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FULGURITE AND ITS ARTIFICIAL PRODUCTION IN LABORATORY

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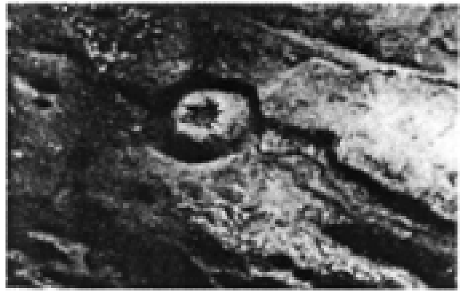
ABSTRACT

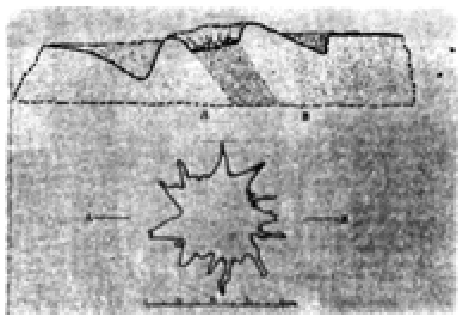
In an ISH 93 companion paper, the authors described their success in the production of fulgurite by artificially-triggered lightning. In this paper, authors describe their effort and success in the production of fulgurite in a high voltage laboratory. In the present study, natural river sand was filled up in a container and lightning impulse currents of various magnitudes were passed through it which were supplied from an impulse current generator. It is believed that this is the first success in laboratory production of fulgurite in the world.

INTRODUCTION

A fossil of thunderbolt was discovered in Germany in 1706, and the fossil was identified by Withering in 1709 [1]. Harland, et al. found a red-color sandstone in Arran aeolian deposit in Scotland [2]. It seems that the fulgurite was produced by lightning striking in the desert in the Permian period of the Palaeozoic era, about 2.5 million year ago. Figure 1(a) is the photograph of the fulgurite fossil. As seen in the photograph, the part of the fulgurite made of quartz glass has been satisfactorily preserved, having been withstanding the weathering. The hollow portion in the central position was scraped off.



(a) Photograph of fulgurite fossil 250 milllon years ago



(b) Sketch view of fig.1(a), upper: transversal section, lower: radial section

Figure 1: Fulgurite fossil

In most cases, natural lightning-striking is accidental independently of time, places, and materials. Accordingly, it is only through the artificial production of fulgurite that the process and mechanism of it can be known. Some more explanation is made in a companion paper [3].

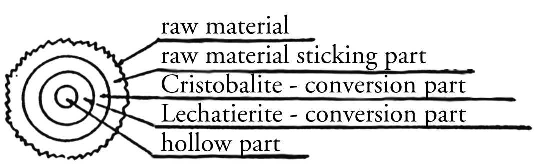


Figure 2: Cross-sectional view of fulgurite

At any rate, the following conditions will be required for the production of the fulgurite:

- Huge electromagnetic energy is supplied for a very short time, in the order of microsecond, so that the soil and sand, or rocks are vitrified;
- Principally, the fulgurites take a cylindrical shape, having a hollow portion which is a trace of the streamer passing through; After the passage of the streamer, the hollow portion is sometimes filled with a melted substance;
- As outlined in Fig. 2, the cross-section of the fulgurite is substantially concentric: In the concentric cylinders of the fulgurite, the next outer part is done of striking raw material, and the outer most part is remained raw material; These materials are present in the circular range with a radius of several cm and sometimes with a diameter of 15 - 16 cm. Such constitutions can not be produced by any other means.

For completely artificial production, the following materials were prepared:

(1) river sand (Tempaku River): The reasons for the use are that the river sand is natural without being processed, and that it can be conveniently obtained.

(2) fluorite powder: Fluorite belongs to a cubic system, so that the refractive index after the convention can be easily determined.

Residual rate % unit

Type	grain size mm	19.10	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074	less 0.074
Tempaku river sand	coarse	0.	0.74	44.97	54.21	0.13	0.11	0.11			
	middle			0.	15.90	78.32	2.81	1.87	0.79	0.31	
	fine				0.	19.34	52.26	17.09	10.30	0.98	0.03
Sab sand	middle			0.	27.37	59.46	5.18	2.94	1.82	0.30	2.93
	fine			0.	0.85	37.80	42.68	9.91	5.18	0.69	2.89

Type	grain size mm	2.00	0.84	0.42	0.25	0.105	0.074	0.051	0.037	0.025	0.015	0.011	less 0.011
Silica sand	coarse	0.	0.12	13.83	50.75	32.86	2.09	0.35					
	middle			0.	0.15	33.43	2.38	19.22	3.95	12.62	21.31	1.57	5.37

Table 1: Grain size distribution of material for production of fulgurite.

(3) silica sand: Natural sand contains a mixture of a variety type of minerals. The sand was selected for the purpose of analytical experiment (Si0 about 95%).

(4) Saba sand: During the experiment, saba sand contains a large amount of feldspar of which the melting point (l200 - 900 C) is lower than quartz.

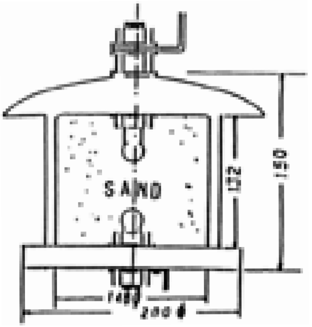


Figure 3: Container of material for the production of fulgurite

(5) polyethylene: During the experiment, polyethylene particles of which the melting point is much lower was used to know the state of streamers.

It was estimated that the grain size of the materials would exert an influence over the fulgurite production. The grain size was classified into three groups, that is, coarse, middle, and fine grain groups as shown in Table 1.

The following devices are prepared for the experiments:

(1) Sample Container: High strength and dielectric strength are required to prevent the container from being broken when applied with voltage and mechanical pressure. An ebonite plate was used at the bottom of the container. The distance between the electrodes was adjustable within the range of 10 - 80 mm. Figure 3 shows shape and size of the container, and the volume of it was about 2000 cc.

(2) Impulse Current Generator: Several different impulse voltage generators were used. The largest generator used had a maximum charging voltage of 3600kV. For the experiment, first, an impulse voltage of 14kV was used. Then, the voltage was gradually increased. As described below, the impulse voltage generators were modified into impulse current generators. Figure 4 illustrates a typical generator circuit used in the present study.

Experimental procedures were as indicated below. First, filling the container with raw materials. In the study, the standard impulse voltage wave 1x40 microsecond was used. There was thus some difference in the wave form between the test

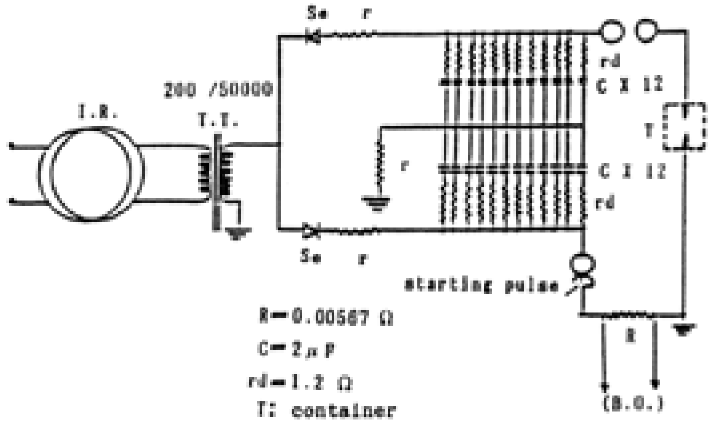


Figure 4: Circuit diagram for production of fulgurite in laboratory

voltage used this time and that of typical cases of the traveling waves of actual thunders, whose total duration and the wave front are, 100 microseconds or so, and about 1 - 10 microseconds, respectively.

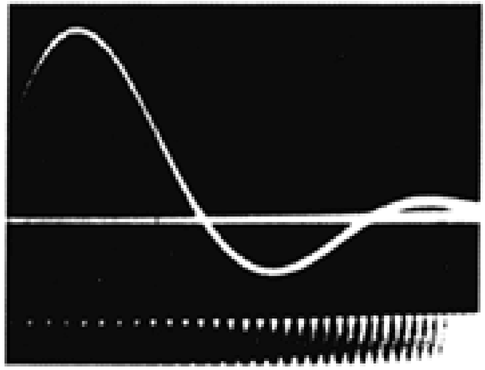
At first, the impulse voltage was applied to one sample at a time, but fulgurite could not be produced. Then, the impulse voltage was repeatedly applied 5 - 3 times.

In the total 84 cases of the experiment, there was observed substantially no conversion to fulgurite in the 1 - 44th cases. In the 45th or latter cases, fragments of fulgurite became to appear. Thus, the number of application of impulse voltage was found very important.

As seen in Table 2, simple increase in voltage did not result in the production of fulgurite. Thus, the generator circuit was modified: the capacitors were connected in parallel so that the current intensity could be increased.

Main points of the experimental results were as follows. Along a streamer of onion-like shape traveling between the electrodes, a spherical, hollow, dark brown, fragile fulgurite was produced which had a sea-urchin-like rough surface in appearance. The diameter was about 4 cm, the height was 2 - 4 cm. A great attention should be paid to the relation between the voltage application number and the production of fulgurite, in order to prevent the shell-shape fulgurite from being broken - See Fig.6(a)(b).

Table 3 summarizes the experimental results of the relation obtained at a current ranging from 0.01kA to 15kA and a voltage from 10kV to 600kV. The results were discussed, based on the fulgurite including partial product of it. All the products seemed rather fragile. This may be attributable to the low current compared to the natural lightning current. For the production of fulgurite, a current of 50 kA or higher seems necessary although a

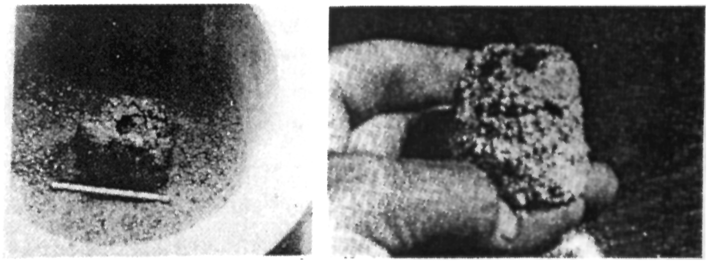


Time marker: 500kHz

Figure 5: Waveform of impulse current for production of fulgurite

KA / KV	10~20	21~50	51~100	101~600	Total	Production rate %
0.01	30		0		30	6.25
~0.1	0		2		2	
0.11				9	9	0
~5.0				0	0	
5.1		0	1		1	93.8
~10.0		2	13		15	
10.1		4	0		4	85.2
~15.0		19	4		23	
Total	30	4	1	9	44	
	0	21	19	0	40	
Production rate %	0	84.0	95.0	0		

Table 2: Test Parameters and results
Upper line: number of case of no production
Lower line: number of case of successful production



(a) produced from Tempaku river sand (b) produced from Saba sand
Figure 6: Fulgurites produced this time

high voltage is not necessarily needed. Thus, a generator of a high energy is preferred. Provided that the generated energies are equal, a higher current is favorable for the production of fulgurite.

The influence of the selection of materials on the production is of interest. In the case of Saba sand, the production ratio is highest, that is, 100%. The Tempaku River sand has the next highest production ratio of 84X. For the silica sand which is purest, the ratio is low, e.g., 7.25 as seen in Table 3. As for the grain size, the fine grain of the Tempaku River sand and the middle-sized grain of the Saba sand had a relatively high production ratio. As a whole, no significant difference was found between the grain sizes.

Next, relation between discharge time and production of fulgurite is of interest. The extent of fulgurite production was divided into four stages. The experimental results of the relation were summarized, depending on the materials and the discharge time. In the case of the discharge time of 20 - 50 microseconds, a largest amount of fulgurite was produced.

As a trial, the discharge test was conducted for 1 - 2 millisecond, giving no successful results. For the silica sand, substantially no fulgurite was produced.

Relation between Energy and production of fulgurite was examined. In the range of 5,000 - 50,000 Joule, the production frequency was highest. When evaluated as a whole, based on the above results, the energy required shall be at least 5,000 J, and for more complete production of fulgurite, 10,000 J or higher is favorable.

Raw Material		Production	Non-production	Total	Production rate %	
Polyethylene		0	8	8	0	0
Flourite		0	8	8	0	0
Saba sand	coarse	2	0	2	100	100
	middle	1	0	1	100	
	fine	5	0	5	100	
Silica sand	middle	2	8	8	25.0	17.2
	fine	3	18	21	14.3	
Tempaku river sand	middle	8	2	10	80.0	84.0
	fine	13	2	15	86.7	
Total		34	44	78		

Table 3: Materials used and results

When the current intensity is increased, the production possibility is increased. The discharge time of 20 - 50 microsecond is preferable. In the case of the generators used in the present study, silica sand containing feldspar and so forth gave a high production ratio than that composed of quartz only.

An X-ray analysis was made. Namely, the Saba sand before and after the voltage application was compared. For most of the feldspar as well as all the quartz, the reflectivities were reduced. The produced fulgurites were observed with a microscope for minerals. Substantially no changes in quartz were found, while the peripheries of the feldspar grains were vitrified.

Accordingly, for production of fulgurite, silica sand containing feldspar and so forth such as Saba sand, Tempaku River sand, etc. is preferable to that made of quartz only.

Conclusions

- The artificial production of fulgurites has been realized in the present study. The authors think that this is probably the first to describe the artificial production of fulgurite.

- New classification of fulgurite: fulgurites are not a simple product by nature. It is necessary to classify such fulgurites into three types; that is, natural, semi-natural and artificial fulgurites. Also, conventional classification of two types, depending on materials of soil and stone, and rock, is necessary.

- Importance of the accumulation of information: It is needless to say that thunderbolts are natural phenomena and are almost impossible to foresee the event. Thus, it is important to gather as much information as possible relating to the actual lightning strike.

- Future investigation of fulgurite: The following will be investigated and revealed; as for natural fulgurites: (1) discovery of fulgurites in as many countries possible, (2) historical, geological and palaeozoic meteorological significance of fulgurites and the values as faces fossil, (3) relation between the remained magnetism of lightning-striking products, especially basic rocks and stones and lightning current; and as for artificial fulgurites: (1) elucidation of production mechanism and conditions, (2) the production of crystallite by devitrification, (3) deposition of free silicon, and so forth.

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1993
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THE EVENT

Petrified Lightning from Central Florida

a Project by Allan McCollum

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