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(54) Carbon fiber aggregate capable of feeding by gravity-feed and production method therefor.

(57) A compressed carbon fiber aggregate has a ball-shaped, elongated ellipsoidal or cylindrical configuration made up of individual carbon fibers. The carbon fiber aggregate is produced without the need for a binder but is made sufficiently dense by compression into the ball-shaped, ellipsoidal or cylindrical configuration.To produce the aforementioned carbon fiber aggregate with increased density, loose carbon fibers are circulated by means of a gas, such as air, within a circular chamber. As they are being driven around the circular chamber by the gas, individual carbon fibers separate and then reaggregate into a more compact ball-shaped or ellipsoidal configuration. By performing the aforementioned process for a sufficient period of time, e.g. 10 to 20 min., a ball-shaped or ellipsoidal carbon fiber aggregate with a density sufficiently high for gravity-feed can be obtained. The obtained carbon fiber aggregates may be of essentially uniform size and density.

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Description

CARBON FIBER AGGREGATE CAPABLE OF FEEDING BY GRAVITY-FEED AND PRODUCTION METHOD THEREFOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to a carbon fiber aggregate which facilitates fabrication of a composite material in conjunction with a matrix material, such as synthetic resin, cement and so forth. More specifically, the invention relates to a high-density carbon fiber aggregate allowing gravity-feed, and which is therefore easy to handle. The invention relates in particular to an inexpensive method of producing a carbon fiber aggregate.

Description of the Background Art

Carbon fiber is known as a valuable and useful material because of its high strength and high conductivity. Carbon fiber can be used in composite materials in conjunction with a matrix material, such as synthetic resin, cement and so forth. Such composite materials can be used in electric shields, fiber-reinforced plastics (FRP), fiber- reinforced concrete and so forth.

Carbon fiber usually has a very low density which makes it difficult to employ gravity-feed processes. This hinders mass production of the composite material by mixing with the matrix material. In particular, in cases where the carbon fiber is made from coal pitch by the centrifugal spinning process, the density of the loose or matted carbon fiber is so low that gravity feed is impractical. Furthermore, since the density of loose carbon fiber tends to vary greatly, uniformity of carbon fiber concentration in the composite material can not be ensured.

In order to allow production of a composite material of uniform density, Japanese Patent First Publication (Tokkai Showa) 58-181760 discloses a method for separating matted or loose carbon fibers during mixing with the matrix material. In the proposed method, the matrix material and the loose carbon fibers are put into a mixing machine which is designed to separate and shorten the fibers to ensure uniform concentration of the carbon fiber in the finished composite material. Although this proposal may ensure a uniform carbon fiber concentration in the composite material, there still remains the problem of difficulty in feeding the loose carbon fiber into the mixer.

On the other hand, a carbon fiber aggregate with sufficient density to enable gravity-feed has also been proposed. In the proposed technique, an aggregate of the carbon fiber is formed with the aid of a suitable binder. This process is useful when the carbon fibers are of sufficient length. If the fibers are relatively short, this proposed method may not be practical. Therefore, in the case of carbon fibers made from coal pitch by the centrifugal spinning process, which tend to have relatively short fibers, the proposed method is not applicable. Furthermore, since the proposed method requires a binder, production costs will be high even if a sufficiently high density can be achieved.

SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to provide a carbon fiber aggregate of sufficient density to allow gravity-feed.

Another object of the invention is to provide a carbon fiber aggregate which is less expensive than the prior proposed aggregates.

A further object of the invention is to provide a simple method for forming carbon fiber aggregates.

A still further object of the invention is to provide an apparatus for implementing the carbon fiber aggregate production method according to the invention.

In order to accomplish the aforementioned and other objects, a compressed carbon fiber aggregate, according to the present invention, has a ball-shaped or elongated ellipsoidal configuration made up of individual carbon fibers. The carbon fiber aggregate is produced without the need for a binder but is made sufficiently dense by compression into the ball-shaped or ellipsoidal.

To produce the aforementioned carbon fiber aggregate with increased density, loose carbon fibers are circulated by means of a gas, such as air, within a circular chamber. As they are being driven around the circular chamber by the gas, individual carbon fibers separate and then reaggregate into a more compact ball-shaped or ellipsoidal configuration.

By performing the aforementioned process for a sufficient period of time, e.g. 10 to 20 min., a ball-shaped or ellipsoidal carbon fiber aggregate with a density sufficiently high for gravity-feed can be obtained. The obtained carbon fiber aggregates may be of essentially uniform size and density.

An apparatus designed to perform the above method includes an essentially cylindrical container defining therein an essentially cylindrical working chamber. A feed passage introduces loose carbon fibers into the working chamber. The feed passage enters the working chamber tangentially.

In the preferred construction, the feed passage is connected at an intermediate junction to a pressurized gas source which supplies gas to the circular chamber under pressure. The gas flow through the feed passage creates a vacuum at the end of the feed passage remote from the circular chamber. This end is opens into a reservoir containing loose carbon fibers. Therefore, the loose carbon fibers are drawn by the vacuum in the feed passage into the circular chamber with the gas.

Preferably, the container defining the working chamber may be in the form of a cyclone so that the resultant carbon fiber aggregate with sufficient density for gravity-feed can be removed through an outlet in its floor.

According to one aspect of the invention, a carbon fiber aggregate consists of a plurality of individual carbon fibers aggregated to form a body having round surface and having a bulk density higher than that of a starting loose carbon fibers.

The carbon fiber aggregate consists of a plurality of individual carbon fibers, each having fiber length less than or equal to 10 mm. The carbon fiber aggregate is formed into ball-shaped configuration, an ellipsoidal configuration or a cylindrical configuration. The ellipsoidal or cylindrical carbon fiber aggregate has individual carbon fibers making up are essentially parallel to each other.

According to another aspect of the invention, a method for producing high bulk density carbon fiber aggregate from low bulk density loose carbon fibers comprising the steps of:
forming an essentially circular working chamber;
introducing the loose carbon fibers into the working chamber;
circulating pressurized gaseous fluid within the working chamber so as to circulate the loose carbon fiber within the working chamber; and
continuing circulation of loose carbon fibers with gaseous fluid for a predetermined period of time in order to compact the loose carbon fibers into the carbon fiber aggregate having round surface.

The loose carbon fiber is carried by flow of the gaseous fluid and introduced into the working chamber with the gaseous fluid. The gaseous fluid carrying the loose carbon fibers are discharged into the working chamber in tangential direction with respect to the working chamber.

The loose carbon fibers are circulated within the working chamber with the gaseous fluid for a period of time long enough to provide a bulk density for the resultant aggregate greater than or equal to 0.02.

Preferably, the method further comprises a step of adjusting flow velocity of the gaseous fluid to adjust circulation speed of the loose carbon fibers within the working chamber.

According to a further aspect of the invention, an apparatus for producing a high bulk density carbon fiber aggregates from low bulk density loose carbon fibers, comprises a working chamber having a round periphery, an induction passage communciated with the working chamber, means for forming gaseous fluid flow toward the working chamber through the induction passage for carrying the loose carbon fibers therewith, and means for circulating the loose carbon fibers with gaseous fluid along the round periphery so as to form the aggregate.

The loose carbon fibers consist of a plurality of individual carbon fiber, each having fiber length less than or equal to 10 mm. The loose carbon fibers usually has bulk density less than or equal to 0.015.

In the practical embodiment, the means for forming gaseous fluid flow comprises a blower connected to the induction passage and the means for circulating the loose carbon fibers with the gaseous fluid within the working chamber comprises the induction passage connected to the working chamber and having a connecting end having an axis directed tangential direction to the round periphery of the working chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given herebelow and from the accompanying drawings of the preferred embodiment of the invention, which however, should not be taken to limit the invention to the specific embodiment but are for explanation and understanding only.

In the drawings:

Fig. 1 is a diagram of the overall structure of the preferred embodiment of an apparatus for fabricating carbon fiber aggregates according to the invention;

Fig. 2 is a horizontal section through a container in the apparatus of Fig. 1;

Fig. 3 is a section taken along line III-III of Fig. 2;

Fig. 4 is an illustration of loose carbon fibers;

Fig. 5 is a photograph of the loose carbon fibers of Fig. 4;

Fig. 6 is an illustration of a ball-shaped carbon fiber aggregate produced by the apparatus of Fig. 1;

Fig. 7 is a photograph of the carbon fiber aggregate of Fig. 6;

Fig. 8 is a scanning electron micrograph (SEM) showing the structure of the carbon fiber aggregate of Fig. 7;

Fig. 9 is a scanning electron micrograph (SEM) of a composite formed by mixing carbon fibers in the form of the inventive carbon fiber aggregate with a matrix material; and

Fig. 10 is a diagram of the major section of another embodiment of an apparatus for producing the carbon fiber aggregate of Figs. 6 and 7.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, particularly to Figs. 1 to 3, the preferred embodiment of an apparatus for forming or producing a carbon fiber aggregate, according to the present invention has an essentially cylindrical container 10. The cylindrical container 10 defines therein a circular working chamber 12. The cylindrical container 10 has an outlet 12a through which loose carbon fibers in the form shown in Figs. 4 and 5 are introduced into the working chamber 12.

A feed pipe 14 is connected to the cylindrical container 10. A feed or induction passage 16 defined within the feed pipe 14 communicates with the working chamber 12 through the inlet 12a. The feed passage 16 is so oriented that it enters the working chamber 12 almost at a tangent. The feed pipe 14 is connected to a blower 18 which serves as a pressurized gas or gaseous fluid source. In the shown embodiment, ambient air is used as a carrier gas for the loose carbon fibers. However, any gas suitable for use as a carrier gas can be selected as a replacement for air. An ejector type material feeder 40 is installed at an intermediate section of the feed pipe, to which the blower 18 is connected. The ejector type material feeder includes an induction pipe 20 having an inlet 20a inserted into a carbon fiber reservoir (not shown), which may be in the form of hopper. The blower 18 generates gas flow toward the working chamber 12 through the ejector type material feeder 40 and the feed passage 16. With the gas flow, the pressure at the outlet of the induction pipe 20 inserted into the ejector type material feeder 40 becomes lower than the atmospheric pressure or vacuum to draw the carbon fiber in the reservoir via the inlet 20a. The carbon fiber thus drawn into the induction pipe 20 is carried by the gas flow in the feed passage 16 and introduced into the working chamber 12 through the inlet 12a.

It can be easily appreciated that the above feed system which conveys the loose carbon fibers by means of an air stream is not meant to limit the invention to the shown structure and that any appropriate system can be used to feed the carbon fibers into the working chamber. Furthermore it is not essential to feed the loose carbon fibers into the working chamber with air. For instance, if necessary, the carbon fibers may be introduced directly through an appropriate hopper into the working chamber without air flow. The air flow is introduced into the working chamber 12 after the introduction of the carbon fibers to cause circulation of the carbon firbers along the periphery of the working chamber with the introduced air flow.

The cylindrical container 10 also has a gas outlet 24 in the center of its ceiling. Air is vented from the working chamber 12 through the gas outlet 24. A filter 26 in the gas outlet 24 prevents the carbon fibers in the working chamber from flowing out through the gas outlet. The cylindrical container 10 may also have a carbon fiber aggregate outlet in its floor to facilitate removal of the carbon fiber aggregate product. A closure lid may seal the carbon fiber aggregate outlet during production of carbon fiber aggregates.

As will be appreciated, the air circulating around the working chamber 12 drives the loose carbon fibers around the circular periphery of the working chamber. As the individual carbon fibers circulate, they repeatedly separate from and recombine with the growing aggregate, each time being packed somewhat tighter with other carbon fibers.

The resultant aggregates formed by this operation are illustrated in Figs. 6 and 7. Fig. 8 shows the structure of part of an individual carbon fiber aggregate. Since the resultant carbon fiber aggregate is in the form of a ball or nut and has a relatively high density, the resultant carbon fiber aggregates can be used in processes relying on gravity feed.

When the resultant carbon fiber aggregate is mixed with cement to form carbon fiber-reinforced cement, the individual carbon fiber making up the aggregate are resolved and separated into individual fibers. A typical mixture or composite material is shown in Fig. 9.

It should be noted that the shape of the aggregate will vary with upon the characteristic length of the loose carbon fibers. Specifically, when relatively long carbon fibers are used, the aggregate will tend to be ellipsoidal. On the other hand, when relatively short carbon fibers are used, the aggregate will be more nearly spherical.

It should also be noted that a ratio α of volume (v) of the loose carbon fibers versus the volume (V) of the working chamber is an important parameter affecting formation of the carbon fiber aggregate. Also, the circualting rate of the fibers and the operation time are believed to be important parameters affecting formation of the carbon fiber aggregate. For instance, in experiments, when carbon fibers with a length of 10 mm, a diameter of 16μ and a specific gravity of 1.6, and matted to a bulk specific gravity of 0.015, are processed in a cylindrical container 10 with a diameter of 30 cm, the yield of the carbon fiber aggregate is significantly lowered if the ratio α is allowed to be greater than or equal to 15%. If the circulation rate γ(rps) is set to the range of $2 > \gamma > 3$rps and the operation time (t) is held to less than 15 min, a cylindrical or ellipsoidal aggregate with a diameter of 2 to 3 mm is obtained. In this case, the individual carbon fibers making up the aggregate are essentially parallel and the density of the carbon fiber aggregate is about 0.02. On the other hand, when the circulation rate is set to less than 1 rps, and operation time is set to the range of 3 to 15 min, a cylindrical or ellipsoidal aggregate made up of parallel fibers is obtained. In this case, the bulk specific gravity of the aggregate is increased to 0.03. Furthermore, if the aggregation operation is performed at a circulation rate in the range of $2 < \gamma < 3$ rps for a period longer than 15 min., the resultant aggregate will be ball-shaped and have a density of about 0.02.

Additional experiments have been performed under various conditions. The following are the conditions and results of these experiments.

EXPERIMENT I

Loose carbon fibers with a bulk density of 0.015 and an average fiber length of 10 mm, diameter of 10 and specific gravity of 1.6 derived from the coal pitch were loaded into the cylindrical container of Fig. 1 to a volumetric ratio (= v/V) of 10%. An air stream was introduced through the feed passage 14 to circulate the carbon fibers at a rate of 2.5 rps. The operation was performed for 5 min. The resultant carbon fiber aggregates were cylindrical or ellipsoidal, about 10 mm long, 2 to 3 mm in diameter, and had a density of 0.02.

EXPERIMENT II

The carbon fiber aggregates obtained in the above experiment I were again circulated within the working chamber at a rate of 0.5 rps for 10 min. The resultant aggregates were cylindrical or ellipsoidal, 10 mm in length, 3 to 4 mm in diameter and had a density of 0.03.

EXPERIMENT III

The aggregation operation was performed using the same carbon fibers as in experiment I and the operation time was expanded to 20 min. The resultant carbon fiber aggregates were spheres 5 to 7 mm in diameter. The density of the ball-shaped aggregates was 0.02.

EXPERIMENT IV

A cylindrical container 50 cm in diameter was used. Carbon fibers 3 mm in length, with a specific gravity of 1.6 and derived from the coal pitch was used. The bulk density of the starting carbon fiber material was 0.04. The carbon fibers were introduced into the working chamber via air stream through the feed passage. The carbon fibers were circulated at a rate of 20 rps for 30 min. The resultant carbon fiber aggregates were ball-shaped and had a bulk specific gravity of 0.15.

The carbon fiber aggregates obtained from the foregoing experiments could be handled by gravity-feed. This makes it easy to handle carbon fiber. Furthermore, since the method and apparatus according to the present invention does not require any binder, the production cost of the aggregates can be held relatively low.

Fig. 10 show another embodiment of a cylindrical container 10 including a cyclone. The cyclone has a lower, conical section 30 which collects the carbon fiber aggregates for easy removal through the bottom outlet 32. This cyclone makes collection of the finished aggregates easier.

As will be appreciated herefrom, the present invention fulfills all of the objects and advantages sought therefor.

While the present invention has been disclosed in detail with reference to the accompanying drawings, the invention is not limited to the shown embodiments. Any modifications of the shown embodiments and implementation of the discussed process in any way without departing from the principle of the invention set out in the appended claims should be regarded to be within the scope of the invention.

Claims

1. A carbon fiber aggregate consisting of a plurality of individual carbon fibers aggregated to form a body having round surface and having a bulk density higher than that of a starting loose carbon fibers.

2. A carbon fiber aggregate as set forth in claim 1, which consists of a plurality of individual carbon fibers, each having fiber length less than or equal to 10 mm.

3. A carbon fiber aggregate as set forth in claim 2, which is formed into ball-shaped configuration.

4. A carbon fiber aggregate as set forth in claim 2, which is formed into an ellipsoidal configuration.

5. A carbon fiber aggregate as set forth in claim 4, wherein individual carbon fibers making up are essentially parallel to each other.

6. A carbon fiber aggregate as set forth in claim 2, which is formed into a cylindrical configuration.

7. A carbon fiber aggregate as set forth in claim 6, wherein individual carbon fibers making up are essentially parallel to each other.

8. A method for producing high bulk density carbon fiber aggregate from low bulk density loose carbon fibers comprising the steps of:
forming an essentially circular working chamber;
introducing said loose carbon fibers into said working chamber;
circulating pressurized gaseous fluid within said working chamber so as to circulate said loose carbon fiber within said working chamber; and
continuing circulation of loose carbon fibers with gaseous fluid for a predetermined period of time in order to compact said loose carbon fibers into said carbon fiber aggregate having round surface.

9. A method as set forth in claim 8, wherein said loose carbon fiber is carried by flow of said gaseous fluid and introduced into said working chamber with said gaseous fluid.

10. A method as set forth in claim 9, wherein said gaseous fluid carrying said loose carbon fibers are discharged into said working chamber in tangential direction with respect to said working chamber.

11. A method as set forth in claim 10, wherein said loose carbon fibers are circulated within said working chamber with said gaseous fluid for a period of time long enough to provide a bulk density for the resultant aggregate greater than or equal to 0.02.

12. A method as set forth in claim 11, which further comprises a step of adjusting flow velocity of said gaseous fluid to adjust circulation speed of said loose carbon fibers within said working chamber.

13. An appratus for producing a high bulk density carbon fiber aggregates from low bulk density loose carbon fibers, comprising:
a working chamber having a round periphery;
an induction passage communicated with said working chamber;
means for forming gaseous fluid flow toward said working chamber through said induction passage for carrying said loose carbon fibers therewith; and
means for circulating said loose carbon fibers with gaseous fluid along said round periphery so as to form said aggregate.

14. An apparatus as set forth in claim 13, wherein said loose carbon fibers consist of a plurality of individual carbon fiber, each having fiber length less than or equal to 10 mm.

15. An apparatus as set forth in claim 14, wherein said means for forming gaseous fluid flow comprises a blower connected to said induction passage.

16. An apparatus as set forth in claim 15, wherein said means for circulating said loose carbon fibers with said gaseous fluid within said working chamber comprises said induction passage connected to said working chamber and having a connecting end having an axis directed tangential direction to said round periphery of said working chamber.

FIG. 1

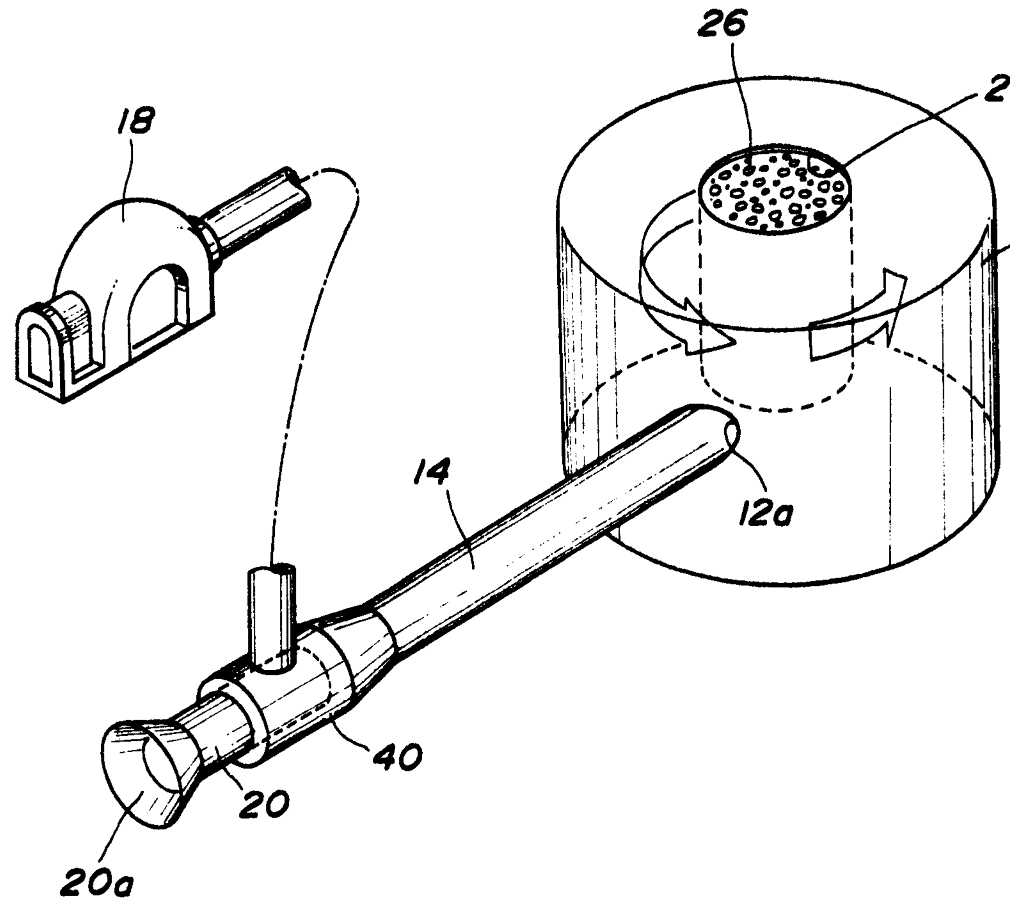


FIG. 2

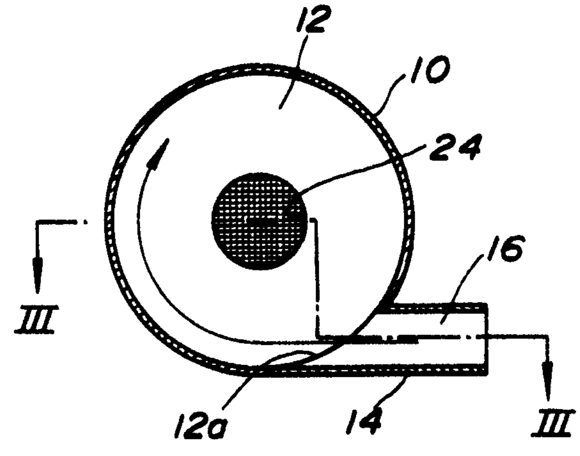


FIG. 3

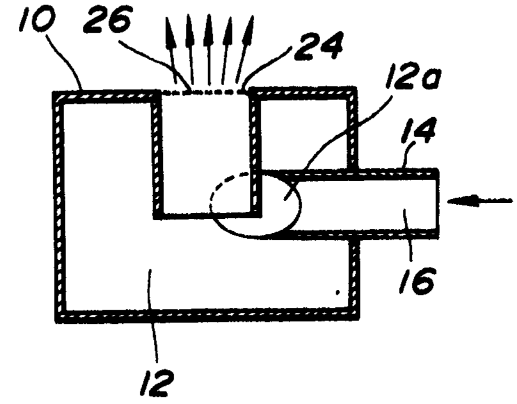


FIG.5

FIG.4

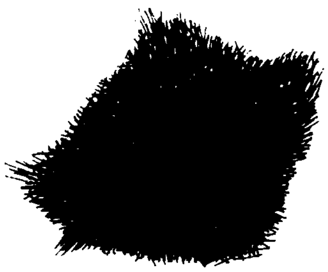
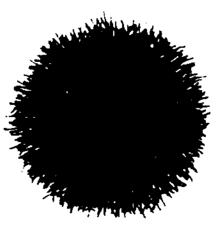


FIG.7

FIG.6



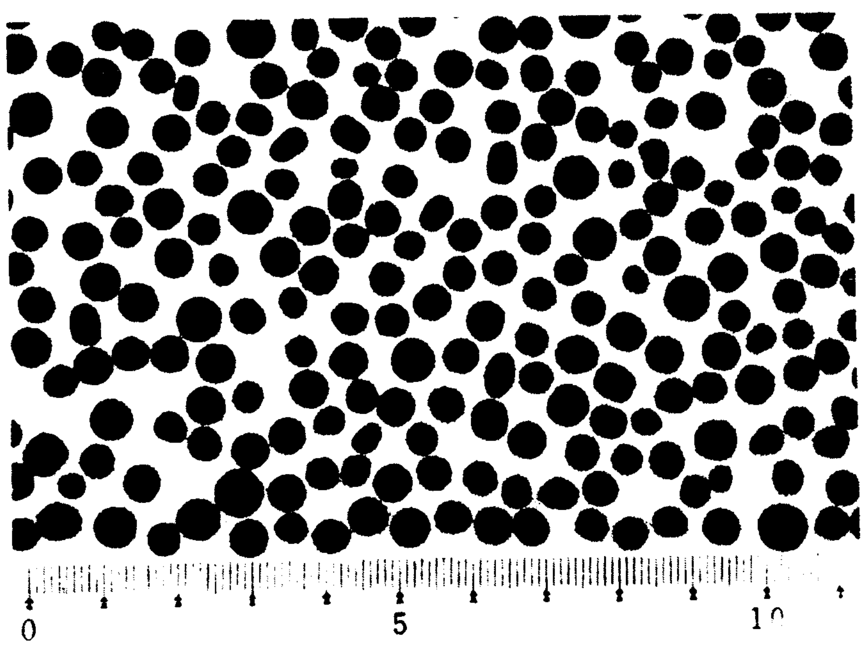


FIG.8

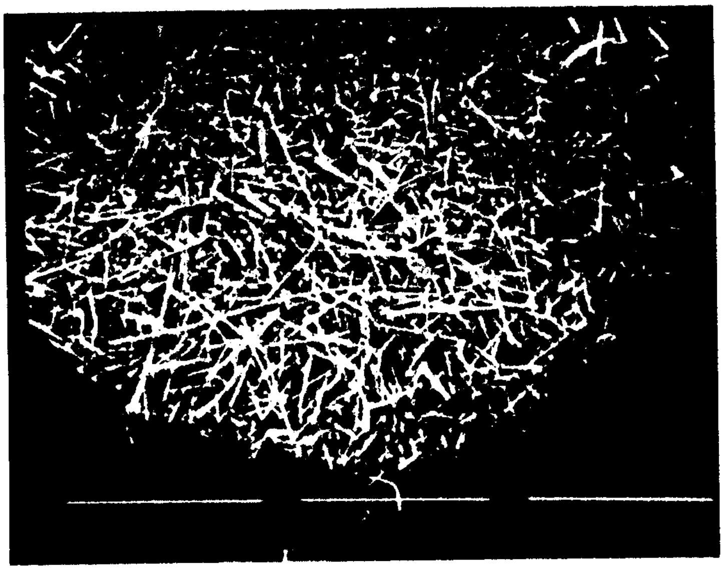


FIG.9

FIG.10