Artificial ball lightning formed by explosion of nanostructured silicon in humid air atmosphere

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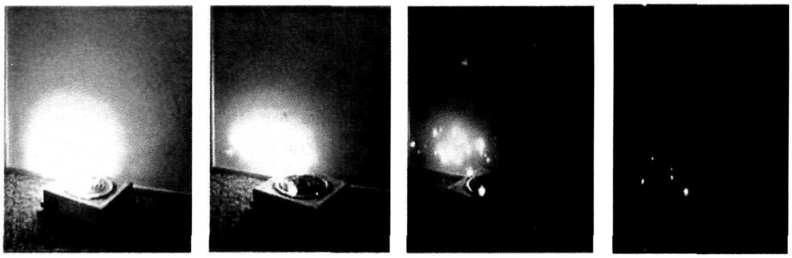
Ball lightning remains one of the most mysterious phenomena in nature. Its unpredictable appearance/disappearance and very short lifetime ranging from few seconds to tens of seconds destroy efforts to study this phenomenon regularly and substantially. Most attempts to generate ball lightning in laboratory conditions were based on the believe that it is closely related to electric charges accompanying normal lightning during a stormy whether. Meanwhile, studying fast of porous silicon explosive oxidation [V.A. Labunov, V.E.Borisenko, Semiconductors 39, 2005, pp. 881-884.] we have first found that at certain conditions this material can blow up yielding ball lightning with the behavior very similar to that observed in nature [S.K.Lazarouk, A.V.Dolbik, V.A.Labunov, V.E.Borisenko, Pisma v ZETPH 84, 2006, pp. 581-584.]. This work presents experimental details of nonelectric generation of ball lightning and regularities observed.

The samples with porous layers were fabricated by electrochemical anodic etching of p-type, 12 Ohm·cm and n-type 0.01 Ohm·cm monocrystalline silicon wafers in 48 % water solution of HF at the current density of 50 mA/cm^2. The anodized area of 1 cm in diameter was defined by the window in a Si_3N_4 thin film mask deposited onto the wafers. The anodization time was chosen in the range of 15-90 min in order to get porous layers of a thickness from 30 to 180 μm. The integral porosity was estimated by gravimetry to be of about 60 %.

The pores were filled with KNO_3 by deeping the samples into its water solution and subsequent drying in air at 50-60 °C. We used KNO_3 as a local solid source of oxidizing species. The ignition of the porous silicon explosion was performed by contact heating from a plate kept at 900 °C.

Ball formation and evolution are illustrated by photos presented in Fig. 1. The formed ball separates from the sample surface and slowly moves out of the origin. Experiments with different ignition techniques show that ball lightning always pushes away heated surfaces. Even proximity of a hand of an experimentalist igniting porous silicon by mechanical scratching can influence trajectory of the ball. In fact, the artificial ball lightning is "cold". It leaves no burns or damages in case of direct contact with the hand. Final period of the ball life can follow one of two scenarios. The ball lightning can disappear instantaneously or can divide into balls of different size before disappearance.

In the latter case the smaller balls disappear first and then the bigger ones do. The balls disappear within 0.1-0.2 s. The total lifetime of the artificial ball lightning is from 10 ms to 1 s. It greatly depends on the air humidity in the laboratory: higher humidity provides a longer lifetime.



a) b) c) d)

Fig. 1 Ball lightning produced by thermal ignition of 100 μm thick 1 cm in diameter porous silicon filled with KNO_3: a) as formed, b) 0.1 s after formation, c) 0.3 s after formation, d) 1 s after formation.

We have shown that artificial ball lightning can be reproducibly generated in a laboratory by an explosion of porous silicon filled with a solid oxidant like KNO_3. Being of nonelectric origin it confirms that electric discharges or ionized species are not so important for appearance of ball lightning in nature. Meanwhile, there is no doubt that nanoparticles of silicon and an oxidizing ambient do play the most dramatic role in this mysterious performance. We believe that the artificial ball lightning opens new horizons in power generation.