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Short Communication

Application of Ultrasonic Bonding in Leds and Led Lamps Production

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This article presents the results of studies of the effect ultrasonic bonding on the current-voltage characteristic nitrides chips with using methods of planning the experiment.

Keywords: Nitride chip, Current-voltage characteristic of the LED, Ultrasonic microwelding, Planning eksperiment.

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1. INTRODUCTION

As the LED energy efficiency is increasing, the number of their possible applications is growing. The promising field of great economic importance is the development of filamentary LED emitters that are the base for led lamps for home and industrial application [1]. Compared with filament and luminescent lamps they have such advantages as higher light efficiency and longer service life [2]. The service life of modern LEDs based on blue nitride crystals with luminophor can reach up to 60 thousand hours [3]. The technology to produce electrical bonding of crystal chip pins with the body elements during LED production is well-developed [4]. The problem of adjacent crystal chip pins of filamentary LED emitters bonding has not yet been completely solved.

The study aim is to determine the filamentary LED emitter nitride crystal bonding modes that have the minimal impact on crystal degradation during their further service. The work aim provides the following objectives:

a) to research the microbonding method;

b) to bond nitride crystal electrical contacts with the base contacts by different bonding modes;

c) to estimate how the selected bonding modes influence on the nitride crystal current-voltage characteristics (CVC).

The bonding mode influence on the crystal degradation during their further service is estimated by the CVC slope change. The article [4] shows that the poor quality bonding causes the CVC slope increase. The authors conclude that such a CVC change takes place because the impurities with breakdown paths occur in the semiconductor. Such localized areas have significantly higher conductivity than the areas with the barrier structure.

2. MICROWELDING METHOD REVIEW

Three main microbonding methods: thermal compression bonding (TCB), thermosonic bonding (TSB) and ultrasonic bonding (USB) as well as two types of bonded seal: "ball-wedge" and "wedge-wedge" are examined in the study.

The simultaneous impact of temperature and pressure occurs when TCB is used. The bonding pad heats up to about 300 °C and consequently the metal ductility increases when the electrode contacts with the pad. USB occurs without additional heating. Ultrasonic energy disrupts the crystal structure of metal and as a result it becomes deformed under low clamping force and temporarily becoming soft and ductile provides the bonding. TSB occurs under the simultaneous impact of temperature, pressure and ultrasonic oscillations. The operation area heats on average from 100 to 150 °C and bonded seal formation time lies within 20-200 ms. TSB is especially effective for wire bonding to the pads from different metals [5].

TSB and USB with the wire 20-75 microns in diameter are the most widely used methods to bond microconductors. This is due to better capacity of these methods and operation area lower temperature in comparison with the TCB. We decided to use TSB with a ball formation at this stage. The obtained contacts are flexible and have high thermal and electrical conductivity and low direct-current resistance in contact with metal films. Wire diameter is 30 microns. We selected this size assuming that the bonded seal size should not exceed ¾ of the crystal bonding pad square (100 microns). The obtained ball size is approximately 2-3 wire diameters.

3. THE RESEARCH

The research has been carried out with the help of device iBond5000 Dual produced by Kulicke&Soffa. This device allows lead wire bonding both of "ball-wedge" and "wedge-wedge" types. We have performed the "ball-wedge" bonding for blue nitride crystals. The quality control of bonded seals has been carried out visually. The seals have been checked for cracks and delaminations.

It is important to select the optimum bonding mode for nitride crystals because ultrasound accelerates the nonradiative recombination appearance that results in a loss of up to 50 % of light flux after 10,000-15,000 service hours [5]. Therefore, the adequate mode shifts the recombination processes to 25-30 thousand service hours and the crystal characteristics will suit the stated ones.

The experiment has been carried out according to the orthogonal central composite design. The planning matrix comprising twenty-five experiments has been composed in compliance with the selected method of experiment. Every matrix row represents a combination of variable factor values: ultrasonic oscillation power Pus, tool (capillary) pressure *F*, bonding time t and temperature *T*. We have defined the variability intervals and calculated the basic, upper and lower levels taking into account the recommendations given in the instruction manual for device iBond5000, the known data on microbonding and the results of preliminary experiments (Table 1). Three bonded seals have been performed for all bonding modes and thus three response functions have been taken. The electric power generated in the LED has been taken for the response function *Y* because one can estimate the CVC slope by its average value within the required range of direct current change. We have carried out the data statistical processing after their obtainment. We received a mathematical model of the examined process as a result of the data processing. The final model is presented in the form of the following formula:

$$Y = 139.7657 + 18.9143 \cdot P + 0.0155 \cdot t - 0.0499 \cdot P \cdot t$$

This equation shows that the ultrasonic oscillation power has major impact on the response function. The voltage applied to the crystal and consequently the electric power increases as the ultrasonic oscillation power increases under the same current for different bonding modes.

Our experiment confirmed the results given in the article [6]. Fig. 1 shows the experimentally measured crystal CVC before and after bonding under three groups of modes. The modes changing the CVC minimally but sufficient for the bonded seal formation have been defined after estimating the ultrasound impact on CVC.

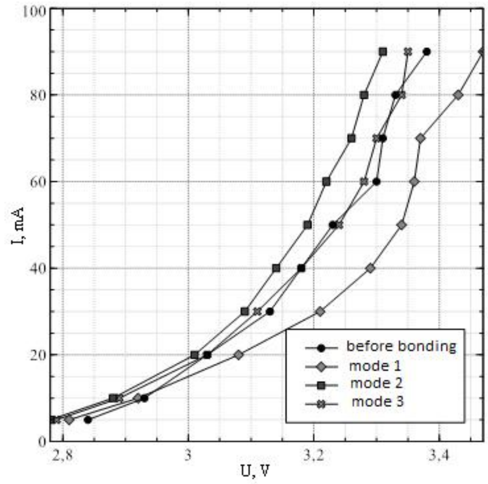

Fig. 1 – Nitride crystal CVC in different bonding modes:
mode 1 – ultrasound power 0,156 W, time 400 ms, clamping force 32 g;
mode 2 – ultrasound power 0,455 W, time 400 ms, clamping force 32 g;
mode 3 – ultrasound power 0,455 W, time 400 ms, clamping force 60 g.

Table 1 – Variability intervals and levels

Factor notation	*Pus*(X1), W	*F*(X2), g	*t*(X3), ms	*T*(X4), °C
Basic variability level	0,31	46	300	100
Variability interval	0,15	14	100	15
Upper level (+1)	0,46	60	400	115
Lower level (-1)	0,16	32	200	85

4. CONCLUSION

The previously set objectives have been completely achieved as a result of the work done. The bonding mode impact on electric power generated in the LED has been researched with the help of orthogonal design. The experiment result proves that the selected modes really influence on electric power. The electric power change results in LED CVC slope change.

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