varying the epoxy resin composition, especially by reducing the accelerator content (**Fig. 2**). In-depth investigations show, however, that optimum performance is obtained with unboxed capacitors, i.e. *silver* types. This statement not only applies to reduction of capacitance loss, but also to optimized mechanical behavior under temperature cycle conditions. Problems commonly found with boxed types and caused by different thermal expansion coefficients can be neglected completely if

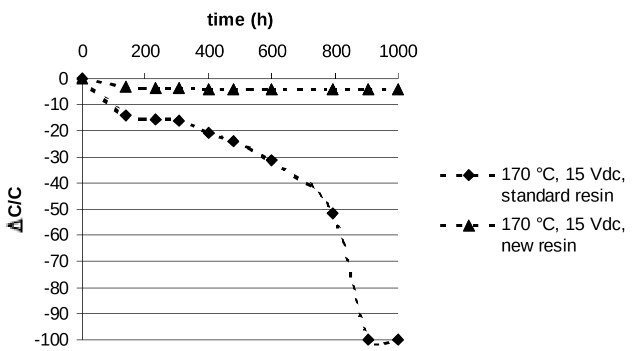

Fig. 2 Typical capacitance loss for a 1.5 • F/100 V MKT capacitor at high temperature and low voltage with standard and new formula epoxy resins

silver types are used. If this is not possible, e.g. if the capacitor is wetted with water during assembly or if insulation of the capacitor body is mandatory, it is common to use boxed or powder-dipped capacitors. In any case, optimum welding of the leads to the capacitor winding must be ensured to withstand the mechanical stress between capacitor and PCB. This parameter can be improved by using low-shrinkage polyester material initially developed for film capacitors for surface mounting[2]. This polyester film, which is submitted to a thermal treatment that relaxes the elastic properties during production, not only permits welding under optimized welding conditions, but also ensures optimum contact between the metalized film and the metal spray layer under temperature cycle conditions.

3. CAPACITOR DESIGN

Since the high current load of the igniter capacitor corresponds to an increasing d*v*/d*t* value with decreasing capacitance, the capacitor design must be adapted to the rated voltage of the SSG. The stacked-film design used for SSG ratings up to 800 V is therefore replaced by a film-foil (MFT) design at higher voltages (**Fig. 3**). The film thickness and the number of plain film layers are adjusted to the maximum charging voltage. If stacked-film capacitors are used, special care must be taken in cutting the capacitor to avoid a flashover along the cutting surface. A

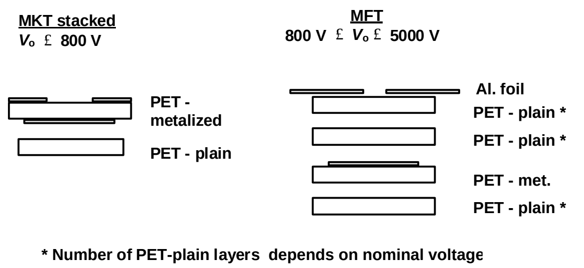

Fig. 3 As d*v*/d*t* values increase, the MKT capacitor of stacked-film design is replaced by an MFT type of film-foil design for higher SSG ratings

compact mechanical design must be ensured, e.g. by optimizing annealing processed during production.

The inherent pulse handling capability of the stacked-film construction is improved further by implementing a so-called heavy edge, i.e. using a thicker metalization in the contact zone of the plastic film. Since pulse capability – the most critical parameter in this application – might be affected by scratches on the film metalization and variation of winding and welding parameters, it is carefully monitored during production of capacitors of both designs. A combination of non-destructive pulse tests, measurement of the dissipation factor at high frequency and statistical destructive tests using a special pulse unit ensure consistently high pulse handling capability.

4. CONCLUSIONS AND OUTLOOK

Using the materials and technologies described above, EPCOS has developed solutions matching the typical requirements of HID lamp applications, offering both MKT stacked-film capacitors and MFT (film-foil) capacitors for switching spark gaps with lower and higher rated voltages respectively.

Alternative circuit designs based on semiconductors instead of SSGs are currently being discussed for HID lamps. Up to now, it has not been clear whether the disadvantages of complex semiconductor designs can be overcome, but since the capacitor load basically remains the same, the film capacitor solutions described above can be considered suitable for such alternative designs.

In addition, ceramic capacitors have frequently been cited as replacements for film capacitors. However, experience shows that apart from mechanical problems such as cracks etc., the variation of the electrical parameters of ceramics with voltage and temperature is normally too high to be tolerated.

The lighting industry is currently devoting considerable expense to standardizing HID lamp circuitry and integrating the igniter into the base of the lamp itself. Capacitance can then be reduced as a result of minimization of losses along cables and of overall inductance. As the more compact design with integrated igniter results in higher temperatures at the base of the lamp and in view of the trend toward reflow soldering or direct welding, PEN (polyethylene naphthalate) appears the right choice for the dielectric. A circuit based on a stacked-film capacitor with PEN dielectric and a EPCOS SSG rated at 800 V was recently tested with excellent results.

REFERENCES

1. G. Bernard: Study of the reaction to high temperatures of polyester film capacitors, CARTS Europe, Oct. 1991
2. A. Bursch and H. Kliesch: Hostaphan SMD, a PET film offering good performance in SMD capacitors, CARTS Europe, Oct. 1997