

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 1 019 209 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:

08.12.2004 Bulletin 2004/50

(21) Application number: **99938971.1**

(22) Date of filing: **04.08.1999**

(51) Int Cl.7: **B22D 11/04**, B22D 11/18

(86) International application number:
PCT/US1999/017602

(87) International publication number:
WO 2000/007752 (17.02.2000 Gazette 2000/07)

(54) **AN IMPROVED CONTINUOUS CASTING MOLD SYSTEM AND RELATED PROCESSES**

VERBESSERTES STRANGGUSS-KOKILLEN-SYSTEM UND ENTSPRECHENDES VERFAHREN

SYSTEME MOULE DE MOULAGE CONTINU AMELIORE, ET PROCESSUS Y RELATIFS

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE**

(30) Priority: **06.08.1998 US 130144**

(43) Date of publication of application:
19.07.2000 Bulletin 2000/29

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(56) References cited:
US-A- 4 687 344 US-A- 4 954 365

- **PATENT ABSTRACTS OF JAPAN vol. 008, no. 276 (M-346), 18 December 1984 (1984-12-18) & JP 59 147751 A (SUMITOMO DENKI KOGYO KK), 24 August 1984 (1984-08-24)**
- **PATENT ABSTRACTS OF JAPAN vol. 011, no. 348 (M-642), 14 November 1987 (1987-11-14) & JP 62 130748 A (TOSHIBA CORP), 13 June 1987 (1987-06-13)**

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Description

BACKGROUND OF THE INVENTION**1. Field of the Invention**

[0001] This invention relates to the technical field of metal making and processing using the continuous casting process. More specifically, this invention pertains to an improved mold surface for a continuous casting machine, and to a system and method for controlling the casting process by actually monitoring the temperature of the casting at the mold surface while the machine is operating.

2. Description of the Prior Art and the Related Technology

[0002] Production of metals by use of the continuous casting technique has been increasing since its large-scale introduction about thirty years ago, and now accounts for a large percentage of the volume of steel, among other metals, produced each year worldwide. It is well known that continuous casting machines typically include a mold that has two essentially parallel and opposed wide walls, and two essentially parallel opposed narrow walls that cooperate with the wide walls to define a casting passage of rectangular cross section. Molten metal is supplied continuously into a top end of the casting passage, and the mold is designed to cool the metal so that an outer skin forms before the so-formed slab or strand exits a bottom of the casting passage. In order to efficiently dissipate the heat from the molten steel, the mold casting surfaces are typically lined with copper or have a copper alloy surface layer and contain numerous passages through which water flows, during the molding process for rapid heat exchange. In some instances, the mold is cooled by spraying water directly against the cooler side of the mold liner. The strand is further cooled by spraying as it travels away from the mold, until it becomes completely solidified. It may then be processed further into an intermediate or finished metal product, such as steel plate, sheeting or coils by traditional techniques such as rolling.

[0003] The mold casting surfaces, also known as the "hot faces" of the mold, are exposed to the high temperature molten steel and corrosive mold flux for prolonged periods of time. Copper is a very efficient thermal conductor, but is relatively soft and is thus susceptible to early wear and other types of degradation. Under normal casting conditions, the hot faces of the mold experience relatively rapid degradation such as wear, cracking and steam and chemical erosion. This effect is exacerbated in high-speed molds, which tend to run at higher temperatures wherein the copper material begins to further soften. The assignee of this invention, A.G. Industries, Inc., is the largest North American provider of maintenance and repair services for continuous casting machines, and is intimately familiar with the degradation and wear that occurs on mold faces during casting.

[0004] In order to prolong the life of the mold surfaces for as long as possible, it is typical to pre-coat the copper mold surface with a friction and corrosion resistant material, such as such as nickel or chromium. Other techniques for protecting the mold wall surfaces have been proposed and/or put into commercial use. For example, U.S. Patent 5,499,672 discloses a process for protecting a copper mold surface by applying a metal carbide protective material onto the mold surface. Another protective coating technique involves applying a Ni-Cr alloy to the copper mold faces by a thermal spraying process. This process is described in the publication *Ni-Cr Alloy Thermal Spraying of the Narrow Face of Continuous Casting Mold*, dated May 1989 by Nippon Steel Corporation and Mishima Kosan Co., Ltd. While the coatings that have been developed to date have been able to reduce the rate and severity of mold wear to some extent, it remains a fact of life in the continuous casting industry that the mold faces must be periodically removed and replaced or repaired. Taking the mold off line to do this represents a significant cost to a steelmaker, perhaps as much as fifteen thousand dollars per hour.

[0005] The strand or slab has a very thin skin when it initially forms in the mold. Rupture of the skin must be avoided at all costs because it can cause a condition known as a breakout, i.e., where molten metal escapes through the skin beneath the mold. A severe breakout can encase portions of the machine that are in its path in molten metal, rendering those components unusable and requiring them to be replaced and reconditioned. One of the factors that is important in determining whether or not a breakout is likely to occur is the thickness of the skin as the casting moves through the mold. Theoretically, skin thickness could be measured *in situ* during casting by monitoring the infrared emissions of the slab, but in practice this has not been feasible because the entire slab is surrounded by the mold, making measurement impossible. Some systems exist that attempt to model the casting thickness by sampling temperatures at selected locations in the mold liner; but these systems can be less than accurate because of the varying thickness of the copper material between the sensors and the casting surface.

[0006] JP 62 130748 discloses a water-cooled mold with a ceramic liner to improve wear resistance and durability. The mold's liner is composed of boron nitride of a thermal conductivity greater than or equal to 50 W/mK. The mold is not in the field of continuous casting however. A mold for casting aluminium is shown in WO98/16335 and consists of mold wall assemblies having an inner portion arranged to conduct heat away from the mold liner, and an outer portion

coated with boron nitride or diamond.

[0007] A need exists for a continuous casting mold that permits improved monitoring of the casting as it moves through the mold so that breakouts and other unwanted conditions can be prevented.

SUMMARY OF THE INVENTION

[0008] It is an object of the invention to provide a continuous casting mold that permits improved monitoring of the casting as it moves through the mold so that breakouts and other unwanted conditions can be prevented.

[0009] In order to achieve the above and other objects of the invention, an improved mold wall assembly for use in a continuous casting machine is provided as defined in claim 1 below. A preferred embodiment comprising continuous casting machine is defined in claim 7. According to a further aspect of the invention, there is provided a method of making a strand of continuously cast material in accordance with claim 8 below.

[0010] For a better understanding of the invention, its advantages, and the objects obtained by its use, reference should be made to the drawings which form a further part hereof, and to the accompanying descriptive matter, in which there is illustrated and described a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIGURE 1 is a fragmentary horizontal cross-sectional view taken through a mold wall assembly for a continuous casting machine that is constructed according to a preferred embodiment of the invention;

FIGURE 2 is a vertical cross-sectional view taken through one component of the assembly shown in FIGURE 1;

FIGURE 3 is a diagrammatical view of a preferred feature in the assembly shown in FIGURES 1 and 2;

FIGURE 4 is a schematic diagram depicting a preferred control system for the assembly shown in FIGURES 1 through 3;

FIGURE 5 is a fragmentary vertical cross-sectional view taken through a mold wall assembly that is constructed according to a second embodiment of the invention; and

FIGURE 6 is a fragmentary vertical cross-sectional view taken through a mold wall assembly that is constructed according to a third embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0012] Referring now to the drawings, wherein like reference numerals designate corresponding structure throughout the views, and referring in particular to FIGURE 1, an improved mold wall assembly 12 for a continuous casting machine 10 includes a plurality of mold walls, including an opposing pair 14, 16 of narrowface walls and an opposing pair of broadface walls 18, 20. Each of the mold walls 14, 16, 18, 20 has at least one mold surface that together define a casting space 26 having an upper opening and a lower opening. The mold wall assembly 12 is designed, as is conventional, so that molten metal can be supplied continuously into the top end of the casting space 26, and so as to cool the metal so that an outer skin forms before the so-formed slab or strand exits a bottom of the casting passage. As is conventional, coolant supply pipes 22, 24 are provided for providing a water coolant to the narrowface walls 14, 16 and the broadface walls 18, 20, respectively.

[0013] Referring now to FIGURE 2, which is a vertical cross-sectional view taken through one of the broad face walls 20 in FIGURE 1, it will be seen that wall 20 includes a liner assembly 27 that bears the mold face 28, and a support assembly 32 to which the liner assembly 27 is secured. As may be seen in FIGURE 2, the liner assembly 27 includes an inner portion 29 that is embodied as a copper liner 30, and an outer layer 44 of degradation-resistant, non-metallic material that forms the mold face 28, and will be discussed in greater detail below. The support assembly 32 includes the coolant supply pipe 24, a coolant return pipe 42, an inlet plenum 36 and an outlet plenum 38. Both the inlet and outlet plenums 36, 38 are in communication with a cooling channel 34 that is defined in the copper liner 30 of the liner assembly 27. In operation, as is conventional, the coolant, which is typically water, is introduced from the coolant supply pipe 24 into the inlet plenum 36, where it flows upwardly through the cooling channel 34 and out into the outlet plenum 38. The coolant is then returned to a circulation pump through the return pipe 42.

[0014] The layer 44 of degradation-resistant, non-metallic material is diamond or cubic boron nitride. These materials preferably are efficient conductors of heat, that are very hard and degradation-resistant, that can tolerate the high temperatures that exist in a continuous casting mold during operation, that are resistant to the acidic environment in which a continuous casting machine typically functions, and that, for reasons discussed in greater detail below, are transparent in the infrared portion of the spectrum.

[0015] Diamond is a allotrope of carbon that is metastable at ordinary pressures, having a large activation energy

barrier that prevents conversion to graphite, the more stable allotrope at ordinary temperatures and pressures. It has long been sought after not only for its intrinsic beauty and value as a gemstone but also for its many unique and valuable mechanical, electrical, optical and thermal properties. Diamond is the hardest material occurring in nature, has a low co-efficient of friction, is extremely resistant to chemical attack, is optically transparent to much of the electromagnetic spectrum, including being highly transparent to infrared radiation, and has the highest heat conductivity of any material. Cubic boron nitride (CBN) has properties that are comparable to diamond in many respects.

[0016] One advantageous feature of the invention is depicted diagrammatically in FIGURE 3. As may be seen in FIGURES 2 and 3, a passage 46 is formed in the copper liner plate 30 of the liner assembly 27. An optical fiber 48 is situated in the passage 46, and is optically coupled to the transparent layer 34 of degradation-resistant, non-metallic material on a side thereof that is opposite to the casting surface or mold face 28 of the layer 44. A sensor 50 is then coupled to a second, opposite end of the optical fiber 48. The purpose of the sensor 50 is to monitor a property of the continuous casting process by examining the spectral characteristics of the light that is carried through the optical fiber 48. In its preferred embodiment, sensor 50 is constructed and arranged to monitor the infrared profile of the transmitted light, so as to monitor the temperature of the exterior of the cast strand as it moves downwardly along the casting surface within the mold. By monitoring this temperature, the thickness of the skin of the casting can be determined, which is a useful indicator for many things, including the susceptibility of the strand to breakouts after it exits the bottom of the mold, the optimal withdrawal speed of the strand from the machine, the optimal rate at which coolant is circulated through the mold walls, and the uniformity of shell growth. Referring now to FIGURE 4, it will be seen that a number of such sensors 50 are provided in the mold assembly, and that each of those sensors provides information to a CPU 52 that serves as a local control system for the mold wall assembly 12. CPU 52 is in two-way communication with a main control system 54 of the continuous casting machine 10, and is further in communication with different subsystems for modifying different performance variables of the continuous casting process. FIGURE 4 depicts four such subsystems 56, 58, 60, 62, but the number could be more or less, depending upon the number of performance variables that are desired to be controlled in response to the optical monitoring that is performed by the sensor 50. For example, one of the subsystems may permit adjustment of the withdrawal speed of the continuous casting machine. Another subsystem may permit adjustment of the taper of the mold. Third and fourth subsystems for adjusting the rate of cooling the mold may constitute a control system for adjusting the volumetric flow of coolant through one or more of the mold walls, or changing the composition of mold flux for changing the heat conduction properties of the mold.

[0017] In order to analyze the data that is gathered by the sensors 50, a commercially available thermal imaging system may be used. One such imaging system that could be used is available from Mikron Instruments of Oakland, New Jersey and is sold as an "Imaging Pyrometer." This system is disclosed in part in U.S. Patent 4,687,344, the disclosure of which is hereby incorporated as if set forth fully herein.

[0018] Looking now to FIGURE 5, a mold assembly 64 that is constructed according to a second embodiment of the invention includes a casting surface 66, and a body 68 that is fabricated entirely of the non-metallic, degradation-resistant material of the type that is discussed in detail above. A cooling channel 70 is defined in the body 68 of material, and a sensor 72, which is similar in construction to the sensor 50 discussed above, is coupled to a rear side of the body 68. In this embodiment of the invention, the entire mold wall is made of the diamond or CBN material. It is believed that this embodiment holds great potential for the future, because such a mold wall would be expected to substantially outperform any mold wall that is in service today. Fabricated entirely of a material such as diamond, it would be much more efficient at conducting heat away from the strand during casting than a metallic mold wall would, it would exhibit lower friction than any metallic mold wall would, and it would be virtually indestructible in terms of wear.

[0019] FIGURE 6 depicts yet another embodiment of the invention. In this embodiment, as in the embodiment that is described above in reference to FIGURE 5, the entire mold liner 80 is fabricated from a degradation-resistant non-metallic material that has high thermal conductivity, whereby the mold liner will exhibit superior wear and heat transfer characteristics during its operation in a continuous casting machine. As in the embodiment of FIGURE 5, the preferred materials are diamond or CBN, and the mold liner can be constructed according to any of the fabrication processes disclosed below, or by any other process that will be effective. A sensor 72, which is similar in construction to the sensor 50 discussed above, is coupled to a rear side of the mold liner 80. In this embodiment, the mold liner 80 does not have an internal cooling passage, but is constructed as a "spray-type" mold in which the side 86 of the liner that is opposite the casting 82 is subjected to cooling spray from one or more spray nozzles 88. The high thermal conductivity of this type of mold liner will contribute to the effective cooling of the casting and the formation of casting that has a uniform solidified shell 84. In addition, a significant amount of heat will also be transferred away from the casting by means of radiation as a result of the transparency of the mold in the infrared range. This stands in favorable contrast to a conventional continuous casting mold, where there is no heat transfer through the mold wall by means of radiation.

[0020] There are a number of known techniques for artificially building coatings and masses of materials such as diamond and CBN, and the inventors recognize that any one of those known techniques could be used within the purview of the invention. The inventors further appreciate that this technology is advancing at a rapid rate, and expect to be able to utilize other, more efficient techniques for creating the necessary structure when such new technology

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becomes available. The following U.S. Patents and PCT Publications disclose techniques for artificially building coatings and masses of materials such as diamond and CBN, and are to be considered exemplary for purposes of this disclosure. Each of the documents listed below are hereby incorporated into this disclosure as if set forth fully herein:

U.S. Patent No.	Name	Publication Date
4,490,229	Mirtich et al.	12/23/94
4,504,519	Zeletz	3/12/85
4,770,940	Ovshinsky et al.	9/13/88
4,830,702	Singh et al.	3/16/89
4,910,041	Yanagihara et al.	3/20/90
4,939,763	Pinneo et al.	7/3/90
4,948,629	Hacker et al.	8/14/90
4,954,365	Neifeld	9/4/90
4,981,717	Thaler	1/1/91
4,987,007	Wagal et al.	1/22/91
5,015,528	Pinneo	5/14/91
5,071,677	Patterson et al.	12/10/91
5,080,753	Doll et al.	1/14/92
5,082,359	Kirkpatrick	1/21/92
5,096,740	Nakagama et al.	3/17/92
5,154,945	Baldwin et al.	10/13/92
5,221,411	Narayan	6/22/93
5,221,501	Feldman et al.	6/22/93
5,230,931	Yamazaki et al.	7/27/93
5,236,740	Peters et al.	8/17/93
5,243,170	Maruyama et al.	9/7/93
5,260,106	Kawarada et al.	11/9/93
5,264,071	Anthony et al.	11/23/93
5,271,890	Shimura et al.	11/21/93
5,273,731	Anthony et al.	12/28/93
5,273,788	Yu	12/28/93
5,302,231	Bovenkerk et al.	4/12/94
5,516,500	Liu et al.	5/14/96
5,525,815	Einset	6/11/96

PCT App. No.	Name	Publication Date
PCT/US95/05941	Mistry	11/23/95
PCT/US95/00782	Mistry	???

Most Preferred Processes for Applying the Non Metallic Wear Resistant Layer

[0021] In one embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,490,229, a diamond-like carbon

film can be deposited in the surface of a substrate by exposing the surface to an argon ion beam containing a hydrocarbon. The current density in the ion beam is low during initial deposition of the film. Subsequent to this initial low current condition, the ion beam is increased to full power. At the same time a second argon ion beam is directed toward the surface of the substrate. The second ion beam has an energy level much greater than that of the ion beam containing the hydrocarbon. This addition of energy to the system increases mobility of the condensing atoms and serves to remove Lesser-bound atoms, increasing the percentage of diamond bonds.

[0022] In a second embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,504,519, an amorphous, carbonaceous, diamond-like film is produced by a hybrid process in a deposition chamber using a radio frequency plasma decomposition from an alkane, such as n-butane, using a pair of spaced, generally parallel, carbon electrodes, preferably ultra pure carbon electrodes. While most films of this invention were deposited using normal butane, other alkanes, such as methane, ethane, propane, pentane, and hexane can be substituted in the process of this invention to produce the improved carbonaceous, diamond-like film thereof. The deposition chamber, such as a stainless steel chamber, includes a pair of generally parallel and horizontal, vertically spaced, pure carbon electrodes with the substrate to be coated positioned on the lower carbon electrode. The electrodes are typically positioned about 2 up to about 8 centimeters apart from each other, with the preferred electrode spacing being approximately 2.5 centimeters. The chamber is evacuated to its ultimate pressure, generally in the region of about 10^{-7} torr, and then backfilled with an alkane, such as n-butane, to a pressure of approximately 8×10^{-4} torr. Thereafter, the vacuum system is throttled to a pressure in the range of approximately 25 to 100 millitorr. After stabilization of the pressure, the radio frequency power is applied to the pair of pure carbon electrodes with the lower electrode (substrate target) being biased in the range of about 0 to about - 100 volts, and the upper electrode being biased in the range of about - 200 to about - 3500 volts. Radio frequency plasma decomposition is begun, and an amorphous, carbonaceous, diamond-like film is deposited onto the substrate at rates varying between about 8 up to 35 angstroms per minute, to produce a film of up to about 5 micrometers in thickness.

[0023] In a third embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,770,940, a hard carbonaceous film is formed by decomposing a gaseous hydrocarbon having carbon atoms tetrahedrally coordinated to its nearest neighbors through carbon-carbon single bonds. The gaseous hydrocarbon is decomposed in a radio frequency maintained plasma and the plasma decomposition products are deposited on a cathodic substrate. Optionally, fluorocarbons may be present in a decomposition gas.

[0024] In a fourth embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,830,702, a hydrocarbon/hydrogen gas mixture is passed through a refractory metal hollow cathode which is self heated to a high temperature. The gas mixture is dissociated by a combination of thermal and plasma effects. The plasma plume emanating from the hollow cathode heats the substrate, which is positioned on a surface of the anode. Growth of the diamond film is enhanced by bombardment of electrons.

[0025] In a fifth embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,910,041, a film is formed on a substrate through a process of bringing a substrate into contact with a plasma zone formed by generating, by use of a discharge electrode or discharge electrodes, high temperature or quasi-high temperature plasma of a gas containing at least one carbon-containing compound. The electrodes include a sheet-like electrode provided with a slit having a linear portion and connected to a microwave electric source. Alternatively, the plasma zone is formed by forcing a high temperature or quasi-high temperature plasma generated in an arc between the electrodes to move by applying a magnetic field. The process enables energy efficient formation of films on substrate surfaces.

[0026] In a sixth embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,939,763, a synthetic diamond film may be formed by a D.C. plasma-assisted deposition at 0.5 to 1.5 amperes plasma current at a temperature of 600 to 800 degrees C using methane/ hydrogen (0.8-1 : 99.5-1 volume ratio) at a total pressure of 20-30 torr.

[0027] In a seventh embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,948,629, diamond films are deposited at substrates below temperatures of 400 degrees C. by chemical vapor deposition using a high powered pulsed laser and a vapor which is an aliphatic carboxylic acid or an aromatic carboxylic anhydride.

[0028] In an eighth embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,954,365, a thin diamond film is prepared by immersing a substrate in a liquid containing carbon and hydrogen and then subjecting the substrate to at least one laser pulse.

[0029] In a ninth embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,981,717, a method of depositing diamond-like films produces depositing species from a plasma of a hydrocarbon gas precursor. The plasma is generated by a laser pulse, which is fired into the gas and is absorbed in an initiator mixed with the gas. The resulting detonation produces a plasma of ions, radicals, molecular fragments and electrons which is propelled by the detonation pressure wave to a substrate and deposited thereon.

[0030] In a tenth embodiment, which utilizes the process that is taught in U.S. Pat. No. 4,987,007 a method and apparatus is provided which produces a layer of material on a substrate by extracting ions from a laser ablation plume in a vacuum environment. In a basic embodiment, the apparatus includes a vacuum chamber containing a target material and a laser focused on the target to ablate the material and ionize a portion of the ablation plume. An accel-

erating grid within the vacuum chamber is charged to extract the ions from the plume and direct the ions onto a substrate to grow the layer. The basic embodiment has produced diamond-like carbon films on a clean, unseeded silicon substrate at deposition rates approaching 20 microns per hour. The diamond-like carbon films produced were of exceptional quality: uniform thickness with a surface roughness about 1 Angstrom; uniform index of refraction within the range of 1.5-2.5; resistivity greater than 40 megs ohms per centimeter; and a hard surface resistant to physical abuse. An enhanced embodiment includes multiple targets within the vacuum chamber and mechanisms to selectively produce ions from each target. Thus, layers of different materials or doped materials can be made on the substrate. Additionally, the enhanced embodiment includes a mechanism for making patterns or circuits within each layer. One version incorporates a mask within the ion fluence and ion optics to magnify the mask pattern onto the substrate. Another version uses ion optics to form an ion beam and deflection plates controlling the ion beam to write the desired pattern on the substrate.

[0031] In an eleventh embodiment, which utilizes the process that is taught in U.S. Pat. No. 5,015,528, a process for forming synthetic diamond is utilized which involves vapor deposition of a carbon gas source in the presence of atomic hydrogen on a substrate contained in a fluidized bed. The diamond may be overcoated by vapor deposition of a non-diamond material.

[0032] In a twelfth embodiment, which utilizes the process that is taught in U.S. Pat. No. 5,071,677, a method for depositing diamond films and particles on a variety of substrates by flowing a gas or gas mixture capable of supplying (1) carbon, (2) hydrogen and (3) a halogen through a reactor over the substrate material. The reactant gases may be pre-mixed with an inert gas in order to keep the overall gas mixture composition low in volume percent of carbon and rich in hydrogen. Pre-treatment of the reactant gases to a high energy state is not required as it is in most prior art processes for chemical vapor deposition of diamond. Since pre-treatment is not required, the may be applied to substrates of virtually any desired size, shape or configuration. The reactant gas mixture preferably is passed through a reactor, a first portion of which is heated to a temperature of from about 400 degrees C. to about 920 degrees C. and more preferably from about 800 degrees C. to about 920 degrees C. The substrate on which the diamond is to be grown is placed in the reactor in a zone that is maintained at a lower temperature of from about 250 degrees C. to about 750 degrees C., which is the preferred diamond growth temperature range. The process preferably is practiced at ambient pressures, although lower or higher pressures may be used. Significant amounts of pure diamond films and particles have been obtained in as little as eight hours. The purity of the diamond films and particles has been verified by Raman spectroscopy and powder x-ray diffraction techniques.

[0033] In a thirteenth embodiment, which utilizes the process that is taught in U.S. Pat. No. 5,080,753, thin films of single crystal, cubic phase boron nitride that is epitaxially oriented upon a silicon substrate are formed using laser ablation techniques.

[0034] In a fourteenth embodiment, which utilizes the process that is taught in U.S. Pat. 5,082,359, a method of forming a polycrystalline film, such as a diamond, on a foreign substrate involves preparing the substrate before film deposition to define discrete nucleation sites. The substrate is prepared for film deposition by forming a pattern of irregularities in the surface thereof. The irregularities, typically craters, are arranged in a predetermined pattern, which corresponds to that desired for the location of film crystals. The craters preferably are of uniform, predetermined dimensions (in the sub-micron and micron size range) and are uniformly spaced apart by a predetermined distance. The craters may be formed by a number of techniques, including focused ion beam milling, laser vaporization, and chemical or plasma etching using a patterned photoresist. Once the substrate has been prepared the film may be deposited by a number of known techniques. Films prepared by this method are characterized by a regular surface pattern of crystals, which may be arranged in virtually any desired pattern.

[0035] In a fifteenth embodiment, which utilizes the process that is taught in U.S. Pat. 5,096,740, a highly pure cubic boron nitride film is formed on a substrate by a method which involves irradiating an excimer laser on a target comprising boron atoms and optionally nitrogen atom and depositing cubic boron nitride on a substrate which is placed to face the target.

[0036] In a sixteenth embodiment, which utilizes the process that is taught in U.S. Pat. 5,154,945, infrared lasers are used to deposit diamond thin films onto a substrate. In one embodiment, the deposition of the film is from a gas mixture of CH₄ and H₂ that is introduced into a chemical vapor deposition chamber and caused to flow over the surface of the substrate to be coated while the laser is directed onto the surface. In another embodiment, pure carbon in the form of soot is delivered onto the surface to be coated and the laser beam is directed onto the surface in an atmosphere that prevents the carbon from being burned to CO₂.

[0037] In a seventeenth embodiment, which utilizes the process that is taught in U.S. Pat. 5,221,411, a method for developing diamond thin films on a non-diamond substrate involves implanting carbon ions in a lattice-plane matched or lattice matched substrate. The implanted region of the substrate is then annealed to produce a diamond thin film on the non-diamond substrate. Also disclosed are the diamond thin films on non-diamond lattice-plane matched substrates produced by this method. Preferred substrates are lattice and plane matched to diamond such as copper, a preferred implanting method is ion implantation, and a preferred annealing method is pulsed laser annealing.

[0038] In a eighteenth embodiment, which utilizes the process that is taught in U.S. Pat. 5,221,501, a method of producing transparent diamond laminates is used which employs a substrate which is removed once a second layer is deposited over the diamond coating, thereby exposing a smooth diamond surface. The second coating should have a refractive index substantially identical to diamond, with zinc selenide and titanium dioxide being particularly preferred. Diamond films having two smooth surfaces may be produced by simultaneous deposition on parallel, opposed substrates until the two diamond films merge together to form a single film or plate, followed by removal of at least a portion of the two substrates.

[0039] In a nineteenth embodiment, which utilizes the process that is taught in U.S. Pat. 5,230,931, a diamond film or an I-Carbon film is formed on a surface of an object by virtue of plasma-assisted chemical vapor deposition. The hardness of the films can be enhanced by applying a bias voltage to the object during deposition.

[0040] In a twentieth embodiment, which utilizes the process that is taught in U.S. Pat. 5,236,740, a cemented tungsten carbide substrate is prepared for coating with a layer of diamond film by subjecting the substrate surface to be coated to a process which first removes a small amount of the tungsten carbide at the surface of the substrate while leaving the cobalt binder substantially intact. Murakami's reagent is presently preferred. The substrate is then subjected to a process, which removes any residue remaining on the surface as a result of the performance of the process, which removes the tungsten carbide. A solution of sulfuric acid and hydrogen peroxide is presently preferred. A diamond coated cemented tungsten carbide tool is formed using an unpolished substrate, which may be prepared by etching as described above or by etching in nitric acid prior to diamond film deposition. Deposition of a substantially continuous diamond film may be accomplished by reactive vapor deposition, thermally assisted (hot filament) CVD, plasma-enhanced CVD, or other techniques.

[0041] In a twenty-first embodiment, which utilizes the process that is taught in U.S. Pat. 5,243,170, a method for providing a coating film of diamond on a substrate involves the plasma jet deposition method, in which the deposited diamond film has, different from the cubic crystalline structure formed under conventional conditions, a predominantly hexagonal crystalline structure so as to greatly enhance the advantages obtained by the diamond coating of the tool in respect of the hardness and smoothness of the coated surface. The improvement comprises: using hydrogen alone as the plasma-generating gas; controlling the pressure of the plasma atmosphere not to exceed 300 Torr; keeping the substrate surface at a temperature of 800 degrees-1200 degrees C.; and making a temperature gradient of at least 13,000 degrees C./cm within the boundary layer on the substrate surface.

[0042] In a twenty-second embodiment, which utilizes the process that is taught in U.S. Pat. 5,260,106, a diamond film is attached securely to the substrate by forming a first layer on the surface comprising a mixture of a main component of the substrate and a sintering reinforcement agent for diamond, then forming a second layer comprising a mixture of said agent and diamond on said first layer, and finally forming the diamond film on the second layer.

[0043] In a twenty-third embodiment, which utilizes the process that is taught in U.S. Pat. 5,264,071, the bond strength between a diamond and the substrate onto which it is deposited by the chemical vaporization method is decreased to the point where the diamond can be removed from the substrate as a free standing monolithic sheet. The bond strength can be decreased by polishing the substrate, removing comers from the substrate, slow cooling of the substrate after deposition, an intermediate temperature delay in cooling or the application or formation of an intermediate layer between the diamond and the substrate. The freestanding sheet of diamond is envisioned as being of particular use for the embodiment of FIGURE 5.

[0044] In a twenty-fourth embodiment, which utilizes the process that is taught in U.S. Pat. 5,271,890, a coating film of a carbon allotrope is formed on a substrate by continuously supplying a fine carbon powder onto the substrate and simultaneously irradiating the fine carbon powder with a laser beam of a high output level thereby inducing sublimation of the fine carbon powder, and quenching the sublimated fine carbon powder to cause deposition thereof on the substrate.

[0045] In a twenty-fifth embodiment, which utilizes the process that is taught in U.S. Pat. 5,273,731, a substantially transparent polycrystalline diamond film is made having a thickness greater than 50 microns. A mixture of hydrogen and methane is conveyed into a heat filament reaction zone, which is adjacent to an appropriate substrate, such as a molybdenum substrate to produce non-adherent polycrystalline substantially transparent diamond film.

[0046] In a twenty-sixth embodiment, which utilizes the process that is taught in U.S. Pat. 5,273,788, a layer of a hydrocarbon molecule is applied to a substrate by the Langmuir-Blodgett technique, and the surface is irradiated with a laser to decompose the layer of molecules at the surface without influencing the substrate. After decomposition the carbon atoms rearrange on the surface of the substrate to form a DLC film.

[0047] In a twenty-seventh embodiment, which utilizes the process that is taught in U.S. Pat. 5,302,231, a method for growing diamond on a diamond substrate by chemical vapor deposition involves alternately contacting at elevated temperature said diamond substrate with a gas having the formula $C_n X_m$ and then with a gas having the formula $C_1 Z_p$. X and Z each form single bonds with carbon. X and Z also are reactable to form ZX or a derivative thereof. The Z-X bond is stronger than the C-X bond and also is stronger than the C-Z bond. In the formulas, n, m, 1, and p are integers.

[0048] In a twenty-eighth embodiment, which utilizes the process that is taught in U.S. Pat. 5,516,500, diamond materials are formed by sandwiching a carbon-containing material in a gap between two electrodes. A high-amperage electric current is applied between the two electrode plates so as cause rapid heating of the carbon-containing material. The current is sufficient to cause heating of the carbon-containing material at a rate of at least approximately 5,000 degrees C./sec, and need only be applied for a fraction of a second to elevate the temperature of the carbon-containing material at least approximately 1000 degrees C. Upon terminating the current, the carbon-containing material is subjected to rapid-quenching (cooling). This may take the form of placing one or more of the electrodes in contact with a heat sink, such as a large steel table. The carbon-containing material may be rapidly-heated and rapidly-quenched (RHRQ) repeatedly (e.g., in cycles), until a diamond material is fabricated from the carbon-containing material. The process is advantageously performed in an environment of a "shielding" (inert or non-oxidizing) gas, such as Argon (Ar), Helium (He), or Nitrogen (N₂). In an embodiment of the invention, the carbon-containing material is polystyrene (e.g., a film) or glassy carbon (e.g., film or powder). In another embodiment of the invention, the carbon-containing material is a polymer, fullerene, amorphous carbon, graphite, or the like. One of the electrodes is preferably a substrate upon which it is desired to form a diamond coating, and the substrate itself is used as one of the two electrodes.

[0049] In a twenty-ninth embodiment, which utilizes the process that is taught in U.S. Pat. 5,525,815, a continuous diamond structure deposited by chemical vapor deposition is disclosed having at least two thermal conductivity diamond layers controlled by the diamond growth rate where one thermal conductivity diamond layer is grown at a high growth rate of at least one micron per hour for hot filament chemical vapor deposition and at least 2-3 microns per hour for microwave plasma assisted chemical vapor deposition, on a substrate such as molybdenum in a chemical vapor deposition chamber and at a substrate temperature that promotes the high growth rate, and the other thermal conductivity diamond layer is grown at a growth rate and substrate temperature lower than the high growth rate diamond layer. High growth rate and low growth rate diamond layers can be deposited in any sequence to obtain a continuous diamond structure that does not show distinguishable, separate, crystalline columnar layers, having improved thermal conductivity.

[0050] In a thirtieth embodiment, which utilizes the process that is taught in PCT Publication WO 95/31584 (Corresponding to International Application No. PCT/US95/05941), energy, such as from a UV excimer laser, an infrared Nd: YAG laser and an infrared CO₂ laser is directed through a nozzle at the surface of a substrate to mobilize and vaporize a carbon constituent (e.g. carbide) within the substrate (e.g. steel). An additional secondary source (e.g. a carbon-containing gas, such as CO₂) and an inert shielding gas (e.g. N₂) are also delivered through the nozzle. The vaporized constituent element is reacted by the energy to alter its physical structure (e.g. from carbon to diamond) to that of a composite material, which is diffused into the back of the substrate as a composite material.

[0051] In a thirty-first embodiment, which utilizes the process that is taught in PCT Publication WO 95/20253 (Corresponding to International Application No. PCT/US95/00782), laser energy is directed at a substrate to mobilize, vaporize and react a constituent (primary) element (e.g. carbon) contained within the substrate. so as to modify the composition (e.g. crystalline structure) of the constituent element, and to diffuse the modified constituent back into the substrate, as an adjunct to fabricating a coating (e.g. diamond or diamond-like carbon) on the surface of the substrate. This creates a conversion zone immediately beneath the substrate, which transitions metallurgically from the composition of the underlying substrate to the composition of the coating being fabricated on the surface of the substrate, which results in diffusion bonding of the coating to the substrate. Additional (secondary) similar (e.g. carbon) or dissimilar elements may be introduced in a reaction zone on and above the surface of the substrate to augment the fabrication of and to determine the composition of the coating. The laser energy is provided by a combination of an excimer laser, an Nd: YAG laser and a CO₂ laser, the output beams of which are preferably directed through a nozzle delivering the secondary element to the reaction zone. The reaction zone is shielded by an inert (non-reactive) shielding gas (e.g. N₂) delivered through the nozzle. A flat plasma is created by the lasers, constituent element and secondary element on the surface of the substrate and the flat plasma optionally extends around the edges of the substrate to fabricate a coating thereon. Pre-treatment and coating fabrication can be preformed in conjunction with one another (in-situ). Alternatively, a substrate can be pre-treated to characterize its surface for subsequent coating. In either case, certain advantageous metallurgical changes are induced in the substrate due to the pre-treatment. The processes (pre-treatment and coating fabrication) are suitably performed in ambient, without preheating the substrate and without a vacuum. The lasers are directed at any suitable angle (including coaxial) relative to the substrate and/or the plasma.

[0052] It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

Claims

1. A mold wall assembly (20) for use in a continuous casting machine, comprising:

an inner portion (29) that is constructed and arranged to conduct heat away from a mold liner (30) during operation; and
an outer surface (44) that forms a casting surface (28) of the mold, said outer surface (44) comprising a material that is selected from the group consisting of diamond and cubic boron nitride;

characterized in that

the mold wall assembly (20) further includes optical monitoring means (48, 50) for optically monitoring a property of the continuous casting process through said material (44), and comprises an optical fiber (48) that is optically coupled to said material (44) at a side thereof that is opposite the casting surface (28) of the mold.

2. A mold wall assembly (20) according to claim 1, wherein said optical monitoring means (48, 50) comprises spectral measurement means for measuring the spectral characteristics of light that is transmitted through said material (44), and means for analysing the spectral characteristics of light that is measured by said spectral measurement means.

3. A mold wall assembly (20) according to claim 2, wherein said optical monitoring means (48, 50) further comprises means for modifying at least one performance variable of the continuous casting process in response to the analysis that is performed by said means for analysing the spectral characteristics of light that is measured by said spectral measurement means.

4. A mold wall assembly (20) according to claim 2, wherein said means for analysing the spectral characteristics of light that is measured by said spectral measurement means comprises means for sensing the temperature of an outer surface of cast strand that is positioned adjacent the mold wall assembly.

5. A mold wall assembly (20) according to claim 3, wherein said means for modifying at least one performance variable of the continuous casting process in response to the analysis that is performed by said means for analysing the spectral characteristics of light that is measured by said spectral measurement means comprises means for adjusting the withdrawal speed of a continuous casting machine.

6. A mold wall assembly (20) according to claim 3, wherein said means for modifying at least one performance variable of the continuous casting process in response to the analysis that is performed by said means for analysing the spectral characteristics of light that is measured by said spectral measurement means comprises means for adjusting the rate at which heat is transferred away from said inner portion.

7. A continuous casting machine (10) including a mold wall assembly (20) according to claim 1, the machine having a plurality of sensors (50) optically monitoring said property of the continuous casting process and providing information to a CPU (52) which is in two-way communication with a main control system (54) of the continuous casting machine (10) and with one or more sub-systems each controlling a performance variable of the continuous casting process in response to data gathered from said sensors, the performance variables being selected from the group consisting of:

- (a) adjustment of the withdrawal speed of the continuous casting machine;
- (b) adjustment of the taper of the mold;
- (c) adjusting the rate of cooling by adjusting the volumetric flow of coolant through one or more of the mold walls, and
- (d) adjusting the rate of cooling by changing the composition of mold flux thereby changing the heat conduction properties of the mold.

8. A method of making a strand of continuously cast material, comprising:

- (a) introducing molten metal into a mold that includes a plurality of mold surfaces (27), at least one of the mold surfaces (27) having an outer surface (44) comprising a material that is selected from the group consisting of diamond and cubic boron nitride;
- (b) cooling the molten metal by conducting heat away from the molten metal through the outer surface; and

(c) moving the cast strand out of the mold;

characterized in that the method

further comprises optically monitoring a property of the continuous casting process through said outer surface material (44) involving the use of an optical fiber (48) that is optically coupled to said material (44) at a side thereof that is opposite the casting surface of the mold (27).

9. A method according to claim 8, wherein optically monitoring a property of the continuous casting process through said outer surface material (44) comprises measuring the spectral characteristics of light that is transmitted through said material, and the method includes analysing the spectral characteristics of light that is measured by said spectral measurement means.

10. A method according to claim 9, further comprising modifying at least one performance variable of the continuous casting process in response to the step of analysing the spectral characteristics of light that is measured by said spectral measurement means.

11. A method according to claim 9, further wherein analysing the spectral characteristics of light that is measured by said spectral measurement means includes sensing the temperature of an outer surface of a cast strand that is positioned adjacent the mold.

12. A method according to claim 10, wherein modifying at least one performance variable of the continuous casting process comprises adjusting the withdrawal speed of a continuous casting machine.

13. A method according to claim 10, wherein modifying at least one performance variable of the continuous casting process comprises adjusting the rate at which heat is transferred away from said inner portion.

14. An assembly according to any of claims 1-6, wherein said outer surface comprises a smooth surface of a film of said material that is applied to a metallic substrate.

15. An assembly according to claim 14, wherein said film comprises a conversion zone which transitions metallurgically from the composition of the underlying substrate to the composition of said material.

Patentansprüche

1. Formwandanordnung (20) für eine Stranggußmaschine mit:

einem Innenteil (29), der so aufgebaut und angeordnet ist, dass er im Einsatz Wärme von einer Formauskleidung (30) ableiten kann, und einer Außenfläche (44), die eine Gußfläche (28) der Form bildet und aus einem Material besteht, das aus der aus Diamant und kubischem Bornitrid bestehenden Gruppe gewählt ist;

dadurch gekennzeichnet, dass die Formwandanordnung (20) weiterhin optische Überwachungseinrichtungen (48, 50) zur optischen Überwachung einer Eigenschaft des Stranggußprozesses durch das Material (44) hindurch enthält und einen Lichtwellenleiter (48) aufweist, der mit dem Material (44) auf einer Seite desselben, die der Gußfläche (28) der Form gegenüber liegt, optisch gekoppelt ist.

2. Formwandanordnung (20) nach Anspruch 1, bei der die optische Überwachungseinrichtung (48, 50) Spektralmeßeinrichtungen zum Messen der spektralen Eigenschaften von durch das Material (44) hindurch übertragenem Licht sowie Einrichtungen zur Analyse der spektralen Eigenschaften von von der Spektralmeßeinrichtung gemessenem Licht aufweist.

3. Formwandanordnung (20) nach Anspruch 2, deren optische Überwachungseinrichtung (48, 50) weiterhin Einrichtungen aufweist, mit denen mindestens eine Ausführungsvariable des Stranggußprozesses in Reaktion auf die Analyse modifizierbar ist, die die Einrichtung zur Analyse der spektralen Eigenschaften von von der Spektralmeßeinrichtung gemessenem Licht ausführt.

4. Formwandanordnung (20) nach Anspruch 2, bei der die Einrichtung zur Analyse der spektralen Eigenschaften von

von der Spektralmesseinrichtung gemessenem Licht Einrichtungen aufweist, mittels deren die Temperatur einer Außenfläche des Gussstrangs erfassbar ist, die angrenzend an die Formwandanordnung angeordnet ist.

5 5. Formwandanordnung (20) nach Anspruch 3, bei der die Einrichtung zum Modifizieren mindestens einer Ausführungsvariablen des Stranggussprozesses in Reaktion auf die Analyse, die die Einrichtung zum Analysieren der spektralen Eigenschaften von von der Spektralmesseinrichtung gemessenem Licht ausführt, Einrichtungen aufweist, mit denen die Abzugsgeschwindigkeit einer Stranggussmaschine nachstellbar ist.

10 6. Formwandanordnung (20) nach Anspruch 3, bei der die Einrichtung zum Modifizieren mindestens einer Ausführungsvariablen des Stranggussprozesses in Reaktion auf die Analyse, die die Einrichtung zur Analyse der Spektraleigenschaft von von der Spektralmesseinrichtung gemessenem Licht durchführt, Einrichtungen zum Nachstellen der Geschwindigkeit aufweist, mit der Wärme vom Innenteil abgeführt wird.

15 7. Stranggussmaschine (10) mit einer Formwandanordnung (20) nach Anspruch 1, welche Maschine eine Vielzahl von Sensoren (50) aufweist, die die genannte Eigenschaft des Stranggussprozesses optisch überwacht und Informationen an eine CPU (52) liefert, die in zweiseitiger Übertragungsverbindung mit einer Hauptsteuerung (54) der Stranggussmaschine (10) steht, wobei ein oder mehr Subsysteme jeweils eine Ausführungsvariable des Stranggussprozesses in Reaktion auf von den Sensoren gesammelten Daten steuern und die Ausführungsvariablen gewählt sind aus der Gruppe, die besteht aus:

- 20 (a) Einstellen der Abzugsgeschwindigkeit der Stranggussmaschine;
 (b) Einstellen der Formschräge;
 (c) Einstellen der Kühlgeschwindigkeit durch Einstellen der Volumenströmung eines Kühlmittels durch eine oder mehr der Formwandungen; und
 25 (d) Einstellen der Kühlgeschwindigkeit durch Ändern der Zusammensetzung des Flussmittels und daraus resultierendes Ändern der Wärmeleiteigenschaften der Form.

8. Verfahren zum Herstellen eines Stranges aus stranggegossenem Material durch:

- 30 (a) Einführen von Metallschmelze in eine Form mit einer Vielzahl von Formflächen (27), von denen mindestens eine eine Außenfläche (44) aus einem Material hat, das aus der aus Diamant und kubischem Bornitrid bestehenden Gruppe gewählt ist;
 (b) Kühlen der Schmelze durch Abführen von Wärme von derselben durch die Außenfläche hindurch; und
 35 (c) Herausführen des Gussstrangs aus der Form;

dadurch gekennzeichnet, dass man eine Eigenschaft des Stranggussprozesses durch das Außenflächenmaterial (44) hindurch unter Verwendung eines Lichtwellenleiters (48) überwacht, der mit dem Material (44) auf der der Gussfläche der Form (27) entgegengesetzten Seite desselben optisch gekoppelt ist.

40 9. Verfahren nach Anspruch 8, bei dem man zur optischen Überwachung einer Eigenschaft des Stranggussprozesses durch das Außenflächenmaterial (44) hindurch die spektralen Eigenschaften von durch das Material hindurch übertragenem Licht misst und bei dem man die spektralen Eigenschaften von mittels der Spektralmesseinrichtung gemessenem Licht analysiert.

45 10. Verfahren nach Anspruch 9, bei dem man weiterhin mindestens eine Ausführungsvariable des Stranggussprozesses in Reaktion auf die Analyse der spektralen Eigenschaften von von der Spektralmesseinrichtung gemessenem Licht modifiziert.

50 11. Verfahren nach Anspruch 9, bei dem bei der Analyse der spektralen Eigenschaften von von der Spektralmesseinrichtung gemessenem Licht auch die Temperatur einer Außenfläche eines Gussstrangs erfasst, der angrenzend an die Form angeordnet ist.

12. Verfahren nach Anspruch 10, bei dem zum Modifizieren mindestens einer Ausführungsvariablen des Stranggussprozesses die Abzugsgeschwindigkeit einer Stranggussmaschine nachgestellt wird.

55 13. Verfahren nach Anspruch 10, bei dem man zum Modifizieren mindestens einer Ausführungsvariablen des Stranggussprozesses die Geschwindigkeit nachstellt, mit der Wärme von dem Innenteil abgeführt wird.

14. Anordnung nach einem der Ansprüche 1-6, bei der die Außenfläche eine glatte Oberfläche einer dünnen Schicht des auf ein Metallsubstrat aufgetragenen Materials ist.
15. Anordnung nach Anspruch 14, bei dem die dünne Schicht eine Umwandlungszone aufweist, in der die Zusammensetzung des darunter liegenden Substrats metallurgisch in die Zusammensetzung des genannten Materials übergeht.

Revendications

1. Un ensemble de paroi de moule (20) destiné à être utilisé dans une machine de moulage continu, comprenant :
 - une partie intérieure (29) qui est construite et agencée pour conduire la chaleur à distance d'un revêtement du moule (30) pendant le fonctionnement ; et
 - une surface extérieure (44) qui forme une surface de moulage (28) du moule, ladite surface extérieure (44) comprenant un matériau qui est sélectionné à partir du groupe constitué de diamant et de nitrure de bore cubique ;

caractérisé en ce que

l'ensemble de paroi de moule (20) inclut également un moyen de surveillance optique (48, 50) pour surveiller optiquement une propriété du processus de moulage continu à travers ledit matériau (44), et comprend une fibre optique (48) qui est couplé optiquement audit matériau (44) sur un côté de ce dernier qui est opposé à la surface de moulage (28) du moule.
2. Ensemble de paroi de moule (20) selon la revendication 1, dans lequel ledit moyen de surveillance optique (48, 50) comprend un moyen de mesure spectrale pour mesurer les caractéristiques spectrales de la lumière qui est transmise à travers ledit matériau (44) et un moyen servant à analyser les caractéristiques spectrales de la lumière qui sont mesurées par ledit moyen de mesure spectrale.
3. Ensemble de paroi de moule (20) selon la revendication 2, dans lequel ledit moyen de surveillance optique (48, 50) comprend également un moyen servant à modifier au moins une variable de performance du processus de moulage continu en réponse à l'analyse réalisée par ledit moyen servant à analyser les caractéristiques spectrales de la lumière qui sont mesurées par ledit moyen de mesure spectrale.
4. Ensemble de paroi de moule (20) selon la revendication 2, dans lequel ledit moyen servant à analyser les caractéristiques spectrales de la lumière qui sont mesurées par ledit moyen de mesure spectrale comprend un moyen servant à détecter la température d'une surface extérieure de fil de moulage qui est située à côté de l'ensemble de paroi de moule.
5. Ensemble de paroi de moule (20) selon la revendication 3, dans lequel ledit moyen servant à modifier au moins une variable de performance du processus de moulage continu en réponse à l'analyse réalisée par ledit moyen servant à analyser les caractéristiques spectrales de la lumière qui sont mesurées par ledit moyen de mesure spectrale comprend un moyen servant à ajuster la vitesse de retrait d'une machine de moulage continu.
6. Ensemble de paroi de moule (20) selon la revendication 3, dans lequel ledit moyen servant à modifier au moins une variable de performance du processus de moulage continu en réponse à l'analyse réalisée par ledit moyen servant à analyser les caractéristiques spectrales de la lumière qui sont mesurées par ledit moyen de mesure spectrale comprend un moyen servant à ajuster la vitesse à laquelle la chaleur est transférée à distance de la partie intérieure.
7. Machine de moulage continu (10) incluant un ensemble de paroi de moule (20) selon la revendication 1, la machine ayant une pluralité de capteurs (50) surveillant optiquement ladite propriété du processus de moulage continu et fournissant des informations à une unité centrale (52) qui est en communication à deux sens avec un système de contrôle principal (54) de la machine de moulage continu (10) et avec un ou plusieurs sous-systèmes contrôlant chacun une variable de performance du processus de moulage continu en réponse à des données recueillies par lesdits capteurs, les variables de performance étant sélectionnées à partir du groupe constitué des éléments suivants :

- (a) ajustement de la vitesse de retrait de la machine de moulage continu ;
- (b) ajustement de la conicité du moule;
- (c) ajustement de la vitesse de refroidissement par ajustement du flux volumétrique de liquide de refroidissement à travers une ou plusieurs parois du moule, et
- (d) ajustement de la vitesse de refroidissement par changement de la composition du flux de moulage changeant ainsi les propriétés de conduction de la chaleur du moule.

8. Procédé de réalisation d'un fil de matériau moulé en continu, comprenant les étapes consistant à :

- (a) introduire du métal en fusion dans un moule qui inclut une pluralité de surfaces de moulage (27), au moins l'une des surfaces de moulage (27) ayant une surface extérieure (44) comprenant un matériau qui est sélectionné à partir du groupe constitué de diamant et de nitrure de bore cubique ;
- (b) refroidir le métal en fusion en conduisant la chaleur à distance du métal en fusion à travers la surface extérieure ; et
- (c) déplacer le fil de moulage hors du moule ;

caractérisé en ce que le procédé

comprend également la surveillance optique d'une propriété du processus de moulage continu à travers le matériau de la surface extérieure (44) impliquant l'utilisation d'une fibre optique (48) qui est couplée optiquement audit matériau (44) sur un côté de ce dernier qui est opposé à la surface de moulage du moule (27).

9. Procédé selon la revendication 8, dans laquelle la surveillance optique d'une propriété du processus de moulage continu à travers ledit matériau de surface extérieure (44) comprend la mesure des caractéristiques spectrales de la lumière qui est transmise à travers ledit matériau, et le procédé inclut l'analyse des caractéristiques spectrales de la lumière qui sont mesurées par ledit moyen de mesure spectrale.

10. Procédé selon la revendication 9, comprenant également la modification d'au moins une variable de performance du processus de moulage continu en réponse à l'étape d'analyse des caractéristiques spectrales de la lumière qui sont mesurées par ledit moyen de mesure spectrale.

11. Procédé selon la revendication 9, dans lequel l'analyse des caractéristiques spectrales de la lumière qui sont mesurées par ledit moyen de mesure spectrale inclut également la détection de la température d'une surface extérieure d'un fil de moulage qui est situé à côté du moule.

12. Procédé selon la revendication 10, dans lequel la modification d'au moins une variable de performance du processus de moulage continu comprend l'ajustement de la vitesse de retrait d'une machine de moulage continu.

13. Procédé selon la revendication 10, dans lequel la modification d'au moins une variable de performance du processus de moulage continu comprend l'ajustement de la vitesse à laquelle la chaleur est transférée à distance de ladite partie intérieure.

14. Ensemble selon l'une quelconque des revendications 1-6, dans laquelle ladite surface extérieure comprend une surface lisse d'un film dudit matériau qui est appliquée sur un substrat métallique.

15. Ensemble selon la revendication 14, dans lequel ledit film comprend une zone de conversion qui assure la transition métallurgique de la composition du substrat inférieur à la composition dudit matériau.

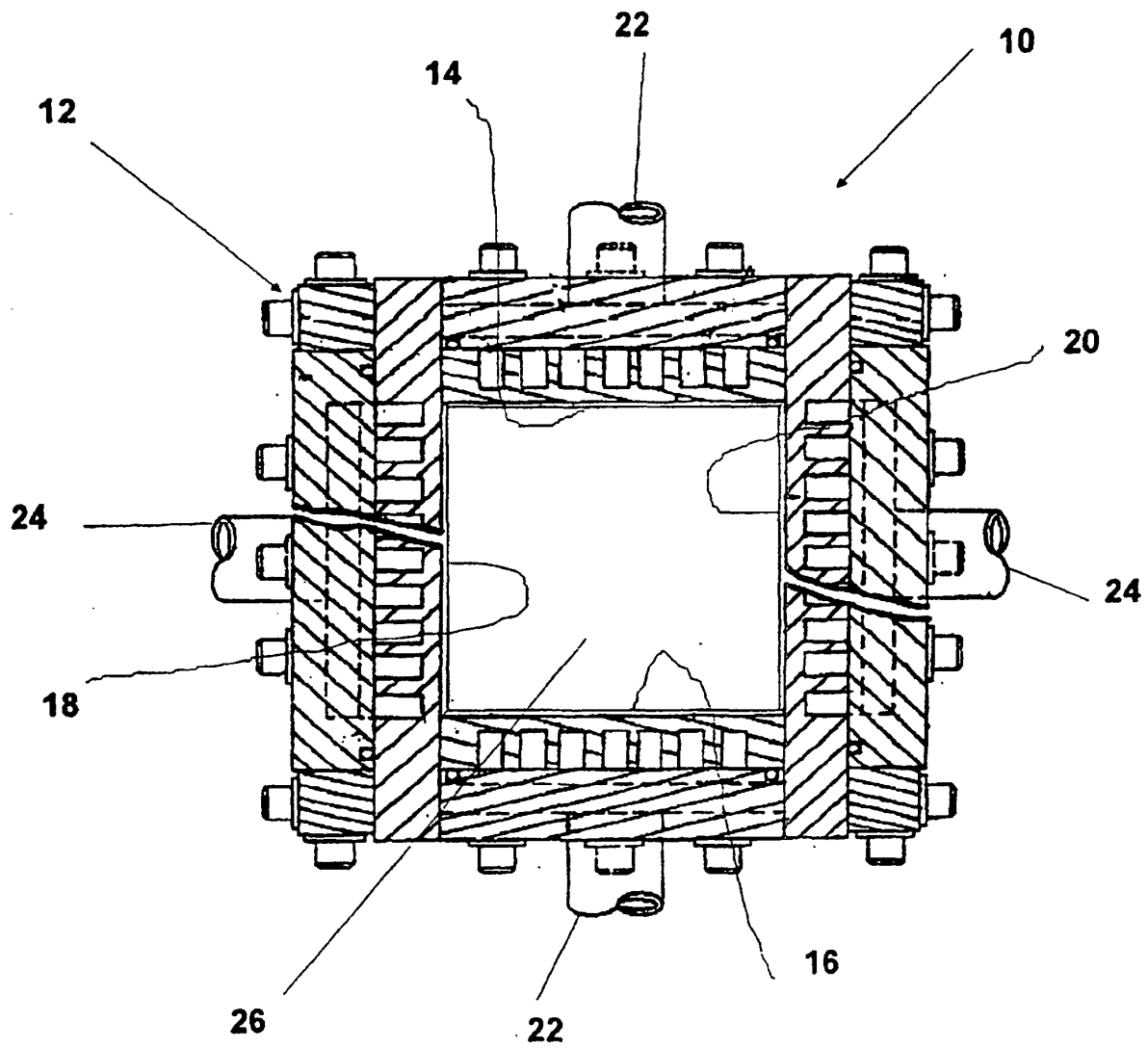


FIG. 1

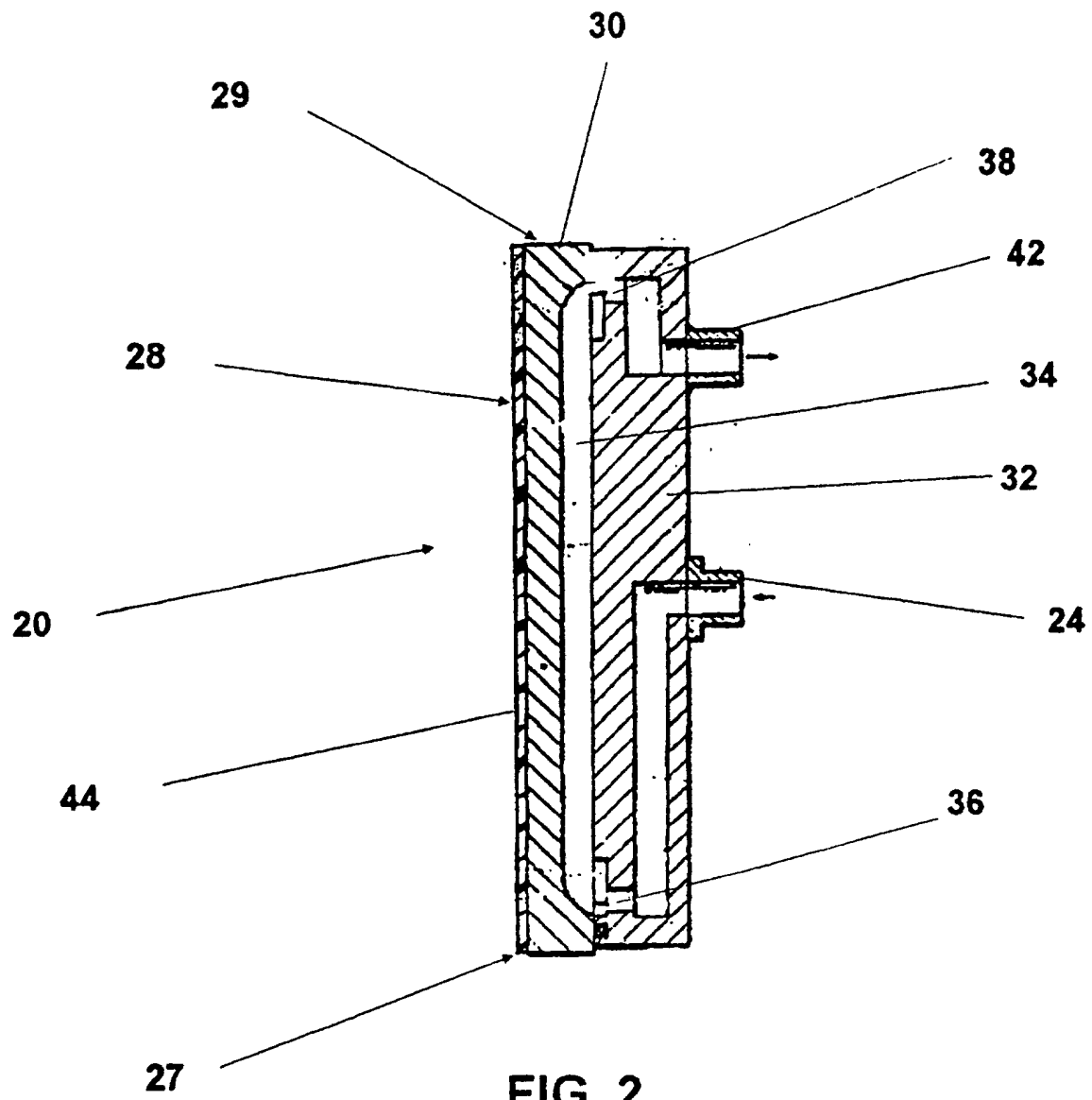


FIG. 2

FIG. 3

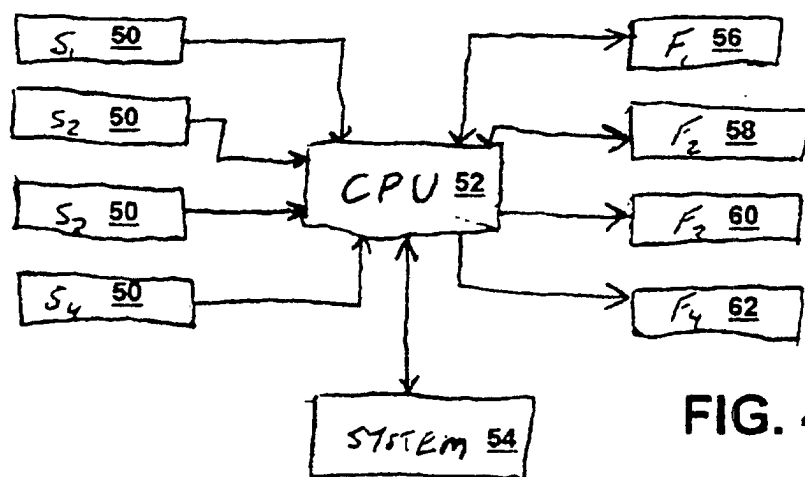
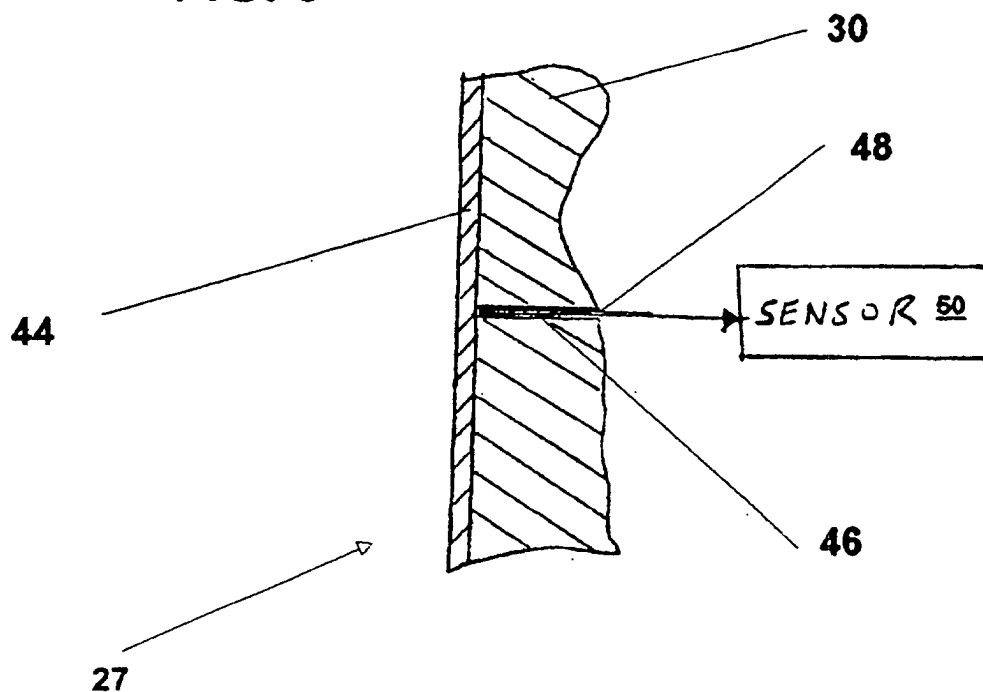


FIG. 4

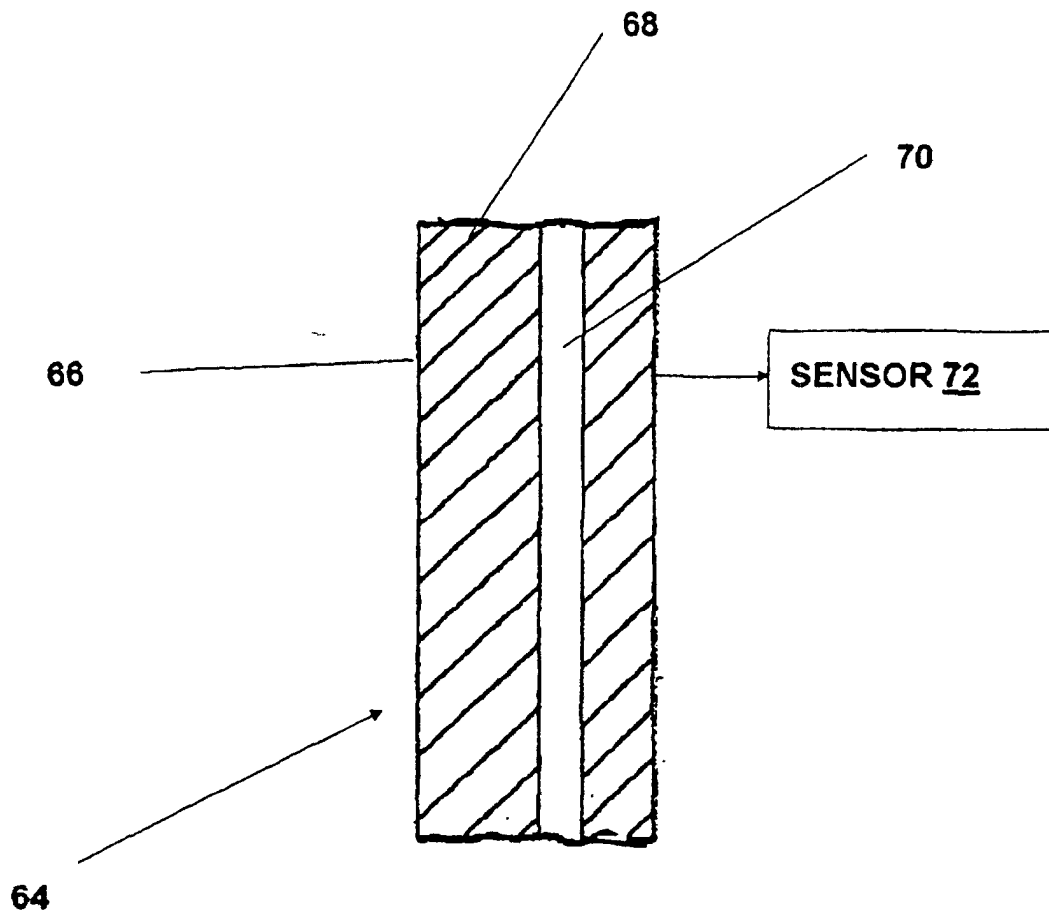


FIG. 5

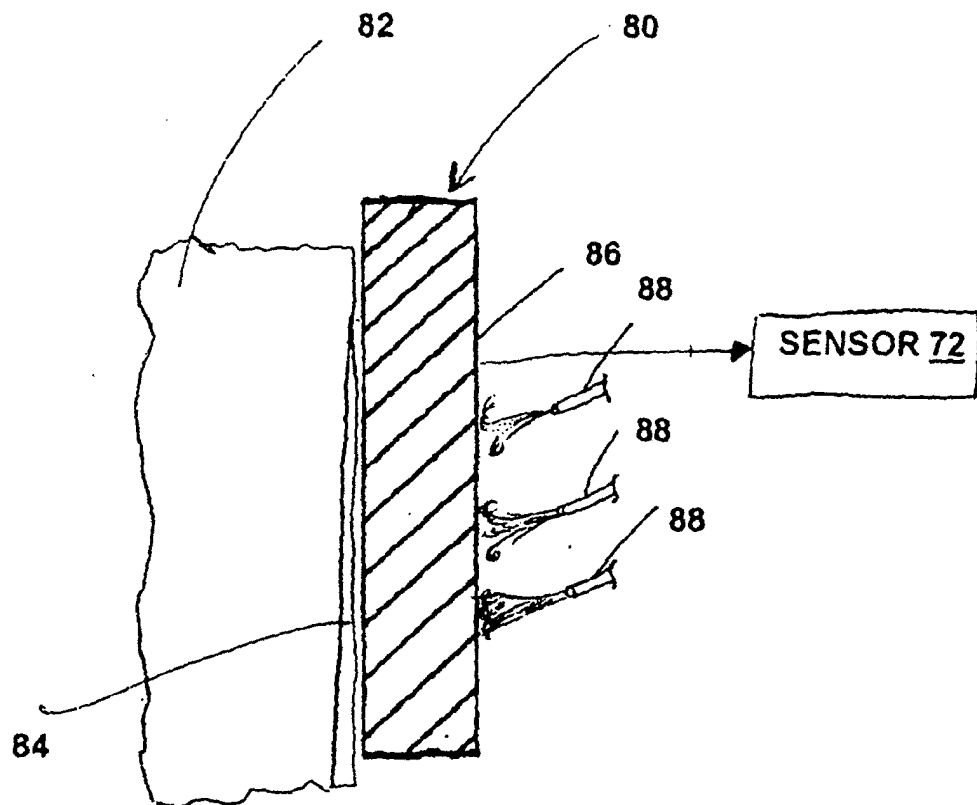


FIG. 6