



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
21.06.2023 Bulletin 2023/25

(21) Application number: **21215683.0**

(22) Date of filing: **17.12.2021**

(51) International Patent Classification (IPC):
C22C 1/10 (2023.01) **B22D 19/00** (2006.01)
B22D 19/02 (2006.01) **B22D 19/14** (2006.01)
C22C 38/04 (2006.01) **C22C 38/38** (2006.01)
C22C 33/02 (2006.01)

(52) Cooperative Patent Classification (CPC):
C22C 33/0292; B22D 19/0081; B22D 19/02;
B22D 19/14; B22D 21/025; C22C 1/1036;
C22C 1/1057; C22C 38/002; C22C 38/02;
C22C 38/22; C22C 38/38; C22C 38/58

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **Sandvik SRP AB**
233 81 Svedala (SE)

(72) Inventor: **MELK, Latifa**
23381 Svedala (SE)

(74) Representative: **Sandvik**
Sandvik Intellectual Property AB
811 81 Sandviken (SE)

(54) **TUNGSTEN CARBIDE REINFORCED MANGANESE STEEL**

(57) A composite material comprising: at least one reinforcing zone comprising tungsten carbide (WC) and a manganese steel matrix; a manganese steel zone that surrounds each of the reinforcing zones; and an interface layer positioned between each of the reinforcing zones and the manganese steel zone characterized in that: the average grain size of the WC particles in each of the reinforcing zone(s) is between 7-12 μm .

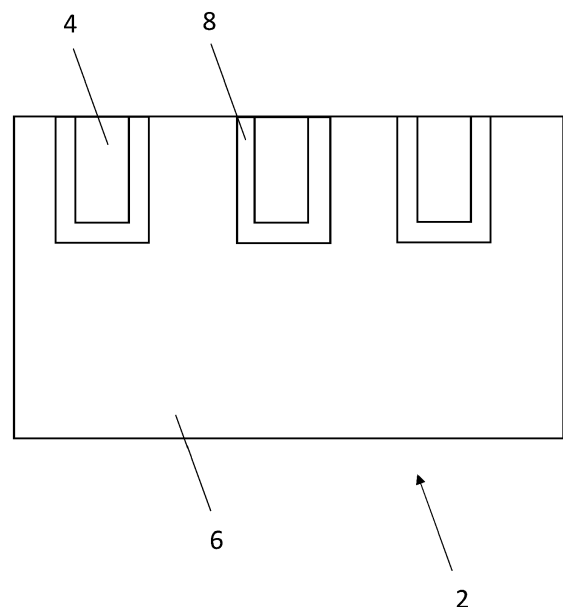


Fig. 1

Description**TECHNICAL FIELD**

5 [0001] The present invention relates to a composite material based on reinforced manganese steel, a wear part made thereof and a method for making the same.

BACKGROUND

10 [0002] A particular category of wear resistant steels is typically referred to as manganese steel or Hadfield steel. These materials are suitable for applications where a high toughness and a moderate abrasion resistance are required including for example use as wear parts for crushers that are subjected to strong abrasion and dynamic surface pressures due to the rock crushing action. Abrasion results when the rock material contacts the wear part and strips-off material from the wear part surface. Additionally, the surface of the wear part is subjected to significantly high surface pressures that cause wear part fatigue and breakage.

15 [0003] Manganese or Hadfield steel is typically characterised by having an amount of manganese, usually above 11% by weight. However, the problem with manganese steel is that it is typically too ductile for wear parts in modern crushers that are subject to extreme operating conditions, meaning the at the lifetime of the wear parts is reduced and the maintenance costs are increased. Therefore, the problem to be solved is to provide a manganese steel with enhanced wear resistance.

20 [0004] A known solution is to reinforce at least part of the manganese steel with particles having an increased hardness. WO20200222662 discloses a composite material, however the problem with this material is that it does not provide an optimal balance between wear resistance and impact resistance and an even more significant problem is that there is poor bonding between the reinforcing particle and the manganese steel matrix and poor bonding between reinforced and non-reinforced zones, which leads to reduced wear resistance and premature failure of the wear parts.

25 [0005] Therefore, the problem to be solved is to provide a composite material that can be used for wear parts having an optimal balance between wear resistance and impact resistance, wherein there is improved bonding between the reinforcing particles and the manganese matrix and the bonding between the reinforced and non-reinforced zones in order to reduce defects and cracking that would lead to premature failure of the wear parts.

30

DEFINITIONS

[0006] A "catalysis" is a metal powder or mixture of metal powders which during the reaction in the self-propagating high temperature synthesis (SHS) undergo melting and form a matrix of the composite zone. The fundamental role of catalysis is to reduce the amount of dissipated energy in the SHS process.

35 [0007] A "compact" is a densified powder composition.

SUMMARY OF INVENTION

40 [0008] It is an objective of this invention to provide a novel and improved composite material for wear parts. The objective is achieved by providing a composite material comprising: at least one reinforcing zone comprising tungsten carbide (WC) and a manganese steel matrix; a manganese steel zone that surrounds each of the reinforcing zones; and an interface layer positioned between each of the reinforcing zones and the manganese steel zone; characterized in that: the average grain size of the WC particles in each of the reinforcing zone(s) is between 7-12 μm , preferably between 7-10 μm .

45 [0009] Advantageously, this produces a composite material that has both increased wear resistance and structural integrity. Therefore, when the material is used on areas of wear parts that are highly exposed to wear the lifetime of the parts is increased. If the average grain size of the WC grains is too large, then the composite material will be too brittle. If the average grain size of the WC grains is too small the wear resistance will be reduced.

50 [0010] Preferably, the composite material comprises between 70-98 wt% of WC in each of the reinforcing zones. Preferably between 80-95 wt%, even more preferably between 90-95 wt%. Advantageously, this provides the optimal balance between wear resistance and impact resistance. If the wt% of WC in each of the reinforcing zones is too high the composite material will be too brittle and more prone to failure. If the wt% of the WC in each of the reinforcing zones is too low, then composite material will have low hardness and therefore it will not have sufficient wear resistance.

55 [0011] Preferably, the composition of the manganese steel in manganese steel zone has the chemical composition by weight of: carbon: 0.5 to 2.0%; manganese: 11 to 22%; silicon: 0.2 to 1.0%; chromium: 1 to 2%; nickel: up to 0.6%; molybdenum: up to 0.5%; and a balance of Iron. Advantageously, this steel composition is characterized by the addition of micro-alloying elements such as chromium, nickel and molybdenum in good amounts which induce high yield strength

and high hardness resulting in increase in wear resistance of manganese steel.

[0012] Preferably, the Vickers hardness of the reinforcing zones is between 580-780 HV1 and the hardness of the manganese steel zone is between 200 - 300 HV1 before work hardening. Advantageously, the increased hardness in the reinforcing zones leads to a more wear resistant material.

[0013] Preferably, the thickness of each of the interface layer is between 90-300 μm , preferably between 130-200, even more preferably between 250-300 μm . Advantageously, this thickness of interface layer or thickness of contact area between manganese and composite zone is an indication of an increase in the reaction propagation rate and the amount of heat generated due to the high combustion temperature taking place at the contact between the molten manganese steel and the insert. A high combustion temperature leads to the precipitation of large grains at the interface. If the thickness is too large the heat conductivity increases in the composite zone which results in a faster heat dissipation towards the inside of the composite zone resulting in high nucleation rate of WC particles. If the thickness is too small the heat conductivity is less which favours growth, consequently less nucleation of WC particles.

[0014] Preferably, the interface layer is free of defects. Advantageously, the absence of any defects in the interface layer means that there is good bonding between the manganese steel zone and each of the reinforcing zones and consequently the structural integrity of the composite material is improved, meaning that the lifetime of the wear parts that the materials is used in is increased. Further, the absence of the presence of any pores is an indication that the composition has the ability to absorb the excess heat and gases from the SHS process and so therefore signifies that the synthesis reaction has been successful.

[0015] Preferably, the wettability between the WC grains and the manganese steel in the reinforcing zone (s) is >99%, preferably >99.5%, even more preferably >99.9%. Advantageously, good wettability induces an excellent bonding between the composite zone and Manganese steel preventing defects such as pores and cracks to form and consequently the wear resistance increases.

[0016] Preferably, the each of the reinforcing zones has a volume of between 30-75 cm^3 . Advantageously, this size provides the optimal balance between wear resistance and impact resistance.

[0017] Preferably, at least 95 % of the WC grains in the reinforcing zones have a triangular prismatic shape. Advantageously, the triangular prismatic shape of WC will contribute to crack deflection and stop crack propagation increasing the ductility and high wear resistance of the reinforcing zone.

[0018] Preferably, the distance between two neighbouring reinforcing zones is between 1-20 μm , preferably between 1-5 mm, more preferably between 1-3 mm. Advantageously, this provides the optimal balance between wear resistance and impact resistance. If the reinforcing zones are spaced too far apart then the wear resistance will not be high enough. If the reinforcing zones are spaced too close together then the impact resistance will not be high enough.

[0019] Another aspect of the present invention relates to a wear part comprising the composite material as described hereinbefore or hereinafter. Advantageously, the presence of the reinforcing zones within the manganese zone will improve the wear resistance and therefore the lifetime of the wear parts which in turn increases profitability.

[0020] Another aspect of the present invention relates to a method of producing the composite material as described hereinbefore or hereinafter comprising the steps of: a) mixing together 60-95 wt% tungsten, 3-8wt% carbon and 0-40 % catalysis powders; b) compacting the mixed powders together to form at least one compact; c) positioning and optionally fixing at least one compact into the interior of a mold; d) pouring molten casting manganese steel into the mold to surround the at least one compact to initiate a self-propagating high temperature synthesis (SHS) reaction to produce a cast; e) heat treating the cast; f) quenching the cast; characterized in that: in step b) the powders are compacting with a pressure of between 400-700 MPa, preferably between 500-600 MPa, more preferably between 550-600 MPa.

[0021] Advantageously, if this pressing pressure is used the compacts have a low density which enables the manganese steel to more easily infiltrate between the WC grains and consequently results in improved bonding between the WC grains and the manganese steel. Further it avoids the creation of defects which would lead to premature failure of the wear parts that the composite material is used in.

[0022] Preferably, the catalysis is selected from Fe, Mn, Ni, Mo, Cr, W, Al, or a mixture thereof. Advantageously, the addition of a catalysis in a specific amount will contribute to a strong stabilization to austenite phase within the microstructure in addition to good mechanical properties and high wear resistance. The catalysis addition will also act as a grain growth inhibitor which results in a fine microstructure.

BRIEF DESCRIPTION OF DRAWINGS

[0023]

Figure 1: Shows a line drawing of the composition of the composite material.

Figure 2: Shows an SEM image taken of the reinforced zone with low magnification on the left and high magnification on the right.

Figure 3: Shows an SEM image taken of the interface layer with low magnification on the left and high magnification on the right.

Figure 4: Shows an SEM image of the composite material.

Figure 5: Shows a perspective drawing of a wear part.

Figure 6: Shows SEM images of the cracking at the interface layer for comparative sample.

DETAILED DESCRIPTION

[0024] Figure 1 shows a composite material 2 comprising at least one reinforcing zone 4 comprising tungsten carbide (WC) and a manganese steel matrix; a manganese steel zone 6 that surrounds each of the reinforcing zones 4 ; and an interface layer 8 positioned between each of the reinforcing zones 4 and the manganese steel zone 6. In each of the reinforcing zones, the WC acts to reinforce the manganese steel matrix.

[0025] The average grain size of the WC particles in each of the reinforcing zone(s) (4) is between 7-12 μm , preferably between 7-10 μm , preferably between 7-9 μm .

[0026] The average grain size of the WC grains is measured by Scanning Electron Microscopy (SEM) analysis where several and different areas from the samples were analysed and particle sizes were measured. Then, the average particle size was calculated.

[0027] Each interface layer 8 comprises WC and manganese steel and can be distinguished from the reinforcing zones 4 as the shape and size of the WC grains are different. The interface layer(s) 8 can be distinguished from the reinforcing zone(s) 4 can either: comparing the geometry and / or comparing the average grain size. If the geometry is being compared, the reinforcing zone(s) 4 comprise >90% WC grains having a triangular prismatic geometry whereas the interface layer(s) 8 comprise <5% WC grains having a triangular prismatic geometry. A WC grain is considered to have triangular prismatic geometry if the grains have 3 sharp edges. If the grain size is being compared the average WC grain size of in the interface layer(s) 8 is at least 5% less than the average WC grain size on the reinforcing zone(s) 4.

[0028] Figure 2 shows a Scanning Electron microscope image using MIRA3 TESCAN equipment. A secondary electron detector (SE) with a high voltage of 15 KV and a working distance of 9 mm configuration were used. SEM image of the WC grains in the reinforcing zone 4. Figure 3 shows an SEM image of the WC grains in the interface layer 8. The different WC grain geometry and size can be clearly be seen when comparing these two figures.

[0029] In one embodiment the wt% of WC in each of the reinforcing zones 4 is between 70-98 %, more preferably between 80-95 %, even more preferably between 90-95%.

[0030] In one embodiment, the composition of the manganese steel in manganese steel zone 6 has the chemical composition by weight of: carbon: 0.5 to 2.0%; manganese: 11 to 22%; silicon: 0.2 to 1.0% ; chromium: 1 to 2%; nickel: up to 0.6%, molybdenum: up to 0.5% and a balance of Fe.

[0031] In one embodiment, the chemical composition of the manganese steel in each of the reinforcing zones 4 has the chemical composition by weight of: 1-1.5 % C, 11-14 % Mn, 0.4-0.8 % Si, 1.3-2.0 % Cr, 0.6 % Ni, 0.065 % P.

[0032] In one embodiment, the hardness of the reinforcing zones 4 is between 580-780 HV1, preferably between 600-700. The hardness of the manganese steel zone 6 is between 200 - 300 HV1.

[0033] Hardness is measured using Vickers hardness mapping on polished samples using a 1 kgf and a holding time of 15 seconds. A micro-hardness tester, Matsuzawa, model MXT was used. Hardness measurement profiles are performed starting from the non-reinforce zone, moving to the interface layer and then to the reinforced zone.

[0034] In one embodiment, the interface layer 6 is between 90-300 μm wide, preferably between 130-200 μm . Figure 4 shows an SEM image taken at 15.0 kV, 563 magnification of the reinforced zone 4, the manganese steel zone 6 and the interface layer 8. The width of the interface layer 6 is measured from a start point 10, which is defined as being adjacent to the manganese steel zone 6 and the point at where the WC grains are present. The end point 12 for measuring where the interface layer 8 ends, and therefore where the reinforcing zone 8 starts is considered to be where the average grain size of the WC grains has increased by 20% compared average WC grains measured at the start point 10 and / or where the percentage of WC grains having a triangular prismatic shape increases above 90%.

[0035] In one embodiment, the interface layer 8 is free of defects. Defects are considered to be cracks or pores.

[0036] In one embodiment, the wettability between the WC grains and the manganese steel in the reinforcing zones 4 is >99%, preferably >99.5%, more preferably >99.9%, most preferably 100%. Wettability is measured by a Scanning Electron Microscope where the contact area and the bonding between the WC grains and the manganese steel have been evaluated.

[0037] In one embodiment each of the reinforcing zones 4 has a volume of between 30-75 cm^3 . For example, but not limited to the reinforcing zone(s) 4 could have a length of between 100-200 mm, preferably between 100-150 mm, a width of between 20-30 mm, preferably between 20-25 mm and a thickness between 15-30 mm, preferably between

15-25 mm.

[0038] In one embodiment >95%, preferably >98%, more preferably >99% of the WC grains in the reinforcing zones 4 have a triangular prismatic shape. Preferably, the WC grains are uniformly distributed in the manganese steel in the reinforcing zone(s).

[0039] In one embodiment, there are a plurality of reinforcing zones 4 with its interface zone 8 and the distance between two neighbouring reinforcing zones 4 with its interface layer 8 is between 1-5 mm, preferably between 1-3 mm, more preferably between 1-2 mm.

[0040] Figure 5 shows an example of a wear part 14 comprising the composite material 2 as described hereinabove or hereinafter. For example, the wear part 2 could be, but not limited to, a cone crusher or a stationary jaw crusher or a mobile jaw crusher that is configured to crush material or other material/rock processing unit. The reinforcing zone(s) 4 are positions on the wear parts 14 in the locations that are most subjected to high wear, for example on a crushing zone 18 of a cone crusher 16.

[0041] The method for producing the composite material 2 as described hereinbefore or hereinafter comprising the steps of: a) Mixing together 60-95 wt%, preferably 75-95 tungsten; 3-8 wt%, preferably 4-5% carbon and 0-40 %, preferably 10-20 % catalysis powders; b) compacting the mixed powders together to form at least one compact using a compacting pressure of between 400-700 MPa, preferably 500-600 MPa more preferably 550-600 MPa ; c) positioning and optionally fixing at least one compact into the interior of a mold; d) pouring molten casting manganese steel into the mold to surround the at least one compact to initiate a self-propagating high temperature synthesis (SHS) reaction to produce a cast; e) heat treating the cast; and then f) quenching the cast.

[0042] Preferably, the cast is treated at a temperature of between 1400-1500°C, the cast is quenched using water. Preferably, the catalysis is selected from Fe, Co, Ni, Mo, Cr, W, Al, or a mixture thereof. Carbon could be added in the form of graphite, amorphous graphite, a carbonaceous material or mixtures thereof. The compacts could for example be held in place using a metallic fixation system to hold them in place during casting.

EXAMPLES

Example 1 - Samples

[0043] Sample A is a comparative sample of non-reinforced manganese steel having the composition 1-1.5 % C, 11-14 % Mn, 0.4-0.8 % Si, 1.3-2.0 % Cr, 0.6 % Ni, 0.065 % P.

[0044] Samples B-K are samples of composite materials produced by mixing together powders of tungsten, carbon and a catalysis powder. The compacting the mixed powders to form compacts which were then positioned in a mold and then molten manganese steel having a composition of 1-1.5 % C, 11-14 % Mn, 0.4-0.8 % Si, 1.3-2.0 % Cr, 0.6 % Ni, 0.065 % was poured into the mold to surround the compacts which initiated a SHS reaction, the cast was then heat treated at a temperature of 1450 °C and then quenching with water. Table 1 shows a summary of the reinforced samples:

Table 1: Summary of samples

Sample	Compacting pressure used (MPa)	Average WC grain size in reinforced zone (μm)	WC content in reinforced zone (wt%)	Wettability (%)
B (invention)	600	12	78	100
C (comparative)	600	13	74	100
D (comparative)	600	14	73	5
E (comparative)	600	13	76	10
F (comparative)	600	5	75	80
H (invention)	600	10	86	100
I (invention)	600	10	87	100
J (comparative)	600	5	74	100
K (invention)	600	7	90	100

[0045] It can be seen if the compacting pressure is not high enough then the wettability is reduced.

Example 2 - Hardness

[0046] Vickers hardness was measured by a micro-hardness tester, Matsuzawa, model MXT using 1 kgf and a holding time of 15 seconds. Hardness measurement profiles are performed starting from the non-reinforce zone, moving to the interface layer and then to the reinforced zone.

[0047] The hardness measurement results are shown in Table 2 below:

Sample	Hardness in manganese steel zone (HV1)	Hardness in interface zone	Hardness in reinforced zone
A (comparative)	240	N/A	N/A
B (invention)	288	560	600
C (comparative)	259	581	584
E (comparative)	-	572	619
F (comparative)	253.5	576	609
H (invention)	326.5	625	709
I (invention)	261	611	731
J (comparative)	241.7	521	582
K (invention)	264.1	740	770
Table 2: Hardness measurement			

[0048] It can be seen that the inventive samples have an increased hardness in reinforced zones compared to the comparative samples.

Example 3 - Wear test

[0049] Wear was tested using a standard wear test using a lab jaw crusher. The wear test procedure consists on using fixed amount of rocks from 1 Ton up to 4 Ton of rocks. Four plates, two stationary and two moving, were placed inside the jaw crusher. Reference plates were also mounted in both positions. The reference plates are based on Weldom type of material.

[0050] The calculation of wear is based on the difference in volume loss of the test plates compared to the reference plates. All plates were weighed before and after wear test. Then volume loss is calculated using the density of 7.85 g/cm³ and 7.6 g/cm³ for the reference and test plates respectively. The total wear ratio (WR) is calculated according to ASTM G81-97a(2013).

[0051] The wear test results are shown in table 3 below:

Table 3: Wear test results

Sample	Wear ratio rate
C (comparative)	0.5
K (inventive)	0.3

[0052] It can be seen that the wear rate for the inventive sample is reduced.

Example 4 - Defects

[0053]

Table 4: Defects

Sample	Defects in the reinforced zone	Defects in the interface layer	Thickness of the interface layer (μm)
B (inventive)	none	none	170
C (comparative)	pores	cracks	93.5
D (comparative)	none	cracks	0
E (comparative)	pores	cracks	190
F (comparative)	none	none	138.5
H (inventive)	none	none	232
I (inventive)	none	none	292
J (comparative)	none	none	158
K (inventive)	none	none	293

[0054] Defects were assessed by using Scanning Electron microscopy analysis where cracks and pores are identified. It can be seen that the inventive samples are free of defects.

[0055] Figure 6 shows an examples of cracking in the interface layer in comparative samples D and E, whereas figure 4 shows inventive sample K, where there is no cracking.

[0056] It can be seen from tables 1-4, that inventive samples have optimal grain sizes, optimal hardness, wear resistance, optimal interface layer thickness, good wettability and are free of cracks and pores, whereas the comparative samples have one or more of low hardness, non-optimal interface layer thickness, poor wettability, low wear resistance, pores and / or cracks.

Claims

1. A composite material (2) comprising:

at least one reinforcing zone (4) comprising tungsten carbide (WC) and a manganese steel matrix;
a manganese steel zone (6) that surrounds each of the reinforcing zones (4); and
an interface layer (8) positioned between each of the reinforcing zones (4) and the manganese steel zone (6);
characterized in that:
the average grain size of the WC particles in each of the reinforcing zone(s) (4) is between 7-12 μm .

2. The composite material (2) according to claim 1 wherein the wt% of WC in each of the reinforcing zones (4) is between 70-98.

3. The composite material (2) according to claim 1 or claim 2 wherein the composition of the manganese steel in manganese steel zone (6) has the chemical composition by weight of:

carbon: 0.5 to 2.0%;
manganese: 11 to 22%;
silicon: 0.2 to 1.0% ;
chromium: 1 to 2%;
nickel: up to 0.6%
molybdenum: up to 0.5%
and a balance of iron.

4. The composite material (2) according to any of the previous claims wherein the hardness of the reinforcing zones (4) is between 580-780 HV1 and the hardness of the manganese steel zone (6) is between 200 - 300 HV1 before

work hardening.

5 5. The composite material (2) according to any of the previous claims wherein the thickness of each of the interface layer (6) is between 90-295 μm .

6. The composite material (2) according to any of the previous claims wherein the interface layer 8 is free of defects.

10 7. The composite material (2) according to any of the previous claims wherein wettability between the WC grains and the manganese steel in the reinforcing zones (4) is >99%.

8. The composite material (2) according to any of the previous claims wherein each of the reinforcing zones has a volume of between 30-75 cm^3 .

15 9. The composite material (2) according to any of the previous claims wherein at least 95% of the WC grains in the reinforcing zones (4) have a triangular prismatic shape.

10. The composite material (2) according to any of the previous claims wherein there are a plurality of reinforcing zones (4) and the distance between two neighbouring reinforcing zones is between 1-5 mm.

20 11. A wear part (14) comprising the composite material (2) according to any of claims 1-10.

12. A method of producing the composite material (2) according to any of claims 1-10 comprising the steps of:

a) mixing together 60-95wt% tungsten, 3-8 wt% carbon and 0-40 % catalysis powders;

25 b) compacting the mixed powders together to form at least one compacts (20);

c) positioning and optionally fixing at least one compact (20) into the interior of a mold (22);

d) pouring molten casting manganese steel (24) into the mold (22) to surround the at least one compact (20) to initiate a self-propagating high temperature synthesis (SHS) reaction to produce a cast (26);

e) heat treating the cast (26)

30 f) quenching the cast (26)

characterized in that:

in step b) the powders are compacting with a pressure of between 400-700 mPa.

35 13. The method according to claim 12 wherein the catalysis is selected from iron, cobalt, nickel, molybdenum, chromium, tungsten , aluminum or a mixture thereof.

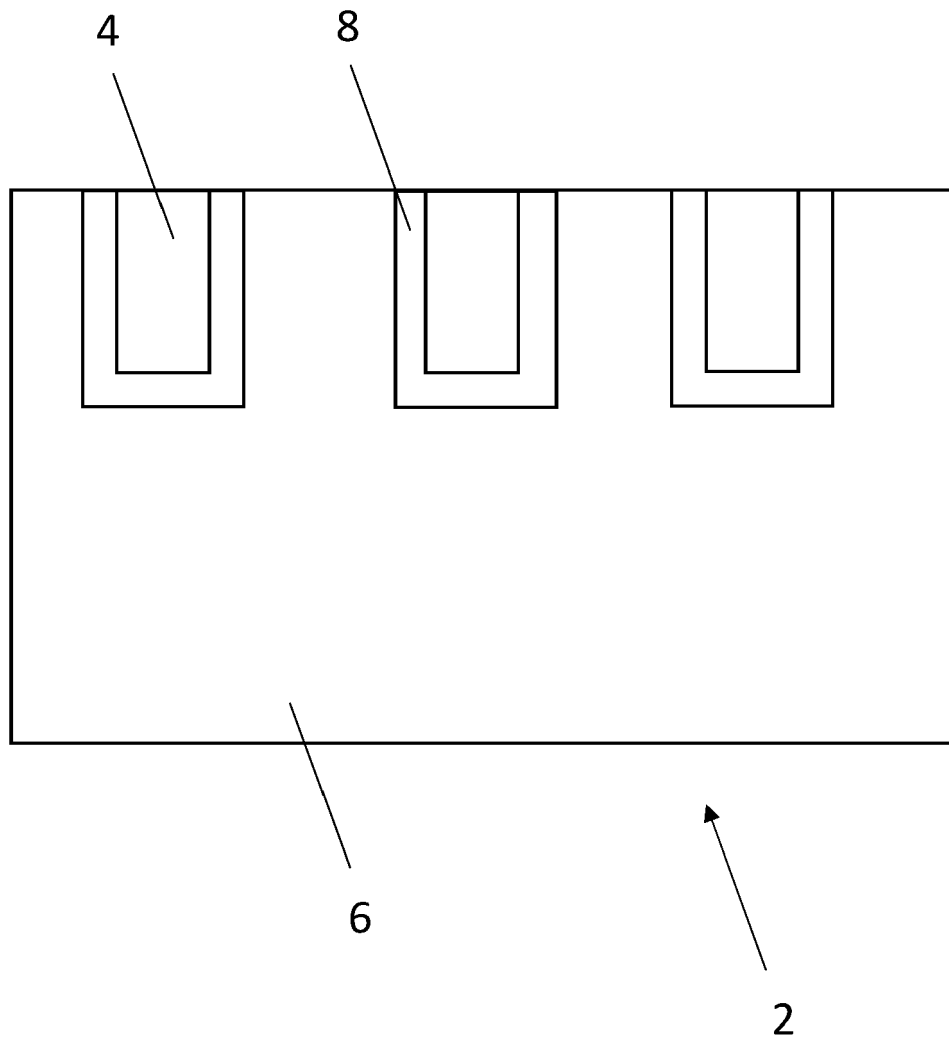


Fig. 1

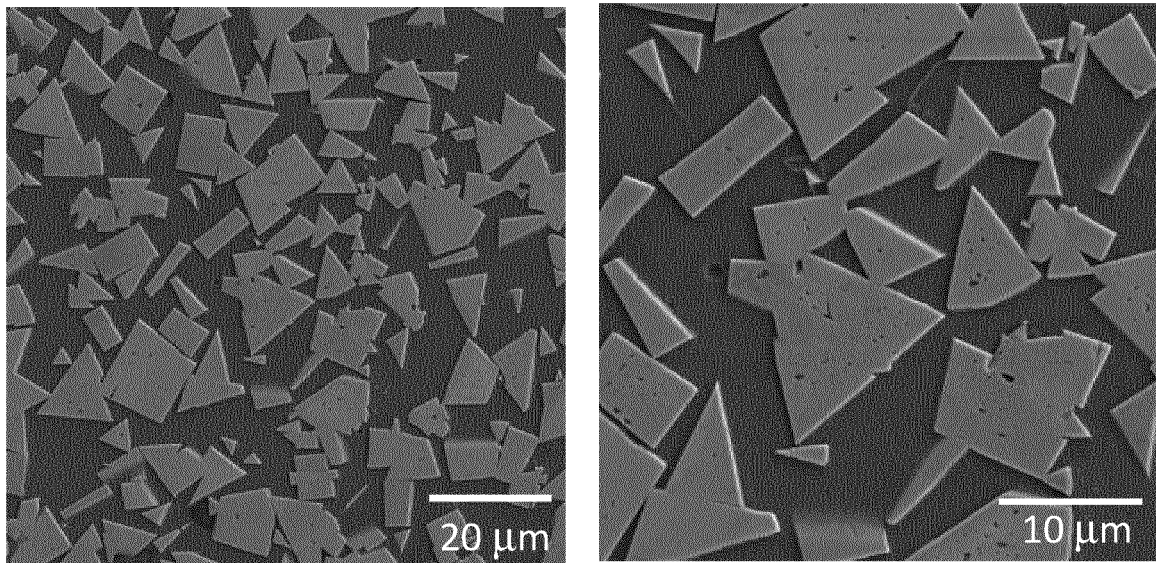


Fig. 2

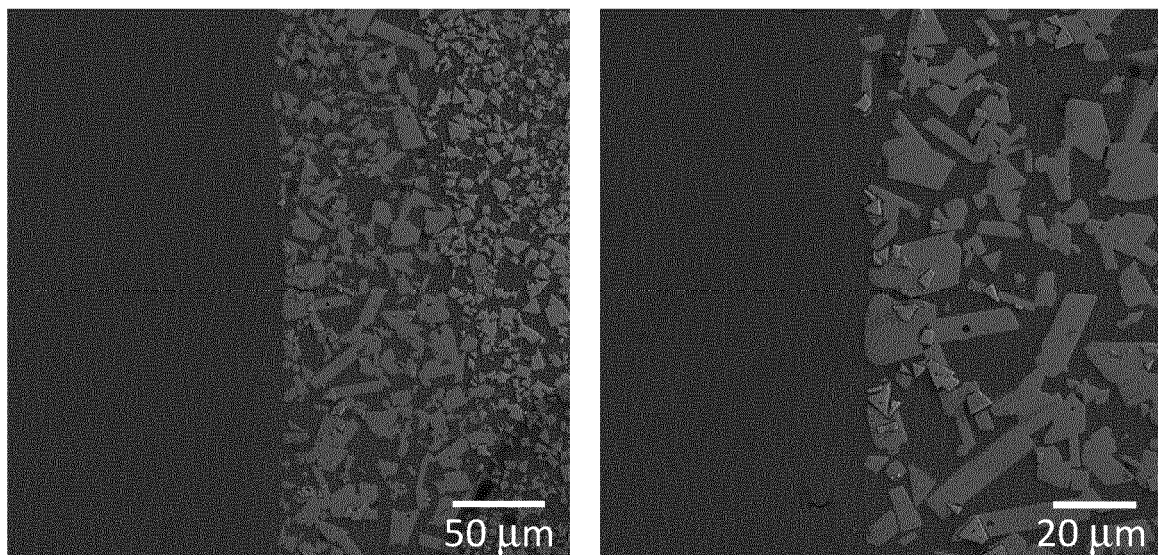


Fig. 3

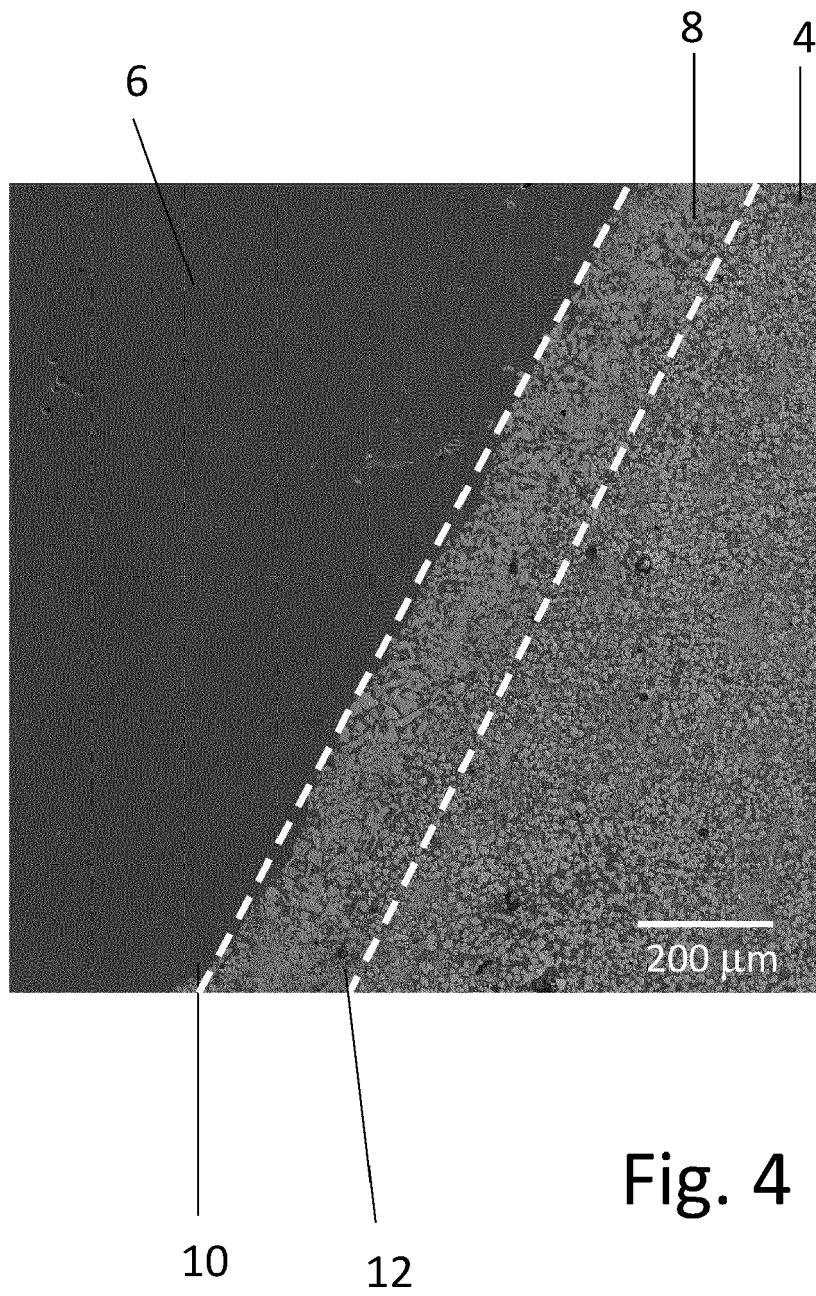
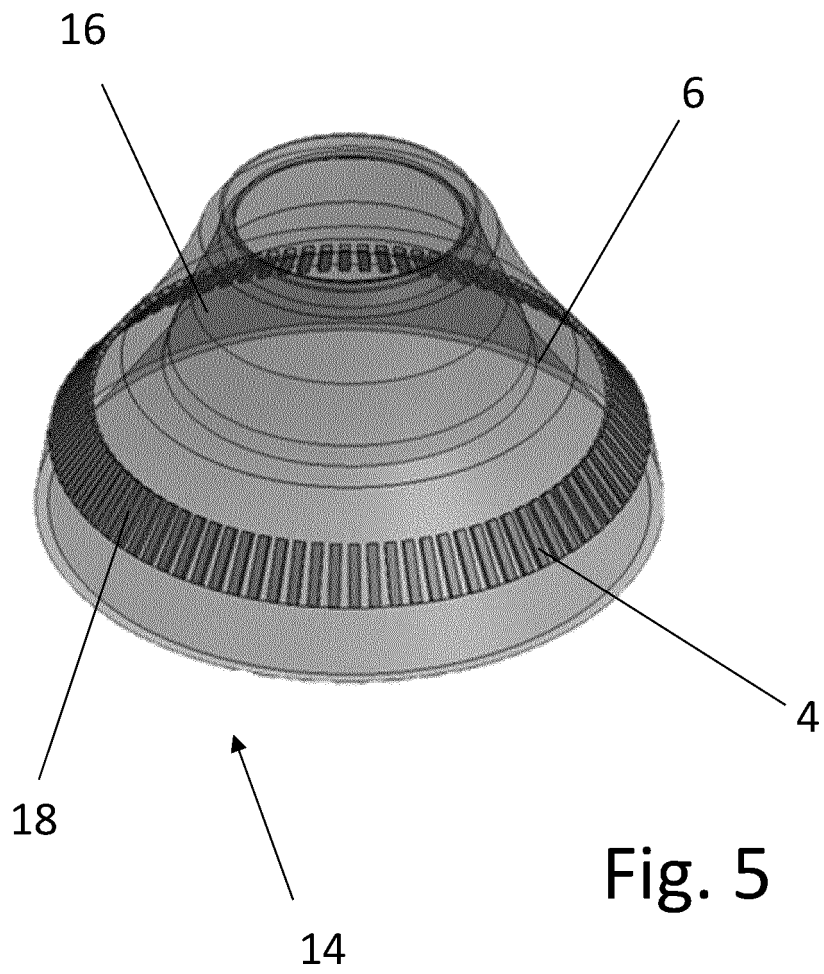


Fig. 4



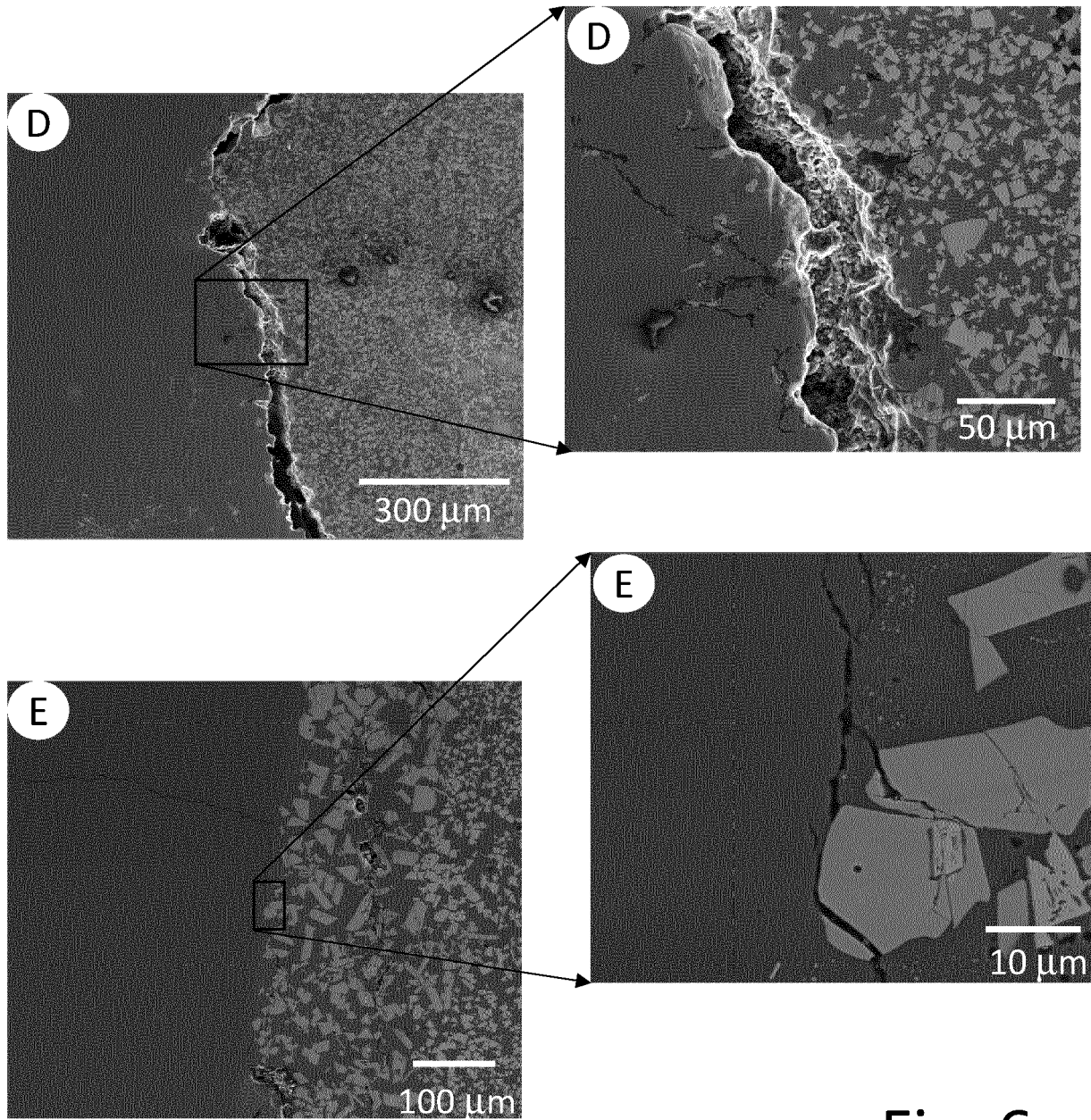


Fig. 6



EUROPEAN SEARCH REPORT

Application Number

EP 21 21 5683

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D	WO 2020/222662 A1 (INNERCO SP Z O O [PL]) 5 November 2020 (2020-11-05) * claims * * example 2 *	1-13	INV. C22C1/10 B22D19/00 B22D19/02 B22D19/14 C22C38/04 C22C38/38 C22C33/02
A	CN 111 455 249 A (UNIV INNER MONGOLIA SCI & TECH) 28 July 2020 (2020-07-28) * the whole document *	1-13	
A	US 2018/369905 A1 (OLEJNIK EWA [PL] ET AL) 27 December 2018 (2018-12-27) * the whole document *	1-13	
			TECHNICAL FIELDS SEARCHED (IPC)
			C22C B22D
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		31 May 2022	Morra, Valentina
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		& : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 21 21 5683

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

31-05-2022

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2020222662 A1	05-11-2020	AU 2019444038 A1	11-11-2021
		CA 3133871 A1	05-11-2020
		CN 113766984 A	07-12-2021
		EP 3962683 A1	09-03-2022
		PE 20220042 A1	13-01-2022
		WO 2020222662 A1	05-11-2020
CN 111455249 A	28-07-2020	NONE	
US 2018369905 A1	27-12-2018	AU 2016352319 A1	07-06-2018
		BR 112018009390 A2	13-11-2018
		CA 3003685 A1	18-05-2017
		CL 2018001259 A1	19-10-2018
		JP 6942702 B2	29-09-2021
		JP 2019501026 A	17-01-2019
		PE 20181032 A1	27-06-2018
		US 2018369905 A1	27-12-2018
		US 2021402464 A1	30-12-2021
		WO 2017081665 A1	18-05-2017
		ZA 201803339 B	27-11-2019

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 20200222662 A [0004]