Graphene-based nanomaterials for field emission applications

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Field electron emission (FE) phenomenon has been a matter of considerable interest for purely academic and applied science since it was discovered in 1897. In contrast to other electron emission mechanisms (thermionic or photo emission) the field emission doesn't need any power supply. Owing to this reason the field emission is frequently referred to as "cold" and corresponding electron emitters as "cold cathodes." The FE is registered only at large electric field strength requiring an extremely high voltage to be applied between the flat cathode and anode. To reduce the voltage down to the values, which are practically suitable for vacuum electronic devices and for research purposes, the creation of emitters in form of needles with high aspect ratio is required. One of the most attractive features of the FE is its potential ability to provide the electron emission with very high current density. However, emitting surface area of a single emitter with high aspect ratio is usually quite small. Thus, to obtain electron beams with reasonable value of total current, the FE cathodes must contain arrays of numerous emitters. The abilities to produce such kind of micron-sized FE cathodes were demonstrated previously using Si and some other semiconductors and hard metals. However conventional lithographic technique of fabrication of such FE cathodes is complicated and expensive hampering wide application of the cold cathodes made of these materials. Since 1990s the interest to the FE has been triggered by the discovery of carbon nanotubes (CNT) and other types of nanocarbons. Having graphitic type atomic structure these nanostructured materials possess advantageous properties for efficient field emission: strong interatomic bonds and corresponding chemical inertness and robustness to ion bombardment; high conductivity and electron mobility, providing low resistive heating and voltage drop across emitter body; and high aspect ratios of the individual nanostructures, allowing usage of moderate voltages.

We report here our recent results on investigation of field electron emission from graphene-based nanocarbon film materials. The films were obtained using chemical vapor deposition (CVD) from methane\hydrogen gas mixture activated by a direct current discharge. Si wafers, Ni or other metal sheets with dimensions up to 50 mm in diameter were used as the substrates. The field emission cathodes were made from the CVD films consisting of tiny graphite flakes with few graphene layers (of 2 to 50) oriented perpendicularly to substrate surface (see Fig. 1). Composition, structure and surface morphology of the nano-graphite films were analyzed with Raman, SEM and HR TEM (see, e.g. [1]). Our investigations of the field emission characteristics of the CVD films shown that this material combine advantages of CNT species (high aspect ratio, chemical inertness etc.) with other characteristics required for practical applications in vacuum electronic devices [2]. To demonstrate abilities of the nano-graphite cold cathodes we have developed device prototypes of the cathodoluminescent light sources (see, e.g. [2, 3] and Fig. 2). The record characteristics were demonstrated for these light sources including power efficiency (more than 10% for green light) and life time (exciding 10000 hours). Other developed device prototypes created with use of the nano-graphite cold cathodes include X-ray source, electro-mechanical oscillators [4], electron guns for particle accelerators and for application in an electric solar wind sail which is a space propulsion concept that uses the natural solar wind dynamic pressure for production spacecraft thrust [5].

References

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Figures

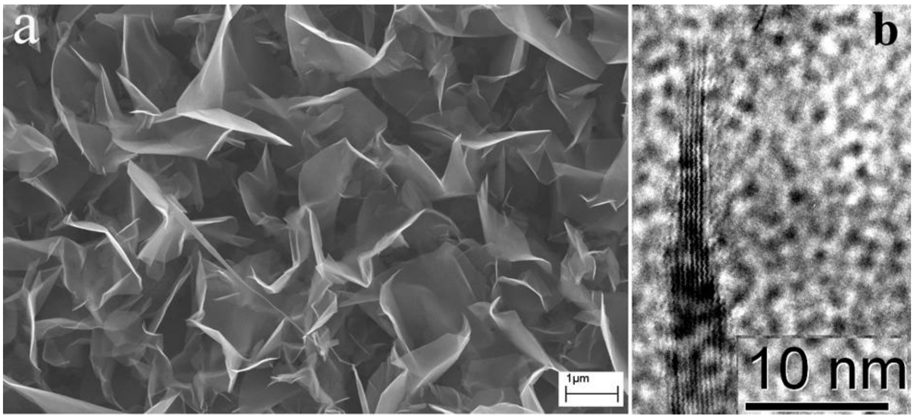

Fig. 1 SEM image of the nano-graphite CVD film morphology (a) and HR TEM image of the top end of a graphite flake composing the film.

Fig. 2 The photographs of the cathodoluminescent lamps with the nano-graphite cold cathodes accordingly to [3].