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METHODOLOGICAL NOTES

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On the penetration of glass by a plasmoid

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Contents

Abstract. It is shown experimentally that an artificial plasmoid being similar to ball lightning can penetrate through glass, leaving a round smooth-edged hole in it.

Keywords: plasmoid, pulsed discharge, ball lightning, exploding wires

1. Introduction

The interest in studying electric phenomena in the atmosphere has a long history and has not ceased to date. A comprehensive review devoted to atmospheric electricity has recently been published in *Usp. Fiz. Nauk* [1]. Paper [2] is another example. The author of Ref. [1] is right when noting that "against the background of general understanding of the physics of atmospheric electricity, some of its elements remain misunderstood." One such element is, in our opinion, ball lightning. Its study, which truly has a history of many centuries, is still under way. Ball-lightning problems have even been discussed at international congresses [3–5].

Ball lightning is thought to be a plasma formation. A number of ball-lightning models and theories exist. One of them, the so-called plasma model, was considered by P L Kapitza [6] in the middle of the 20th century. According to this model, short-lived plasma formations — plasmoids — can appear in the air. Their lifetime is determined by the electron and ion recombination rate.

B M Smirnov successfully dealt with ball-lightning problems and developed a theory. The results of his studies were published in a number of books and papers (see, for example, Refs [7–11]). In paper [11], Smirnov pointed to the importance of an experiment to choose a correct theoretical ball-lightning model. Of great interest is also the monograph by I P Stakhanov [12], which has now become a classic.

Many researchers have tried to experimentally obtain ball lightning in different ways. For instance, ball lightning in study [13] was generated by a pulsed electric discharge above a water surface. In work [14], a high-frequency discharge was utilized. In Ref. [15], we produced artificial plasmoids using a low-voltage pulsed gas discharge in the atmosphere through explosions of thin metal wires (see also Ref. [16]).

In some publications, it was asserted (see, e.g., paper [17]) that ball lightning can pass through glass, leaving round holes in it. Our experiments confirmed the validity of this statement. Making use of the techniques devised in Refs [15, 16], we showed that whenever plasmoids appear near a glass surface with small metal inclusions or holes in it, they can pass through the glass plates, leaving rather large smooth-edged holes.

2. Plasmoid generation

Artificial plasmoids analogous to ball lightning observed in Nature were initiated using an arc low-voltage (100 to 250 V) pulsed discharge between electrodes (the current reached 100 A). For such a low voltage, a breakdown of the discharge gap in atmospheric air is impossible. However, it does occur if metal vapors from an exploding wire appear inside the discharge gap. The discharge gets discontinued only when a considerable portion of the vapor leaves for the electrodes and for the ambient medium. The discharge is then extinguished in spite of the voltage applied to the electrodes. Such breakdowns above the electrodes cause the occurrence of glowing ball-shaped plasmoids hanging freely in the air and having a lifetime of about 0.1 s. In water vapors, the lifetime of plasmoids increases [13].

To generate glowing plasmoids hanging freely in the air, wires were exploded during a free fall of the electrodes. The plasmoidal balls arising due to pulsed breakdowns of a discharge gap were fixed by a video camera; they are shown in Fig. 1. These plasmoids are clearly seen against the background of two sheets of white paper separated by a dark reference line. The plasmoids were obtained at a discharge current of 25 A (Fig. 1a) and 75 A (Fig. 1b). They can be thought of as a laboratory ball-lightning model [15,

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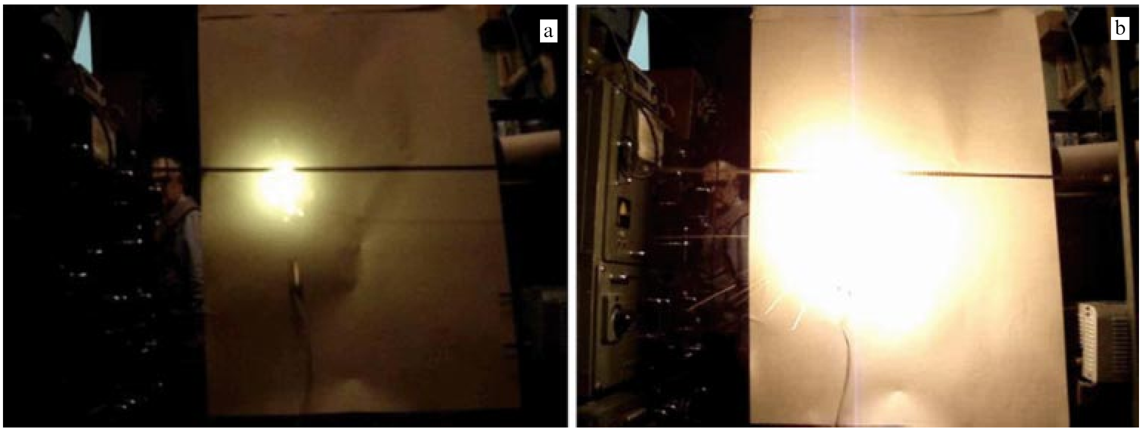

Figure 1. Plasmoids produced due to a pulsed breakdown with a discharge current of (a) 25 A, and (b) 75 A.

16]. In the experiments, the ball size was varied from several dozen centimeters to 1 m.

3. Penetration of plasmoids through glass plates

We examined the possibility of ball lightning penetration through glass by the example of artificially produced in the air plasmoids penetrating through glass plates. For this purpose, we designed the device shown in Fig. 2. Plasmoid *1* appears above electrodes *2* and *3* as a result of the explosion of a 0.2-mg wire 0.05 cm in diameter and 1 cm long. The deposited energy did not exceed 250 J at a pulse duration of ≈ 0.01 s. A plasmoid appears near the glass plate *4*. Placed inside it is another thin wire *6* nearly 0.02 mm in diameter, which is in contact with the grounded metal plate *5*. If, upon closure of key *8*, the appeared plasmoid *1* gets in direct contact with wire *6*, then a current channel forms in glass plate *4*. A hole emerges simultaneously in metal plate *5*.

In Fig. 3, channels are clearly seen in a glass plate 1 mm thick. At a discharge current of 25 A, the diameter of the channel *1* in melted glass was approximately 2 mm, and at a

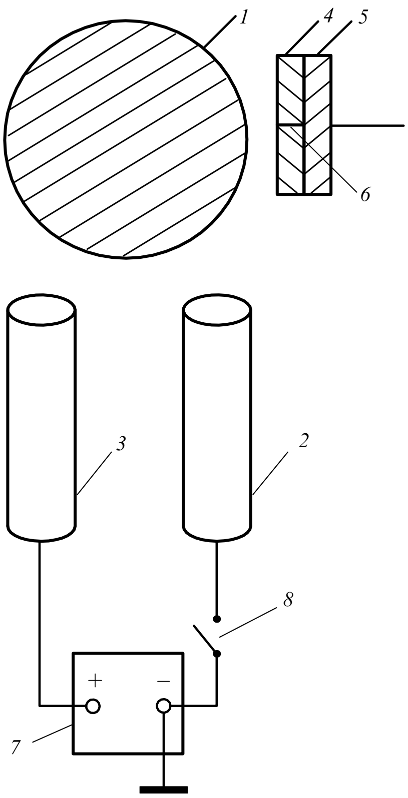

Figure 2. Schematic of a device for plasmoid generation: *1* — plasmoid, *2* and *3* — electrodes, *4* — glass plate, *5* — metal plate, *6* — wire, *7* — power source, and *8* — key.

Figure 3. View of holes after penetration by ball lightning: *1* and *2* — holes 2 and 3 mm in diameter with melted edges in a glass plate 1 mm thick at a discharge current of 25 and 50 A, respectively; *3* — a smooth-edged hole more than 5 mm in diameter obtained after removal of the melted rim of holes *1* and *2*; *4* — a hole produced in a glass plate without a wire but when the glass plate had a small hole (nearly 0.5 mm in diameter) before the discharge; *5* — a hole 4 mm in diameter in a 0.5-mm metal plate.

50-A current the diameter of channel *2* was about 3 mm. If we remove carefully the melted rim, then under it smooth-edged holes more than 5 mm in diameter will be found (see Fig. 3, channel *3*). The diameter of hole *5* in the zinc-coated iron plate 0.5 mm thick is 4 mm.

Notice that plasmoids also pass through glass plates without a wire inside them if the plate has a small hole nearly 0.5 mm in diameter (Fig. 3, channel *4*).

It should also be emphasized that such plasmoids make it possible to form cumulative channels [18], to concentrate energy locally at the cathode [19], and to implement cumulative seam plasma welding of thin metal plates [20].

4. Conclusion

The results presented here demonstrate that ball lightning can penetrate through a window glass and form smooth round holes in it if the glass has small inclusions of highly conductive metals that are not seen by the naked eye or if small holes present in it. When ball lightning affected by electric forces tears along towards such a defect, it can penetrate through glass like a discharge from a Tesla generator. This discharge passes through very small invisible holes in glass vessels, which is a well-known fact widely used in vacuum technology in seeking leakages in vacuum systems.

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