

- [54] **METHOD OF PLATING METAL
UNIFORMLY ON AND THROUGHOUT
POROUS STRUCTURES**
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427/243; 427/251; 252/466 J**
- [51] Int. Cl. **C23c 11/02**
- [58] Field of Search..... **117/107.2 R, 107.1, 98;
118/49.5**

- [56] **References Cited**
UNITED STATES PATENTS
- | | | | |
|-----------|---------|--------------------|---------------|
| 3,004,866 | 10/1961 | Bolton et al. | 117/107.2 R X |
| 3,075,494 | 1/1963 | Toulmin..... | 117/107.2 R X |

3,121,925	2/1964	Toulmin.....	117/107.2 R X
3,158,499	11/1964	Jenkin.....	117/107.2 R
3,160,517	12/1964	Jenkin.....	118/49.5 X
3,213,827	10/1965	Jenkin.....	118/49.5

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[57] **ABSTRACT**

A method of uniformly coating ceramic and alumina porous structures such as honeycomb and sponge structures are disclosed. The method comprises radiantly heating a rotating workpiece until the temperature of the workpiece reaches the decomposition temperature of a thermally decomposable metal bearing gas. Passing a metal bearing gas over the structure whereby a uniform and firmly adhered coating is obtained on and throughout the workpiece.

8 Claims, 4 Drawing Figures

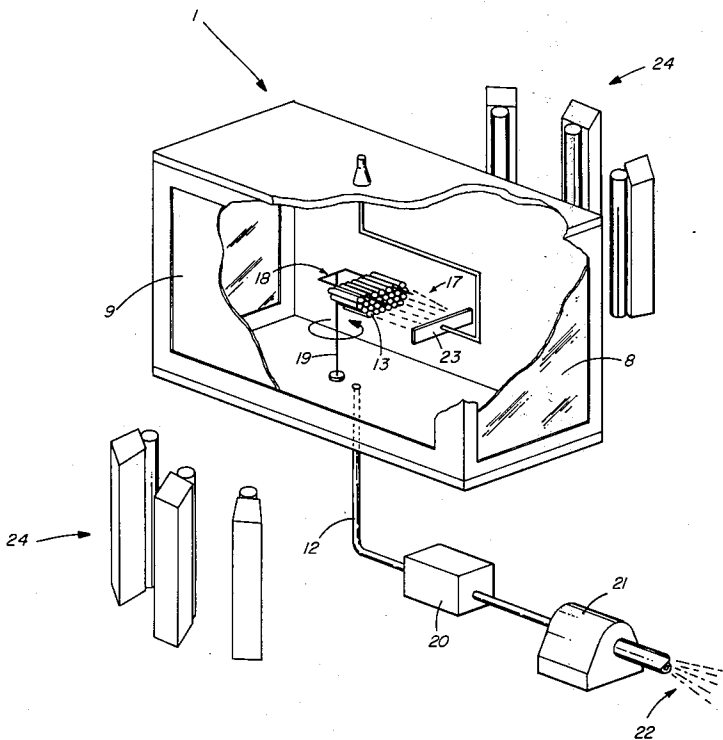


FIG. 1

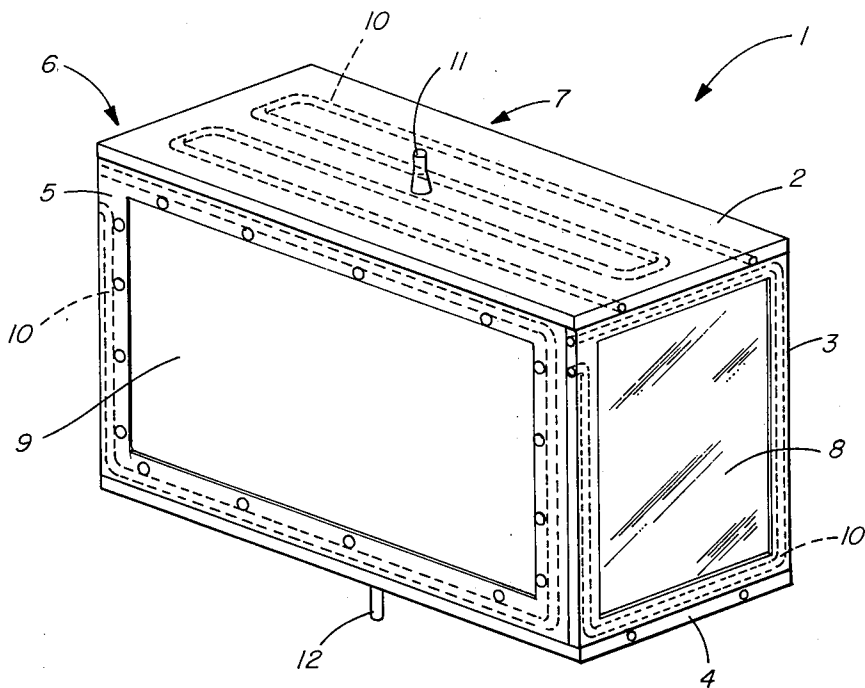


FIG. 2

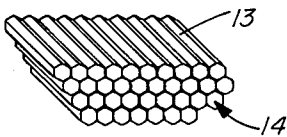
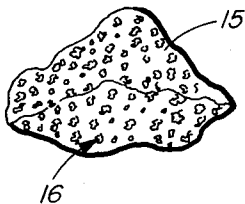


FIG. 3



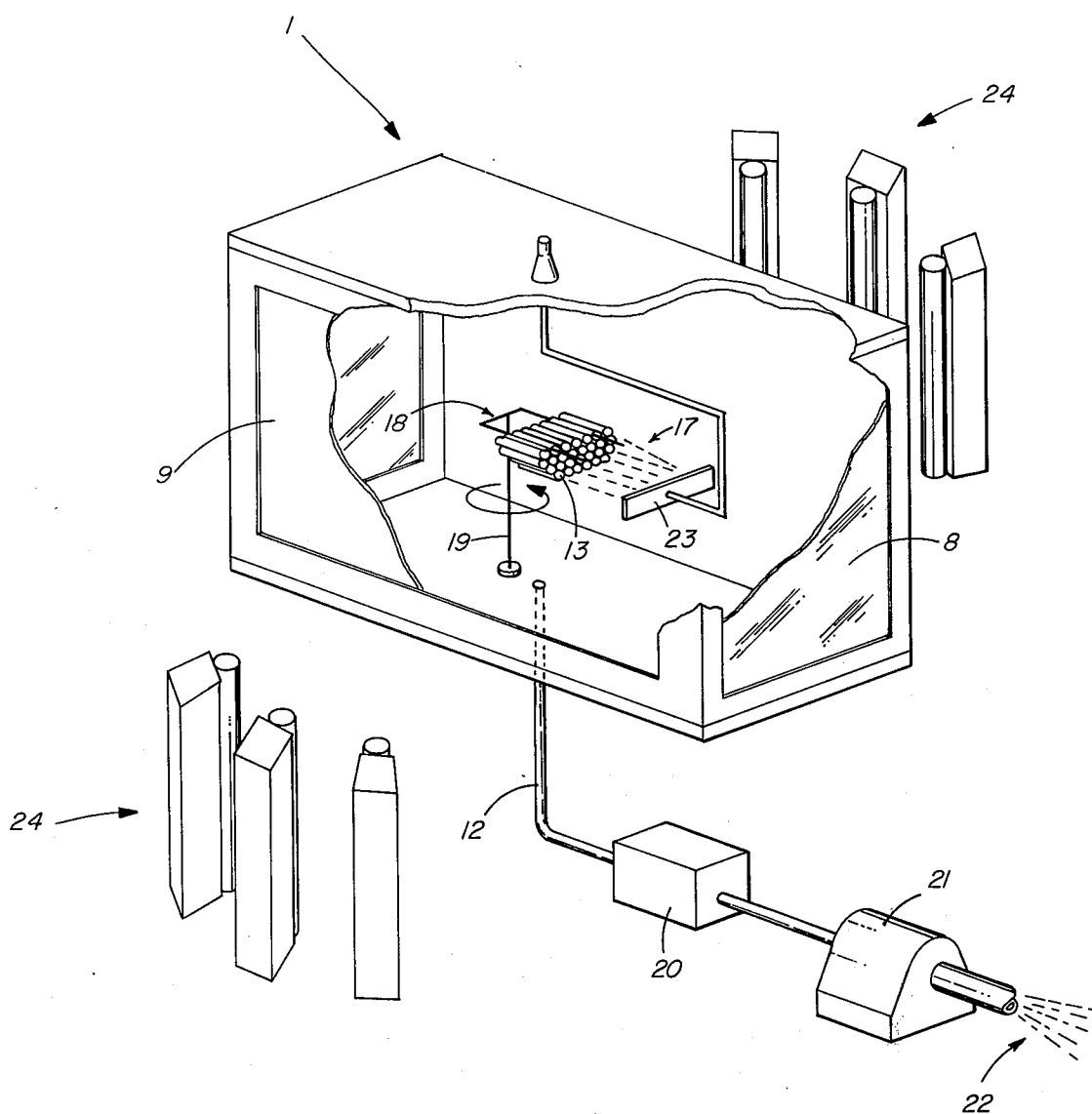


FIG. 4

METHOD OF PLATING METAL UNIFORMLY ON AND THROUGHOUT POROUS STRUCTURES

FIELD OF THE INVENTION

This invention relates to a method of metallizing porous ceramic and alumina structures wherein the metal is plated onto and throughout the structure in a uniform manner. The invention further relates to the products obtained from the method of coating and their uses.

DESCRIPTION OF THE PRIOR ART

There have been a number of methods described for coating alumina and ceramic structures with metals. Among the more prevalent methods are solution deposition of metals onto alumina or ceramic structures and vapor deposition or gas plating of metals on alumina and ceramic structures. The metal plated structures are more popularly employed as catalysts and in heat exchange systems.

The various methods of solution deposition described in the prior art have several disadvantages over the vapor deposition of metals onto alumina and ceramic substrates. Solution deposition is expensive since very often the water soluble or water insoluble salts employed can be costly and the equipment employed is expensive. Quite frequently, the methods employed result in the production of noxious and corrosive compounds such as nitrogen compounds, should the soluble salts employed be in the form of nitrates, and means must be provided for handling the noxious gasses. The methods most often require multiple impregnations and hence therefore require multiple dryings. The purity of the plating of metals is difficult to control since very often contaminating ions are introduced which must be removed either by calcination or washing procedures.

In any event, the technique of solution deposition results in a product wherein the plated metal is generally not firmly adhered to the substrate and flaking readily occurs under high temperatures and severe use. Flaking or breakage can result in the producing of fines which clog packed towers and cause undesirable pressure drops. Should a plated catalyst be employed in an auto muffler, fines can cause back pressure and a drop in engine efficiency. A significant advantage of vapor deposition over solution deposition is that one may obtain a substantially pure metal plate upon a ceramic structure (hereinafter the term ceramic will be understood to include alumina, silicon carbide, silicon dioxide as well as other ceramic materials) which plate strongly adheres to the substrate under high temperatures and severe conditions.

The use of metal plated ceramic sponge or honeycomb structures as catalysts is often more desirable than metal plated ceramic pellets or spheres. With spheres, or pellets, there is an inefficient heat transfer due to the resistance in point to point contact of the particles. As a result of the inefficient heat transfer, there is a loss in the catalytic activity of the materials due to sintering poisoning and flaking. On the other hand, resistance to heat flow is low with respect to sponge or honeycomb structures, heat can readily be removed from or passed into a sponge or honeycomb catalyst more simply. The low resistance to heat flow results in a desirable catalyst for endothermic reactions such as reforming and the production of inert gasses

and for exothermic reactions such as methanation. Due to enlarged void spaces and resultant low pressure drop and high through put, the honeycomb and sponge structures are more efficient as a catalyst and due to the lower weight of the structures as compared to pellets and spheres there is less stress on any supporting plate in a packed column or otherwise.

In U.S. Pat. No. 3,075,494 of Toulman, Jr., issued Jan. 29, 1963, there is disclosed an apparatus and method for making metallized porous refractory material. In order to obtain a uniform plate of the metal on and throughout a sponge or honeycomb workpiece, the temperature of the workpiece must be uniform throughout. Since ceramics are insulators, it is readily understandable that a temperature gradient will necessarily occur across honeycomb and sponge structures unless all portions of the workpiece are uniformly heated. By maintaining the structure in a rigid position as disclosed by Toulman, Jr., the middle, front and backs of the workpieces are heated by convection and thus would not be at the same temperatures as other portions of the material. The temperature gradient across the material will necessarily result in a non-uniform deposition of the metal since the metal bearing gas decomposes slower at the lower temperatures.

U.S. Pat. No. 3,160,517 of Jenkin, issued Dec. 8, 1964, attempts to overcome the problem of non-uniform deposition of the coating on porous structures. In accordance with the described technique infrared heat rays are directed onto one side only of the porous body while forcing the metal bearing gasses through the porous body from one side to the other side. This use of forced gas and heating from only one side again results in non-uniform deposition as a result of temperature gradients within the structure.

It is readily understood that a significant advance in the art would be obtained by a process which would allow for the uniform deposition of metal upon a ceramic honeycomb or sponge structure. The improvement would be even more desirable if the techniques and apparatus employed are simple as compared to the prior art.

SUMMARY OF THE INVENTION

This invention eliminates the major disadvantages of the prior art metal deposition processes in that it has been unexpectedly discovered that a honeycomb or sponge ceramic workpiece can be subjected to gas deposition of a metal in a manner such that the metal can be deposited uniformly on and throughout the structure in a simple manner.

The process for uniformly plating a metal by vapor deposition on and throughout a substrate or workpiece which has a structure of a honeycomb or sponge comprises heating in an enclosure, a rotatably suspended workpiece or substrate by radiant means until the substrate reaches the temperature of a thermally decomposable metal bearing gaseous compound, rotating the substrate and passing a thermally decomposable metal bearing compound into the enclosure along with a carrier gas in a manner such that the gas comes into intimate contact with the substrate while continuously rotating the substrate whereby the metal is uniformly plated on and throughout the substrate.

In accordance with the invention there is further obtained a ceramic honeycomb structure having the longitudinal axes of all its cells parallel to each other, the

improvement comprising a uniform coating on and throughout the structure said coating being firmly adhered to the ceramic substrate. The invention further provides ceramic sponge structures having uniformly coated on and throughout said structures or substrates a firmly adhered metal plate.

It is therefore an object of this invention to provide a process for uniformly plating a metal on and throughout ceramic honeycombs.

It is another object of this invention to provide a process for uniformly plating a metal on and throughout a ceramic sponge.

It is still another object of this invention to provide an improved process for the vapor deposition of a metal uniformly on and throughout a ceramic honeycomb or sponge.

Still another object of this invention is to provide a method for plating a ceramic honeycomb or sponge with a metal in an economic and simple manner.

Yet another object of this invention is to provide a ceramic honeycomb or sponge structures plated uniformly on and throughout the structure with a metal.

Still yet another object of this invention is to provide a ceramic honeycomb or sponge structure having a pure and uniform metal plate on and throughout the structure.

A further object of the invention is to provide ceramic honeycomb and sponge structures having a firmly adhered plate of a pure metal.

A further object of the invention is to provide ceramic structures having a plate of a major amount of one metal and a minor amount of at least one other metal.

Still yet another object of this invention is to provide metal plated ceramic honeycombs or sponges which are useful as catalysts and in heat exchange systems.

These and other objects of this invention will be understood from the description and drawings and the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the enclosure which may be employed in gas plating ceramic objects in accordance with this invention.

FIG. 2 is a perspective view of a ceramic honeycomb structure.

FIG. 3 is a perspective view of a ceramic sponge which may be plated in accordance with this invention.

FIG. 4 illustrates the gas plating apparatus for carrying out the metal plating ceramic honeycombs and sponges.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings in more detail, FIG. 1 depicts the enclosure which can typically be employed in the gas plating operation. The apparatus comprises the overall assembly 1 having a top metal panel 2 and a bottom panel 4. Typically the top and bottom panels are made of steel. Attached to the panels are cooling lines 10 which can be spot welded to the steel. The front panel 3 has a glass window 8 for observation purposes and additionally contains cooling tubes 10. The side panels 5 and 7 contain teflon window panels 9. The apparatus further comprises gas inlet conduits 11 and gas outlet conduits 12.

FIG. 2 illustrates a honeycomb 13 having parallel cells 14.

FIG. 3 illustrates a sponge 15 with random cells and passages 16.

FIG. 4 illustrates a coating method and operation. The workpiece 13 to be coated is suspended from a suspension member arm 18 that holds the workpiece. The suspension member 18 is on a rotating base 19 thereby permitting the workpiece to be continuously rotated during the gas plating operation. The gas spray 17 enters the enclosure through a gas spraying device 23 while the workpiece 13 is continuously rotated. During the coating operation the workpiece is radiantly heated by a bank of infrared tubes 24 located at the sides of the enclosure. The unused gas and carrier gases pass through the outlet tube 12 through a trap 20 burning station 21 and finally exhaust through 22.

In accordance with this invention, it has been unexpectedly and unobviously discovered that by rotating the workpiece having parallel and non-parallel passageways therein, while radiantly heating the workpiece there is essentially no temperature gradient across the workpiece. It is because of the uniform temperature throughout the workpiece i.e. in the middle as well as on the outsides that one obtains a uniform plate of metal on and throughout the workpiece.

Generally, rotation about a single axis is sufficient. With respect to large workpieces or workpieces having odd shapes various portions of the outside, for example, the top and bottom, may not be in line with the direct rays of the heating lamp and therefore not properly radiantly heated. The workpiece can then be alternatively rotated about an axis normal to the original axis of rotation or the workpiece can merely be alternatively angled so as to bring all portions of the piece into the direct ray of the lamp. With very large workpieces, it can be extremely difficult to rotate about 360° and hence it is desirable to oscillate the piece through an angle of about 30° in order to obtain uniform temperature across the piece.

The ceramic honeycombs and sponges and their methods of preparation are well known in the art and need no extensive description herein. U.S. Pat. No. 3,502,596 of Sowards adequately describes ceramic structures and cites a number of patents describing methods for preparing ceramic honeycombs. Other patents disclosing ceramic structures are U.S. Pat. Nos. 3,378,431 of Crandall and 3,090,094 of Schwartzwalder. Crandall, Schwartzwalder and Sowards are hereby incorporated by reference.

The sponges are made in a simple manner, for example, a paste mixture comprising 85.7% water, 10% aluminum hydroxide $[Al(OH)_3]$, 3.5% of a surfactant (CF-54 from Rohm and Hass) and 0.8% of a 35% solution of hydrochloric acid is prepared. A polyvinyl acetate sponge or a sponge made of similar materials such as nylon is soaked in the mixture. The sponge and paste mixture is heated slowly especially through the range of 300° to 350° centigrade where the sponge material, if acetate, decomposes. The remains are slowly heated to 1,000°C. and thereafter slowly cooled, whereby one obtains a ceramic or alumina sponge. The May 1967 issue of Ceramics Industry describes the preparation of foam using albumin.

The ceramic honeycombs or sponge materials are readily obtainable on a commercial basis from companies such as Champion Spark Plug Company, Detroit,

Mich.; American Lava Company, Chattanooga, Tenn.; Hexcel Company of Dublin, Calif.; Scott Paper Company of Eddystone, Pa. and Corning Glass Company of Corning, N.Y.

While it is generally desirable to obtain a workpiece with a pure plate of metal such as nickel, often it is desirable to have a minor portion of a second metal incorporated in with the plate such as platinum, cobalt, ruthenium or copper. Ruthenium for example can be put onto a nickel coated sponge electrolytically. Such a nickel plated sponge having minor amounts of ruthenium plated thereon acts as an excellent methanation catalyst since minor amounts of ruthenium trigger an exothermic reaction which would enable the nickel to carry on as a catalyst and at the same time the nickel sponge with its heat exchange capabilities enables and helps to remove the heat. Rare earth compositions are plated with great difficulty upon ceramics but with a metal plate upon the ceramics, the coating of an adherable rare earth composition, such as for example, lanthanum lead manganite is greatly simplified.

A method of adding platinum to the nickel plate would be to place an amount of platinum acetonyl acetate in the nickel carbonyl line or small amount of the acetate can be dissolved in nickel carbonyl. Other methods of incorporating minor or major amounts of other metals such as palladium, copper and cobalt are well known in the art and would be obvious to those of ordinary skill in the art.

The honeycomb or sponge structures can comprise virtually any ceramic material, for example, these materials could include boro-silicates, soda-lime-silicates, lead silicates, aluminosilicates and alkaline earth silicates; sillimanite magnesium silicate, magnesite, zircon, zirconia, petalite, spodumene, cordierite, corundum, glass ceramics, beryllium oxide and zirconium oxide. In accordance with a preferred embodiment, it is desirable to use as ceramic materials lithium aluminum silicate, alumina and silicon carbide.

The typical plating chamber comprises a rectangular shaped enclosure having a glass front window and ten mil thick FEP teflon tightly stretched. The tops, bottoms and the backs can be made from steel and are cooled with copper tubes containing cooling liquid. In a typical operation for plating small ceramic workpieces, the chamber would be 10 inches wide, 15 inches high and 16 inches deep. However, size of the plating chamber necessarily depends on the size of the piece to be plated. The sides and fronts are cooled either by air fans or a water spray in order to prevent plating of the metal upon the insides of the enclosure. On both sides of the enclosure are located banks of 17 inch long infrared lights and reflectors, the number of lights employed of course is a function of the decomposition temperature of the metal containing gas as well as the size of the workpiece and other factors which are obvious to those of ordinary skill in the art. Round lights can also be employed in place of the light tubes.

In a typical method of plating a workpiece, the workpiece is cleaned in order to remove the grease and fingerprints. The workpiece is placed onto a rotatable suspension means and the airtight chamber is closed. The chamber is then purged with nitrogen gas at about 9.8 cubic feet per hour and shortly thereafter the lights are turned on. It is important that the heating lamps be on for no more than 40 seconds in order to avoid overheating the teflon windows. Typically, lights would be

activated for about 20 to 30 seconds and deactivated for about 20 to 30 seconds. After purging with nitrogen, the chamber is then purged with carbon monoxide for approximately a half an hour. The carbon monoxide not only helps to purge the chamber of air but also helps to activate the surface of the workpiece. The chamber will have a small metal tab in close vicinity to the workpiece and connected with a thermocouple. As soon as the temperature of the workpiece reaches the decomposition temperature of a metal bearing gas the metal bearing gas is allowed to flow in through the chamber at a rate of about 0.3cc/minute. The metal bearing gas will typically go through a vaporizer and then mix with the carrier gas which is typically carbon monoxide and then allowed to flow into the chamber. Plating should begin in about 15 minutes. However, if plating does not begin, 3cc of H_2S gas should be passed into the chamber to help initiate the plating process. Hydrogen sulfide should not be employed however if it will interfere with subsequent catalytic uses of the product. After about an hour, the workpiece will be uniformly coated and the chamber purged and allowed to cool.

In carrying out the gas plating, one may employ any of the known heat-decomposable gaseous metal carbonyls.

Illustrative compounds are the carbonyl types such as for example, nickel, copper, iron or chromium carbonyls and mixed carbonyls of these metals. Other types of heat decomposable compounds are metal nitroxyls, nitrosyl carbonyls; hydrides and metal alkyls such as magnesium diethyl. Further useful gaseous metal compounds are the carbonyl halogens, for example, osmium carbonyl bromide, ruthenium carbonyl chloride, and the like.

The decomposition temperature of the heat-decomposable gaseous metal compound will control the temperature to which the workpiece is brought. For example, nickel carbonyl will decompose at a favorable rate for this process at about 350° to about 450°F. Accordingly, the metal bearing gas is passed into the enclosure when the temperature of the workpiece is from about 350° to about 450°F and preferably from about 410°F to about 450°F. In a preferred aspect, the metal bearing gas is passed into the enclosure when the workpiece is at a temperature of about 410°F.

In a typical operation, the workpiece is rotated at a rate of about two rotations per minute (rpm) to about 20 rpm. However, higher rates of rotation may be employed when so necessary. In a preferred embodiment, the rate of rotation is at about five rpm to about 10 rpm. In another preferred embodiment, the rate of rotation is seven rpm.

The thickness of the plate is determined by its use. In accordance with this process, the plating can be from about 0.1 mils to about 500 mils.

A significant advantage of our process over prior art processes of metal plating onto ceramic porous structures is its speed. Additionally, a thicker plate can be obtained which plate is uniform. Thus, if catalyst poisoning occurs during subsequent use, the outer metal layers can be readily removed such as by dipping in acid and reactivation of the catalyst is obtained.

EXAMPLES

The following examples are included for a further understanding of the invention.

Example 1

An alumina sponge structure, obtained from Champion Spark Plug Company of Toledo, Ohio, having the approximate dimensions of $2 \times 2 \times \frac{1}{2}$ inches is rotably suspended in an airtight chamber. Outside and to the sides of the chamber are located 17 inch long IR lamps with reflectors (three on each side). The lamps are continuously activated and deactivated at a rate so as to prevent the melting of the teflon sides of the chamber but gradually causing an increase in the temperature, as measured by the temperature of the tab next to the workpiece. The chamber is purged for approximately 1.5 hours with nitrogen followed with purging mixture comprising a minor amount of nitrogen with carbon monoxide. The workpiece is heated to a temperature of 410°F, which temperature is maintained throughout the plating operation. Rotation of the suspended structure at the rate of seven rpm is initiated and vaporized nickel carbonyl in carbon monoxide carrier gas is passed into the chamber. At the end of 1 hour there was obtained a medium uniform coating of nickel on and throughout the structure and which firmly adhered to the structure.

Example 2

An alumina sponge structure having the dimension of $2 \times 2 \times \frac{1}{2}$ inches was treated in the same manner as in Example 1 however the time of exposure of the sponge to the plating gas was reduced to 40 minutes. On close examination of the structure, there was observed a uniform thin and firmly adhered coating of nickel on and throughout the structure.

Example 3

An alumina sponge structure as in Example 1 was treated in the same manner as in said Example with the exception that the structure was exposed to the plating gas for 1 hour. At the end of 1 hour, the structure had a uniform heavy coating of nickel of approximately 1.5 mils thickness which was firmly plated onto the structure.

Example 4

An alumina sponge structure in the shape of a cylinder 3 inches high and 4 inches in diameter is suspended so that its longitudinal axis is horizontal and can be rotated about an axis perpendicular to the horizontal axis. The alumina structure weighed 139.99 gms prior to treatment. The sample is treated in the same manner as in Example 1 except that the structure was exposed to the plating gas for 2 hours and 44 minutes, with the temperature gradually increasing to 450°F for the first 1.5 hours and maintained at 450°F thereafter. The sample was observed to have a uniform coating of nickel on and throughout the structure which firmly adhered to the alumina. The sample after treatment weighed 183.10 g.

Example 5

A lithium aluminum silicate honeycomb structure having cells approximately $\frac{1}{8}$ inch in diameter and the dimensions of $1\frac{1}{4} \times 4\frac{1}{2} \times \frac{1}{2}$ inches is suspended in an airtight chamber in a manner such that the longitudinal axis of the honeycomb cells are horizontal and the piece can be rotated about the axis perpendicular to the horizontal axis. The chamber is purged for 1 hour

and 10 minutes first with nitrogen and for the final 10 minutes with a mixture of nitrogen and carbon monoxide. The IR lamps are continuously alternatively activated for 37 seconds and deactivated 25 seconds in order to bring the temperature to 435°F as measured by the temperature of the tab placed next to it. The lights are then activated and deactivated so as to maintain the 435°F temperature throughout the operation. Upon completion of the purge operation, the sample is continuously rotated at seven rpm while passing in vaporized nickel carbonyl in carbon monoxide and nitrogen carrier gasses. At the end of 1 hour an approximate 3.5 mil coating of nickel was uniformly plated on and throughout the honeycomb.

Example 6

A ceramic honeycomb having the dimensions as the honeycomb in Example 5 is treated in the same manner as in Example 5. The ceramic honeycomb was uniformly plated throughout the structure with nickel.

Example 7

A silicon carbide workpiece is treated in the same manner of Example 1. A uniform plate of nickel was obtained on and throughout the workpiece.

Examples 8-11

Four separate silicon carbide workpieces maintained at 410°F and rotating at seven rpm are separately exposed, in an airtight enclosure, to nickel carbonyl in carbon monoxide carrier gas. Each sample is exposed for 15 minutes. Each workpiece was coated with a 4.5 mil thick uniform plate of nickel throughout the piece.

Example 12

An alumina sponge and a ceramic honeycomb structure were each soaked in 100cc of room temperature water having dissolved therein 200g $\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ until the structures had plated thereon a coating of nickel. Each plated sponge was calcined at 900°F for 6 hours in an electric furnace.

Similar samples as above were plated with nickel in the manner of Example 1. The four workpieces were intermittently exposed to the flame of a Bunsen Burner. The solution plated samples evidenced marked flaking whereas the vapor plated sample showed no evidence of flaking.

Example 13 — Measurement of Heat Conductivity

Two $1\frac{1}{8}$ inch columns, one packed with nickel coated sponge pieces of this invention, the second packed with $\frac{1}{4}$ inch nickel coated saddles were placed on a stand sitting on a hot plate. Surrounding each column is 250 ml H_2O . The rate of transfer of heat from the hot plate through the packed columns to the H_2O was measured by measuring the temperature of the water at timed intervals. The results of the test is summarized in Table I. The results show the sponge pieces transfer heat to the water appreciably faster than the saddles.

TABLE I

Time	°C H_2O Around Saddles	°C H_2O Around Sponge
7:33	24	24
7:37	24	25
7:40	26	27.5
7:43	28	31

TABLE I-Continued

Time	T°C H ₂ O Around Saddles	T°C H ₂ O Around Sponge
7:47	38	42
7:50	47	50½
7:54	55	60
7:57	65	69
8:00	70	74

The metal plated honeycombs and structures can be usefully employed as an efficient heat exchange material with or without catalytic activity. With spheres or pellets there is an inefficient transfer of heat due to the resistance in the point to point contacts of the particles. On the other hand, a monolithic structure with random holes transfers heat in several directions without the narrow restriction of the point to point contact and thereby heat can be readily transferred to a pipe wall or flat plate and thereafter removed by a fluid which is located on the other side of the wall area. The use as a heat exchanger therefore would cause the monolithic structures to be useful in exothermic reactions such as in methanation of coal gas. The metal plated monoliths when employed as a catalyst will not suffer as a result of sintering, poisoning and flaking as a result of the failure to transfer heat and therefore can be usefully employed not only as an efficient heat exchanger but as a catalyst such as in the water gas shift reaction ($\text{CO} + \text{Steam} \rightarrow \text{H}_2 + \text{CO}_2$).

Additionally, due to the low resistance of the heat flow, heat can be passed to the catalyst readily from the outside of a barrier such as a pipe or flat piece in order to encourage endothermic reactions such as reforming reactions and in reducing atmospheric generators.

When packed in packing columns, the catalyst produce less stress on the support plates because of the large void spaces and as a result of the large void spaces there is a resultant low pressure drop with a high throughput with respect to gasses.

Other typical exothermic reactions in which the metal plated porous monoliths are useful are in hydrogenations, chlorinations and oxychlorinations.

Because of the excellent heat removal abilities of the honeycombs and sponges, they may be readily employed in rotary kilns to recover a substantial amount of the heat which is normally passed to the atmosphere. The heat exchanger employing the metal coated ceramics can readily recover the waste heat. The waste heat could then be employed to preheat the incoming air. Ordinary heat exchanges are inefficient because the heat transfer coefficient on the gas side is low. By increasing the area on the gas side with a honeycomb or sponge, the heat transfer can be markedly improved. The hot gasses are transferred from the metal coated sponge to the flat plate or tube and thereafter to the cold material on the other side of the plate or tube. Air pollution from the kiln would also be reduced by the catalyst action of the nickel.

In the methanation of coal gas, nickel is an ideal catalyst. The catalytic activity accompanied by the heat transfer as a result of the use of nickel plated sponges would significantly improve methanation of coal gas. Low pressure drop would make it very useful in the hot gas recycle line.

A most important use with respect to metal plated ceramics such as nickel plated honeycombs and sponges

with or without a small amount of platinum would be in auto emission controls.

Pellets tend to abraid each other thereby grinding off the active catalyst whereas the abraiding would be avoided through the use of sponges or honeycombs. The resultant improvements obtained with respect to this process in plating sponges and honeycombs uniformly throughout and on the structures with metal such as nickel causes the structures to be highly desirable in catalytic converters for auto emission control. The structures can also be usefully employed in the Stirling Automotive Engines. The Stirling is a closed-cycle engine which employs a light gas such as hydrogen or helium as a working fluid. The gas is first heated and then expanded and cooled in order to obtain energy. Since metal plated particles of this invention act as an excellent heat transfer agent as well as a catalyst, these materials would be highly useful as regenerators in Stirling Engines or recuperators in stationary units.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

I claim:

1. A process for uniformly plating metal by vapor deposition on and throughout one of a ceramic or alumina substrate having the structure of one of a honeycomb or sponge, the process comprising heating in an enclosure a rotatably suspended substrate by radiant means until the substrate reaches the decomposition temperature of a thermally decomposable metal bearing gaseous compound, rotating the substrate, passing a thermally decomposable metal bearing compound into the enclosure along with a carrier gas so as to have the gas come into intimate contact with the substrate while continuously rotating the substrate at a rate of at least about two rpm and continuously activating and deactivating the radiant means so as to maintain the temperature of the workpiece at about the decomposition temperature of the metal bearing gas, whereby the metal is uniformly plated on and throughout the substrate.

2. The process of claim 1 wherein the honeycomb or sponge substrate is one of Al_2O_3 , LiAlSiO_4 or SiC .

3. The process of claim 1 wherein the metal bearing gaseous compound is nickel carbonyl.

4. The process of claim 3 wherein the substrate is heated to at least from 310°F to about 450°F.

5. The process of claim 1 wherein the substrate is rotated at the rate of from about two to about 20 rpm.

6. The process of claim 5 wherein the substrate is rotated at the rate of about seven rpm.

7. The process of claim 1 wherein the substrate is oscillated through an angle of about 30°.

8. A process for uniformly plating nickel on and throughout an alumina or ceramic sponge or honeycomb substrate, comprising:

a. radiantly heating in a nitrogen and carbon monoxide purged airtight chamber the rotatably suspended substrate to from about 340°F to about 450°F;

b. continuously rotating the substrate at a rate of about 7 rpm;

c. continuously activating and deactivating the radiant means so as to maintain the temperature;

d. while rotating and activating and deactivating the radiant means passing vaporized nickel carbonyl into the chamber so as to come into intimate contact with the substrate whereby nickel is uniformly plated on and throughout the substrate; and

e. removing the plated substrate from the chamber.

* * * * *