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PROCESS FOR CARRYING OUT TECHNICAL OPERATIONS IN A GLOW DISCHARGE

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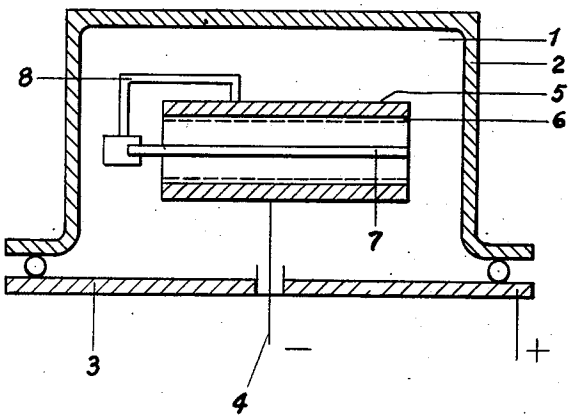

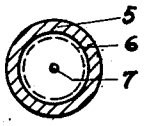

Fig. 2

Fig. 1

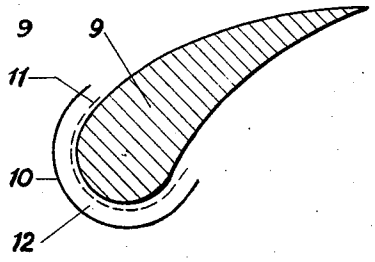

Fig. 3

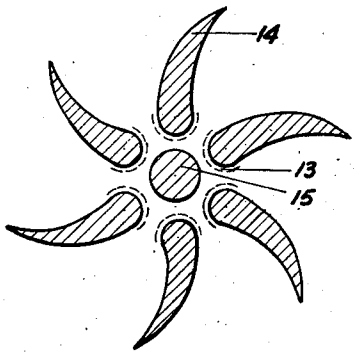

Fig. 4

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PROCESS FOR CARRYING OUT TECHNICAL OPERATIONS IN A GLOW DISCHARGE

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The use of the glow discharge for technical processes, such as hardening, annealing, metallisation, carbonisation etc. in the metallurgical and synthetic processes, with gases and liquids, such as the production of ammonia, is already known. In order to apply these processes in industrial operations, it is important that one should be able to operate with high outputs, and to increase as much as possible the efficiency of the operation.

After many years of expensive investigations the applicants, according to the present invention, succeeded by further improving this glow discharge process by increasing its efficiency substantially. The invention relates to a method of carrying out technical processes in glow discharges, such as annealing, diffusion-annealing, hardening, nitride hardening, carbonisation, metallisation, the carrying out of chemical processes, such as the production of ammonia etc., and it consists in that the energy of the glow discharge is increased in a predetermined part of the discharge space as compared with other parts thereof by the approach of the glow layers on two electrodes. A "glow layer" is to be understood as that region which follows the so-called dark space covering each electrode surface and which can be measured by the occurrence of the cathode drop in the distribution of the potential between the electrodes.

The present invention does away with the so-called hollow cathode effect described in the literature as being detrimental and to be avoided in all circumstances.

According to the invention, a workpiece connected up as a cathode is arranged with its surface to be treated opposite a part also connected as a cathode, for instance, another surface of the same workpiece, another workpiece, or an auxiliary electrode, at such a distance that the overlapping of the glow layers effects an increased ionization. The said surfaces should be arranged so close together that, at the selected gas pressure of the glow discharge, the boundaries of the glow layers at least touch each other. Pursuant to the present invention, the distance between the metal workpieces, parts of workpieces, and/or auxiliary electrodes having approximately the same electric voltage, is chosen to be equal to or greater than a minimum distance corresponding to about double the dark space thickness of the glow discharge for the same pressure.

The work-pieces, parts of work-pieces and/or auxiliary electrodes may be either connected together directly so that they have the same electric voltage, or they may have imparted to them the same or approximately the same voltage, for instance by separate electric leads introduced into the discharge vessel, whereby other applications are made possible as regards the control of the discharge, viz. of the concentration or control of the energy within the desired or predetermined region. Negative direct current potentials, that is to say, parts connected up as cathodes, have an especially strong effect; however, the process can also be carried out with alternating currents. According to one embodiment of the invention, with a given distance between the work-pieces or parts of work-pieces, the proximity of the boundaries of the glow layers is controlled by regulating the pressure of the gas discharge. If the given distance between the work-pieces, or parts of work-pieces, is too great for the boundaries of the glow layers to approach each other also in the case of a low discharge pressure, use is made of auxiliary electrodes, which are arranged opposite the work-pieces or parts of the work-piece. Vice versa, with a given gas pressure the approach of the boundaries of the glow layers is controlled by adjusting the distance between the electrodes or also by using auxiliary electrodes. The distance between the electrodes is adjusted to be equal to, or smaller than double the thickness of the dark spaces. In this way a partly limited region is produced in which a gas discharge of high intensity takes place. Within this discharge space, which is enclosed by the work-pieces or parts of work-pieces and auxiliary electrodes having approximately the same voltage, the specific energy consumed at the surfaces is higher than at the other surfaces of the work-pieces. The local concentration of energy thereby obtained on predetermined parts of the discharge space may be further assisted by suitably dimensioning the auxiliary electrodes with respect to their heat capacity, that is to say, their mass and the radiating surface. A change of these properties may be effected in the work-pieces themselves by connecting, for instance by fitting, a great number of block-like solid holders. Thus, according to the invention, by relatively adjusting the surfaces and masses of work-pieces, parts of work-pieces, and auxiliary electrodes, the balance of energy can be additionally controlled according to the requirements of the problem to be solved. For instance, the mass of the auxiliary electrodes may advantageously be chosen to be different from the mass of the work-pieces. Preferably, the auxiliary electrode is small, if for instance it has to be heated to a very high temperature in order to produce or intensify the effect of disintegration. Thus a suitably large surface of a part thereof may contribute to a large extent to the radiation of heat, for instance, in order to avoid too large an increase in the temperature of the auxiliary electrodes, which are arranged opposite individual parts of the work-piece, if these parts have to be heated to a suitably high temperature. In other cases it is an advantage to adapt the shape of the auxiliary electrodes to the shape of the work-pieces or of parts of the work-pieces. Thus, the auxiliary electrode may partly surround the work-piece. The distance of the auxiliary electrodes from the work-piece, or from parts of the work-piece, is usually according to the invention, in order to obtain uniform effects. However, in the case of one problem, for instance in order to obtain effects which are not evenly distributed, it may be required to have unequal distances between the work-pieces, work-piece parts and auxiliary electrodes. When several work-pieces are being treated, they are preferably arranged at equal distances opposite a smaller number of auxiliary electrodes.

In the case of work-pieces provided with hollow spaces, within which lie work-piece parts of the same potential, the approach of the boundaries of the glow layers is effected likewise by pressure regulation, for instance, in the case of tubular work-pieces. If in these particular tubular work-pieces, the hollow space has too large a diameter for the boundaries of the glow layers to approach each other by regulation of the gas pressure, an auxiliary electrode in the form of a wire, rod or even of tubular form, is introduced or passed through, so that the work-piece surrounds the auxiliary electrode entirely or partly. Finally, according to the invention, in order to increase still further the ion bombardment in the gas discharge and to assist in the abovementioned mass and surface effects on the work-pieces and auxiliary electrodes, a glow discharge of maximum energy is maintained only periodically for several seconds down to frac-

tions of a second, between long intervals, during which at most a glow discharge of smaller energy is maintained or the glow discharge is completely switched off. This production of energy pulses may be effected, for instance, by suitably supplying the electric energy intermittently, or by suitably changing the discharge pressure, for instance in such a manner that the gas pressure is increased to such a value that a discharge of great energy no longer takes place between the work-pieces. A similar effect can be obtained with a reduction in the gas pressure. Preferably, the process according to the invention is used in the case of gas pressures which are higher than those usually employed in glow discharges, for instance in the case of gas pressures of one mm. Hg and more, in order to be able to operate more particularly with larger energies.

An application of the invention will now be described, by way of example, in connection with the production of a coating of high melting metal on a work-piece.

Figure 1 of the accompanying drawing shows diagrammatically a glow discharge apparatus 1 consisting of a base 3 and a removable cover 2. An electric lead 4 passes through the base 3 and is connected to a tubular work-piece 5. A rod-like auxiliary electrode 7 is maintained in the interior of the said tubular piece by means of a support 8. According to the invention, the tube 5 and the auxiliary electrode 7 are connected as cathodes, whilst the base-plate of the vessel is used as an anode. The inner surface 6 of the tube 5 and the rod 7 are each covered by a glow layer so that these two glow layers lie opposite each other. According to the invention, they are so controlled by the adjustment of the gas discharge pressure that finally they touch each other. An approximately flat maximum effect is obtained in dependence upon the gas pressure, so that the process can be easily controlled and a very great intensification of the discharge processes is obtained. Thus, it has been possible to obtain, by using hydrogen of 2.5 mm. Hg, a tube of 20 mm. diameter, and a tungsten rod of 2 mm. diameter, during a testing period of 20 hours, a deposition of tungsten of 0.1 mm. upon the inner surface 6 of the tube 5. Thereby an electric power of 20 to 100 watts per sq. cm. was used. On the other surfaces of the treated tube only a fraction of this power was applied and the concentration of the energy had its full effect upon the desired parts. The work-piece could thereby be maintained at a moderate temperature, whilst the tungsten rod could be heated up to its fusing temperature. Because of the resulting higher rate of disintegration of the tungsten rod than of the workpiece, the net result was a deposit of tungsten on the workpiece.

Figure 2 is a cross-section through the iron tube 5 with the centrally arranged rod 7. The inner surface covered with tungsten is indicated by 6.

Figure 3 shows the treatment of a turbine blade 9 instead of the tube 5. The blade is provided on its front edge 11 with a metal coating of tantalum which is diffused in and therefore adheres and is corrosion and heat resistant. According to the invention, there is arranged opposite this thick part of the turbine blade 9 a tantalum sheet 10, acting as an auxiliary electrode, at a distance 12 which is equal to, or smaller than, double the thickness of the dark space which covers the electrodes in the glow discharge which is being used. It was found that although the whole surface of the blade was enriched on its surface with small amounts of tantalum, the part indicated in dash line received a much thicker adherent coating of tantalum.

Figure 4 differs from Figure 3 in that, for instance, six turbine blades 14 are subjected to such a treatment, the same being arranged around a central tantalum rod 15. The individual turbine blades as well as the central tantalum rod are again so connected as to act as cathodes, so that the glow layers of the blades and of the tantalum rod are close to, or contact, each other. The surfaces 13 indicated in dash line were strongly enriched with tantalum as in the case of the example shown in Figure 3, so that all the blades were covered with a firmly adhering and corrosion resistant outer layer 13.

We claim:

1. In a process for carrying out technical operations in a glow discharge vessel having an anode and two spaced cathodes, the step which comprises adjusting the gas pressure and the distance between the cathodes to bring the boundaries of their glow layers at least into contact with each other to effect increase of the energy of the glow discharge in a predetermined part of the discharge space as compared with other parts of the discharge space.

2. Process as claimed in claim 1 wherein a work-piece constitutes one of the cathodes and is arranged with its surface to be treated opposite the other cathode.

3. Process as claimed in claim 2, wherein the surfaces of the cathodes are arranged so close together that the boundaries of the cathode glow layers, at the prevailing gas pressure of the glow discharge, overlap each other.

4. Process as claimed in claim 1, wherein the cathode dark space of the one cathode is maintained for such a long period of time, while at the same time the dark space of the other cathode is at most only partially built up, that the energy of the glow discharge in the space between these electrodes is increased.

5. Process as claimed in claim 1, wherein a workpiece is connected up as one of the cathodes, and wherein the distance of the second cathode from the work-piece is maintained constant.

6. Process as claimed in claim 1, wherein a workpiece is connected up as one of the cathodes and wherein the second cathode is arranged at different distances from different parts of the workpiece surface.

7. Process as claimed in claim 1, wherein a plurality of workpieces connected as cathodes are arranged at a uniform distance with respect to a smaller number of auxiliary electrodes.

8. Process as claimed in claim 1, wherein a workpiece having a hollow space is arranged as one of the cathodes and at least partly surrounds the second cathode.

9. Process as claimed in claim 1, wherein a glow discharge of maximum energy is produced periodically for intervals ranging from several seconds down to fractions of a second, and between relatively long intervals in which at most a glow discharge of smaller energy is maintained.

10. Process as claimed in claim 1, wherein the gas pressure in the discharge vessel is greater than one mm. Hg, but is less than atmospheric.

11. A process for carrying out metallurgical, chemical and other technical processes in a glow discharge between heated electrodes in a low pressure gas atmosphere, comprising effecting increase of the energy of the glow discharge between the electrodes by so relating the gas pressure and the distance between the electrodes that the glow layers on the two electrodes are caused to at least contact each other.

12. Process according to claim 11, wherein at a given gas pressure the energy of the glow discharge between the said electrodes is increased by reducing the distance between the electrodes to a value at which said contact takes place while keeping such distance greater than twice the height of the dark space covering the electrodes.

13. Process according to claim 11, wherein at a given distance between the two electrodes the energy of the glow discharge between the said electrodes is increased by reducing the gas pressure to a value at which said contact takes place while keeping the pressure above the value at which the height of the dark space covering the electrodes reaches one-half of the distance between the said electrodes.

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