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Amorphous Diamond for Generating Cold Cathode Fluorescence Light

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Abstract

Amorphous diamond has a very low work function (1 eV) at modest temperature (150 ℃). It has been coat coated on electron emitting electrodes. Such electrodes are used for cold cathode fluorescence lamps (CCFL) that illuminate liquid crystal displays (LCD) for rnote books and television sets. Amorphous diamond can dramatically reduce the turn-on voltage to lit CCFL so the lamp life can be greatly extended. Moreover, the electrical current can be increased to enhance the brightness of the light.

Keywords: **amorphous diamond, solar cell, diamond electrode, thermal radiation, electroluminescence**.

1. Cold Cathode Fluorescence Lamp

The principle of CCFL is illustrated in Fig. 1. A sealed glass tube is coated inside with phosphor inside. For emitting white (transparent) light, three types of phosphor are mixed together, each can emit light of a distinct color with the wavelength centered at 611 nm (red), 544 nm (green) or 450 nm (blue). These emissions were triggered by ultraviolet (UV) radiation (wavelength 254-365 nm) emitted from mercury vapor that is sealed in a glass tube along with an inert gas (e.g. Ar). The UV radiation is emitted in vacuum from mercury atoms that are excited by electron bombardments. The electrons were ejected from two electrodes located at opposing ends of the lamp.

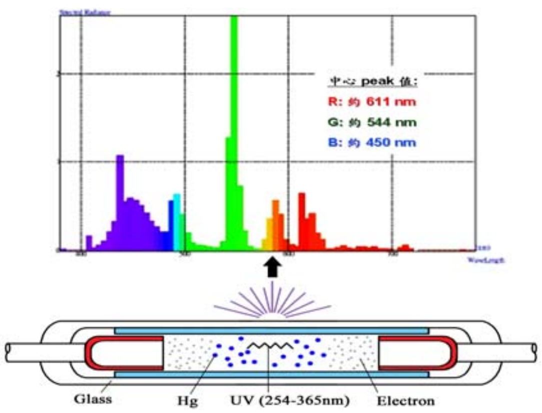

Fig. 1. The perspective view of a CCFL. A example of CCFL is 430 mm in length. It is operated at 800 volts (input 12V) with a current of 5 miliamperes. The vacuum level in the tube is about 80 torr.

The brightness of CCFL is dependent on the current of electron emission from the electrodes. In order to increase the current, the tip of the electrode is often enlarged to form a cup shape so more electrons can be ejected from the rim, as well as the inside surface of the cup instead of the needle tip with restricted size.

The emitted current is inversely related to the exponent of the work function, so a small decrease of the latter will cause a tremendous increase of the former. The amorphous diamond has an effective work function that is much lower than all other elements, hence, the electrical current is the highest under the same voltage, particularly at an elevated temperature, such as the case for the electrode of CCFL. This phenomenon of thermally excited emission is known as thermionic emission. Amorphous diamond is by far the most effective and efficient thermionic materials known.

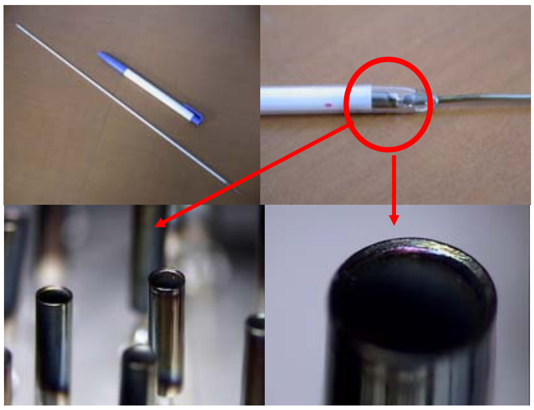

Fig. 2. Amorphous diamond coated CCFL electrodes.

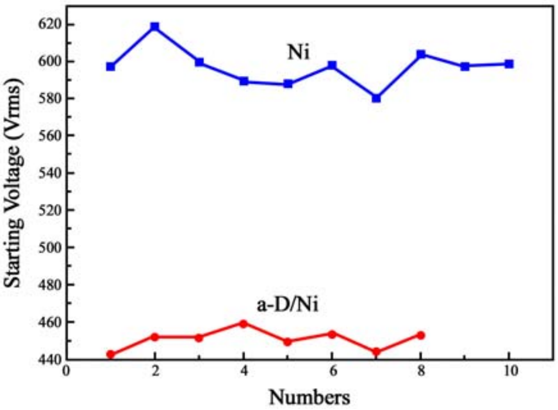

Fig. 3. The significant reduction of voltage for electron emission by coating the nickel electrode with amorphous diamond.

2. CCFL Emissions

A typical electrode material is made of nickel, but molybdenum has also been used. The latter materials are much more expensive, but their emitting life can be lengthened from about 20,000 hours to about 50,000 hours.
However, the activation energies for both metals are very high, hence voltage must be built up to force electrons to go out. The result is that a significant voltage (about 150 V) is consumed in creating heat that consumes about 30% of the electricity power. One way to help electrons to overcome the activation energy is to coat the surface of the electrode with a lower energy barrier material, such as a cesium or lanthanum alloy. However, due to the high temperature (up to 200℃) present at the electrode during the electron emission, the coated material will decompose or even evaporate. Recently, Toshiba applied boron doped diamond film of a few microns thick to molybdenum electrodes and found that the voltage drop across the electrode was reduced to less than 90 V, moreover, the power consumption was decreased by 10%. Although this breakthrough is encouraging, however, the coating must still applied to expensive molybdenum electrode. Furthermore, diamond film must be deposited by chemical vapor deposition that is low in throughput and high in cost. Consequently, more cost effective solution must be sought for commercial applications.

The electron emissions in vacuum (not CCFL) were compared between metal cup electrodes and amorphous diamond coated ones. Amorphous diamond was found to boost the electrical current density at the working voltage of CCFL by four orders of magnitude. Moreover, when the electrode was heated to 100℃, the emitted current was increased so much that it went out of the scale as shown in Fig. 4. The electrodes of CCFL is heated to about 150℃ during use, so the thermionic boost of electron emission for amorphous diamond is a great advantage.
Amorphous diamond can increase the service life of CCFL with another attribute, that its sputtering rate is the lowest of

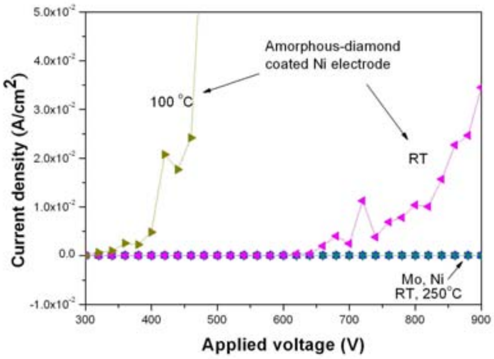

Fig. 4. The dramatic increase of emitted current density by coating metal with amorphous diamond and the even larger boost of the current by modest heating. The above measurement was made by Industrial Technology Research Institute in Taiwan. The electrical current was induced by a needle anode located at 10 microns above the rim of the cup electrode. The vacuum level for the measurement was 10^{-5} torr.

all materials. Electron emission can sputter atoms off the electrode so the slower sputtering rate would preserve the working conditions of the electrode for a longer duration of time.
Moreover, the CCFL's life time can also be reduced by reduction the amount of mercury in the CCFL tube. Amorphous diamond would not react with mercury in CCFL (Fig. 5). Consequently, mercury will not be depleted by forming amalgam with the electrode metal.

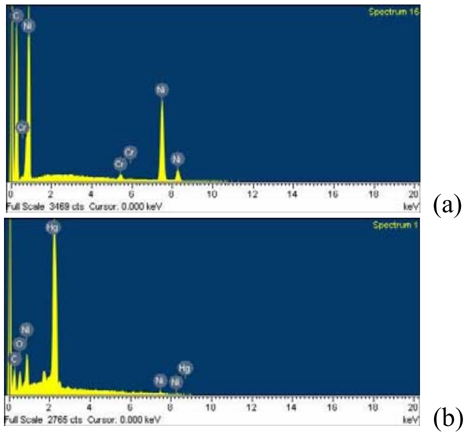

Fig. 5. The EDS analysis of amorphous diamond coated electrode (a) and uncoated nickel electrode (b) after CCFL operation for 100 hours. Note the former contains no mercury, but the latter indicate the presence of mercury.

References

1. Chien-Min Sung, U.S. Patent 6,806,629. (2004)
2. Chien-Min Sung, China Patent 15485842. (2004)
3. Chien-Min Sung, U.S. Patent 6,949,873. (2005)
4. Chien-Min Sung, Taiwan Patent I230740. (2005)