(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 March 2009 (12.03.2009)

PCT

(10) International Publication Number
WO 2009/029993 A1

(51) International Patent Classification:
B22F 3/16 (2006.01) *B22F 3/10* (2006.01)
B22F 7/00 (2006.01) *B28B 1/24* (2006.01)

(21) International Application Number:
PCT/AU2008/001321

(22) International Filing Date:
5 September 2008 (05.09.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2007904878 7 September 2007 (07.09.2007) AU

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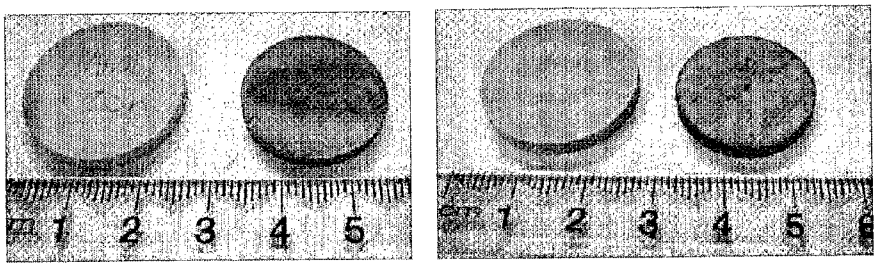
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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

(54) **Title:** METAL INJECTION MOULDING METHOD



(a) (b)

FIGURE 1

(57) **Abstract:** A method of forming an article by metal injection moulding comprising the steps of forming a first mixture containing an V powder or a aluminium alloy powder, a binder, optionally a sintering aid and optionally ceramic particles, forming a second mixture containing an aluminium powder or aluminium alloy powder, a binder, optionally a sintering aid and optionally ceramic particles, the first mixture being of different composition to the second mixture, injection moulding the first mixture and the second mixture to form a green body, removing the binder from the green body; and sintering the green body to form the article. The powder loading of the first mixture and the powder loading of the second mixture are controlled so that the first mixture and the second mixture exhibit similar or identical shrinkage during sintering.

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METAL INJECTION MOULDING METHOD

FIELD OF THE INVENTION

The present invention relates to a metal injection moulding method.

BACKGROUND TO THE INVENTION

Injection moulding is a widely used technique in the field of commercial plastics processing. Many variations of injection moulding have been developed and one of the rapidly expanding fields is multi-material injection moulding. There are three major types of multi-material injection moulding used in plastics injection moulding, namely multi-component moulding, multi-shot moulding and over moulding.

Multi-component moulding can be further subdivided into co-injection moulding (sandwich moulding) and interval injection moulding (marbling). Co-injection moulding involves making sequential injections into the same mould with one material as the core and one as the skin. Interval injection moulding involves the simultaneous injection of different materials through different gates giving limited mixing. Multi-shot moulding describes any process where distinct material shots are applied to produce the final component. This includes transfer moulding, core back moulding, and rotating tool moulding.

Metal injection moulding is a hybrid of powder metallurgy and plastic injection moulding technologies. The process has inherited the capability of mass production and geometrical complexity from plastic injection moulding and material flexibility from powder metallurgy technology.

Metal injection moulding involves the mixing of powder metal with a binder to form a feedstock. This mixture is then injection moulded using injection moulding equipment that is similar to that used in the plastics industry. This forms a "green body". The green body has sufficient rigidity and strength to enable handling. The green body is then further treated to remove the binder and to sinter the metal powder particles to form the final article.

The binder typically comprises one or more thermoplastic compounds, plasticisers and other organic material. Ideally, the binder is molten or liquid at the injection moulding temperature but solidifies in the mould when the green body is cooled. The feedstock may be converted into solid pellets, for example by granulation. These pellets may be stored and fed into the injection moulding machine at a later time.

Typical injection moulding equipment includes a heated screw or extruder having a nozzle through which the mixture is extruded into the die cavity. The extruder is heated to ensure that the binder is in liquid form and the nozzle temperature is typically carefully controlled to ensure constant conditions. Desirably, the temperature of the die is also controlled so that the temperature is low enough to ensure that the green body is rigid when it is removed from the die.

As the binder can occupy a substantial volume fraction of the green body, the green body will be larger than the final article.

Further processing of the green body involves removing the binder and sintering. The binder may be completely removed before sintering. Alternatively, the binder may be partly removed before the sintering step, with complete removal of the binder being achieved during the sintering step.

Removal of the binder may take place by using a solvent to dissolve the binder or by heating the green body to cause the binder to melt, decompose and/or evaporate. A combination of solvent removal and thermal removal may also be used.

The sintering step involves heating the body to cause the separate metal particles to metallurgically bond together. Sintering in the production of metal injection moulded parts is generally similar to sintering used in the production of traditional powder metal parts. Non-oxidising atmospheres are typically used during the sintering step in order to avoid oxidation of the metal. During sintering in metal injection moulding methods, the very porous body remaining after removal of the binder densifies and shrinks. The sintering temperature and temperature distribution will typically be closely controlled in order to retain the shape of the article during sintering and to prevent distortion of the article. In this fashion, net shape articles can be recovered from the sintering step.

Recently, powder co-injection moulding has emerged to produce components which are engineered in-situ. Similar to co-injection moulding in plastic injection moulding, two different kinds of feedstock are injected from the barrels. The materials in each barrel can be different. By such means, a material with graded properties can be made.

Metal injection moulding is suitable for producing articles from almost any metal that can be produced in a suitable powder form. However, aluminium is difficult to use in metal injection moulding because the adherent aluminium oxide film that is always present on the surface of particles of aluminium or aluminium alloy inhibits sintering.

In our international patent application number PCT/AU2007/001108, the entire contents of which are incorporated herein by cross-reference, a method for forming an article by metal injection moulding of aluminium or an aluminium alloy is described. The method comprises the steps of forming a mixture containing an aluminium powder or an aluminium alloy powder or both and optionally ceramic particles, a binder, and a sintering aid comprising a low melting point metal, injection moulding the mixture, removing the binder and sintering; wherein sintering is conducted in an atmosphere containing nitrogen and in the presence of an oxygen getter.

The oxygen-getter may comprise any metal that has a higher affinity for oxygen than aluminium. Some examples of suitable metals for use as the oxygen-getter include the alkali metals, the alkaline earth metals and the rare earth metals. Where one or more rare earth metals are used as the oxygen-getter, it is preferred that rare earth metals from the lanthanide series are used.

Magnesium is the preferred metal for use as the oxygen-getter because it is has a high vapour pressure, it is readily available and it is relatively inexpensive.

The sintering aid is a low melting point metal. For example, the sintering aid may be a metal that has a melting point that is lower than the melting point of aluminium. Preferably, the sintering aid comprises a low melting point metal that is insoluble in solid aluminium. Some examples of suitable sintering aids include tin, lead, indium, bismuth

and antimony. It has been found that tin is especially suitable in assisting in sintering of aluminium and aluminium alloys. Therefore, tin is a preferred sintering aid.

Ceramic particles can be mixed with the aluminium or aluminium alloy powders to create an aluminium metal matrix composite. The ceramic particles are used to improve or control the properties of the sintered article. Such properties can include, but are not limited to, wear resistance, stiffness or coefficient of thermal expansion. A non-exhaustive list of typical ceramic materials includes SiC, Al_2O_3, AlN, SiO_2, BN and TiB_2.

The applicant does not concede that the prior art discussed in this specification forms part of the common general knowledge in Australia or elsewhere.

Throughout this specification, the term "comprising" and its grammatical equivalents are taken to have an inclusive meaning unless the context indicates otherwise.

BRIEF DESCRIPTION OF THE INVENTION

It is an object of the present invention to provide a method that allows for the production of articles using metal injection moulding that involves multi-material injection moulding.

In a first aspect, the present invention provides a method of forming an article by metal injection moulding comprising the steps of:

- forming a first mixture containing an aluminium powder or an aluminium alloy powder, a binder, optionally a sintering aid and optionally ceramic particles;

- forming a second mixture containing an aluminium powder or an aluminium alloy powder, a binder, optionally a sintering aid and optionally ceramic particles;

- the first mixture being of different composition to the second mixture;

- injection moulding the first mixture and the second mixture to form a green body;

- removing the binder from the green body; and

- sintering the green body to form the article

-wherein a powder loading of the first mixture and a powder loading of the second mixture are controlled so that the first mixture and the second mixture exhibit similar or identical shrinkage during sintering.

In the mixtures used in the method of the present invention, the "powder loading" of each mixture is determined from the total powder content added to the mixture as a percentage by weight of the total weight of the green body. The total powder content includes the metal powder or metal alloy powder, the sintering agent content (where present) and the ceramic particle content (where present).

Any aluminium alloy can be used in the present invention, including aluminium alloys from the 1000 series, 2000 series, 3000 series, 4000 series, 5000 series, 6000 series, 7000 series and 8000 series.

As the first mixture and the second mixture are of different compositions, the present invention allows for designing or engineering articles such that they have desirable physical or chemical properties. For example, it may be possible to make a first mixture as a lightweight material to be used as a central part or core of the article and to make a second mixture that will form a durable, hard wearing part that is used as a coating over the core, with the first mixture and the second mixture being injection moulded and subsequently treated to form the final article.

The first mixture and the second mixture are of different compositions. For example, the first mixture may comprise an aluminium or aluminium alloy powder and the second mixture may comprise a different aluminium alloy powder. Alternatively, the first mixture may comprise two or more aluminium or aluminium alloy powders and the second mixture may comprise the same two or more aluminium or aluminium alloy powders but with a different proportion of those powders. Alternatively, the first mixture may comprise a different sintering agent to that used in the second mixture. Alternatively, the first mixture may comprise no ceramic particles and the second mixture may comprise ceramic particles (and vice versa). Alternatively, the first mixture may comprise ceramic particles and the second mixture may comprise different ceramic

particles. Alternatively the first mixture may comprise two or more ceramic particles in the second mixture may comprise differing proportions of the same two or more ceramic particles. Various combinations of the above differences are also possible.

The binder used in the present invention may be any binder or binder composition known to be suitable for use as a binder in metal injection moulding. As will be known to persons skilled in the art, the binder is typically an organic component or a mixture of two or more organic components.

The binder desirably includes thermoplastic components that enable the binder to melt upon application of heat. The binder should also impart sufficient strength to the green body following injection moulding to enable the green body to be handled. Desirably, the binder is able to be removed from the green body in a manner that retains integrity of the body during the binder removal process. It is preferable that the binder leaves no residue following removal.

The binder may be made from two or more materials. The two or more materials that comprise the binder may be selected such that they may be sequentially removed from the green body. In this fashion, a controlled removal of the binder is more easily achieved, thereby facilitating retention of shape integrity of the body during binder removal. In this regard, it will be appreciated that if the binder is removed too rapidly, the risk of the body losing its shape integrity is increased.

The binder may be removed by one or more of the known techniques used in metal injection moulding for removing the binder. For example, the binder may be removed by dissolution in a solvent, by thermal treatment to cause the binder to melt, evaporate or decompose, by catalytic removal of the binder or by wicking.

Two or more binder removal techniques may be used in the binder removal stage. For example, a first step in the binder removal may involve solvent extraction, followed by thermal removal of the remainder of the binder.

The person skilled in the art will appreciate that a large range of binder materials may be used. Some examples include organic polymers such as stearic acid, waxes, paraffin and polyethylene.

Without wishing to be limited in any way, the present inventors have used a binder comprising stearic acid, palm oil wax and high density polyethylene in experimental work relating to the present invention.

A sintering aid will normally be used in the method of the present invention and, for convenience, the present invention will be described hereinafter with reference to embodiment in which a sintering aid is used. However, it will be appreciated that the metal powder used in the present invention may have properties that allow for satisfactory sintering to take place in the absence of a separate sintering aid.

The sintering aid is added to the mixture prior to injection moulding of the mixture.

The sintering aid may comprise a low melting point metal. For example, the sintering aid may be a metal that has a melting point that is lower than the melting point of aluminium. Preferably, the sintering aid comprises a low melting point metal that is insoluble in solid aluminium. Some examples of suitable sintering aids include tin, lead, indium, bismuth and antimony. It has been found that tin is especially suitable in assisting in sintering of aluminium and aluminium alloys. Therefore, tin is a preferred sintering aid.

Tin is a preferred sintering aid for use in embodiments of the present invention where aluminium powder or aluminium alloy powder is used because it has been found that tin suppresses the formation of aluminium nitride during sintering (thereby avoiding formation of excessive aluminium nitride, which might have a detrimental effect on the properties of the final article) and also changes the surface tension of molten aluminium, thereby promoting good distribution of liquid aluminium phase during sintering.

The sintering aid may be added in an amount of up to 10% by weight, based upon the total weight of the metal powder and the sintering aid. Preferably, the sintering aid is present in an amount of from 0.1% to 10% by weight, more preferably 0.5% to 3% by weight, even more preferably about 2% by weight.

Where tin is used as the sintering aid, it may be added in an amount of from 0.1% to 10%, more suitably from 0.5% to 4%, even more suitably from 0.5% to 2.0% by weight of the mixture.

Tin melts at 232°C, which is considerably lower than that of aluminium (660°C) and there are no intermetallic phrases. Tin is sparingly soluble in solid aluminium: the maximum solid solubility is less than 0.15%. Aluminium is completely miscible in liquid tin and no immiscible liquids form. Further, the surface tension of liquid tin is significantly less than that of aluminium and trace amounts of tin have been shown by the present inventors to improve the wetting characteristics and sintering behaviour of aluminium. For these reasons, tin is an especially preferred sintering aid.

Ceramic particles may be mixed with the metal or metal alloy powders to create a metal matrix composite. The ceramic particles may be used to improve or control the properties of the sintered article. Such properties can include, but are not limited to, wear resistance, stiffness or coefficient of thermal expansion. A non-exhaustive list of typical ceramic materials includes SiC, Al_2O_3, AlN, SiO_2, BN and TiB_2.

Once the mixtures have been formed, they are injection moulded to form a green body. The two mixtures may be sequentially injection moulded (for example, the first mixture may be injection moulded and an end of the second mixture may be subsequently injection moulded). The two mixtures may be simultaneously injection moulded through different gates of the injection moulding equipment. The two mixtures may be injection moulded using multi-shot moulding techniques.

After the green body has been formed by injection moulding, the binder is removed using conventional de-binding techniques. The binder may be removed using solvents or using thermal removal, or both.

Following removal of the binder, the green body is subjected to sintering.

In embodiments where the metal powder is aluminium or an aluminium alloy, it is generally desirable to conduct the sintering step in the presence of an oxygen getter and in an atmosphere containing nitrogen.

In some embodiments, blocks of an oxygen-getter may be positioned around the article that is being sintered during the sintering step. In other embodiments, powder of the oxygen-getter may be placed around or on the article that is being sintered during the sintering step. As a further alternative, the oxygen-getter may be mixed in with the aluminium or aluminium powder alloy, or mixed in with the mixture that is fed to the injection moulding apparatus. A high magnesium containing master alloy powder may be used.

In a further embodiment, the oxygen getter is present as a component of an alloy added to the mixture, such as being present in an alloy powder added to the mixture. For example, powder of an alloy containing aluminium and magnesium (and possibly other components) may be added to the mixture or incorporated into the mixture. Examples of some alloys that can be incorporated into the mixture include Al-7.9wt%Mg and Al-2 wt%Cu-9.3 wt%Mg-5.4 wt%Si.

Without wishing to be bound by theory, the present inventors have postulated that the oxygen-getter removes any oxygen that may be present in the atmosphere surrounding the part during the sintering step. The oxygen-getter may also act to reduce the aluminium oxide that surrounds the aluminium or aluminium alloy particles. This assists in disrupting the aluminium oxide layer around the particles, exposing fresh metal, thereby allowing sintering of the aluminium or aluminium alloy particles to take place.

Magnesium is a suitable oxygen-getter. In addition to being relatively inexpensive, magnesium also has a high vapour pressure. Consequently, during the sintering step (which takes place at elevated temperature), magnesium vapour may surround the article that is being sintered.

In embodiments in which aluminium powder or aluminium alloy powder is used, the sintering step is conducted in a nitrogen-containing atmosphere. Without wishing to be bound by theory, the present inventors have postulated that conducting the sintering step in a nitrogen atmosphere may promote the formation of aluminium nitride. The present inventors have postulated that forming aluminium nitride in the sintering step may assist in disrupting or breaking down the aluminium oxide film that normally

surrounds the particles of aluminium or aluminium alloy. The use of tin as a sintering aid may also assist in controlling the formation of AlN as formation of excessive amounts of AlN during sintering may cause detriment to the properties of the final article.

If high purity aluminium is being used as a feed powder, the present inventors have found that conducting sintering of aluminium powder in a nitrogen atmosphere can result in the rapid conversion of the aluminium to aluminium nitride. Due to the rapid rate at which the aluminium can be converted to aluminium nitride in these circumstances, there is a risk that the entire article may be converted to aluminium nitride. Using tin as a sintering aid acts to limit the formation of excess AlN in such circumstances.

Without wishing to be bound by theory, the present inventors have postulated that the nitrogen atmosphere disrupts the aluminium oxide film on the surface of the aluminium or aluminium alloy particles by forming aluminium nitride. It is further postulated that this disruption of the aluminium oxide film enables sintering of the aluminium or aluminium alloy particles to occur.

The atmosphere in which the sintering step is conducted may have a low water content, for example, it may have a water vapour partial pressure of less than 0.001kPa. The atmosphere used on the sintering step may have a dew point of less than -60°C, more preferably, less than -70°C. Magnesium, when used as an oxygen getter, reacts with oxygen and water, thereby further lowering the water content of the atmosphere. It is believed that water vapour is extremely detrimental to the sintering of aluminium.

The atmosphere may be an atmosphere containing nitrogen. The atmosphere may be predominantly nitrogen. The atmosphere may be 100% nitrogen. The atmosphere may also include an inert gas. The inert gas may comprise a minor part of the atmosphere. The atmosphere may be essentially free of oxygen and hydrogen. In this regard, the gas that is supplied as the atmosphere during sintering suitably contains no oxygen or hydrogen.

The sintering step used in the present invention involves heating the green body to a temperature at which the aluminium or aluminium alloy sinters to form a dense body.

The sintering step suitably involves heating to a temperature within the range of about 550°C to about 650°C, more suitably 590°C to 640°C, most suitably between 610°C to 630°C. The sintering time may vary. Typically, a shorter sintering time may be used for a higher sintering temperature. Essentially, the sintering time should be long enough to ensure that maximum densification of the article has occurred. Sintering at temperatures of from 620°C to 630°C for up to two hours has been found to provide satisfactory results. However, both longer sintering times and shorter sintering times are encompassed by the present invention.

The heating rates and thermal profile used in the sintering step are normally closely controlled in metal injection moulding methods to obtain optimum properties in the final article. The person skilled in the art will readily understand how to determine suitable heating rates and temperature profiles for use in the sintering step.

The method of the present invention may be carried out in known metal injection moulding apparatus.

It will also be understood that the method of the present invention may include injection moulding more than two mixtures to form the article.

In a second aspect, the present invention provides a method of forming an article by metal injection moulding comprising:

forming a first mixture containing an aluminium powder or aluminium alloy powder, binder and optionally a sintering agent and optionally ceramic particles, moulding the first mixture, removing the binder and sintering to thereby determine a shrinkage factor for the first mixture,

forming a second mixture containing an aluminium powder or aluminium alloy powder, binder and optionally a sintering agent and optionally ceramic particles, moulding the second mixture, removing the binder and sintering to thereby determine a shrinkage factor for the second mixture,

forming a third mixture having the same powder components as the first mixture mixed with a binder, forming a fourth mixture having the same powder components as

the second mixture, controlling a powder loading in the third mixture and the fourth mixture so that the third mixture and the fourth mixture exhibit similar or identical shrinkage characteristics during sintering,

- the third mixture being of different composition to the fourth mixture;

- injection moulding the third mixture and the fourth mixture to form a green body;

- removing the binder from the green body; and

- sintering the green body to form the article.

In a third aspect, the present invention provides a method of forming an article by metal injection moulding comprising

forming a first mixture containing an aluminium powder or aluminium alloy powder, binder and optionally a sintering agent and optionally ceramic particles, moulding the first mixture, removing the binder and sintering to thereby determine a shrinkage factor for the first mixture,

forming a second mixture containing an aluminium powder or aluminium alloy powder, binder and optionally a sintering agent and optionally ceramic particles, moulding the second mixture, removing the binder and sintering to thereby determine a shrinkage factor for the second mixture,

determining a powder loading of the first mixture and a powder loading of the second mixture that will result in the first mixture and the second mixture exhibiting similar or identical shrinkage properties during sintering,

forming a third mixture having the same powder components as the first mixture mixed with a binder, the third mixture having the determined powder loading

forming a fourth mixture having the same powder components as the second mixture, the fourth mixture having the determined powder loading, whereby the third

mixture and the fourth mixture exhibit similar or identical shrinkage characteristics during sintering,

- the third mixture being of different composition to the fourth mixture;

- injection moulding the third mixture and the fourth mixture to form a green body;

- removing the binder from the green body; and

- sintering the green body to form the article.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows green and sintered surfaces of the top layer (figure 1 (a)) and the bottom layer (figure 1 (b)) of a disk made from two different starting mixtures;

Figure 2 shows low (a) and high (b) magnification optical microstructures of the disc shown in figure 1.

EXAMPLE

A two layer hybrid material was formed by making a first metal injection moulding mixture comprising a powder of aluminium alloy AA6061 + 2% Sn (as a sintering aid) with appropriate binder and making a second metal injection moulding mixture comprising a powder of aluminium alloy AA6061 + 2% Sn + 10%AlN ceramic particles. The separate mixtures were separately packed into 1.5 mm thick discs. The discs were then packed together into 3 mm thick discs under a pressure of 30 MPa at 160°C. The samples were solvent debound in hexane at 45°C for 24 hours. Subsequent thermal de-binding and sintering was conducted in a horizontal tube furnace. The furnace was nitrogen purged at 10 litres per minute for 30 minutes to ensure a low oxygen environment before heating. De-binding and sintering was conducted in nitrogen at a flow rate of 1 litre per minute. Magnesium blocks were placed beside the samples to scavenge oxygen in the gas flow.

Specimens for metallography were vacuum impregnated in epoxy and polished using standard mechanical techniques. The optical micrographs were taken with an Olympus AX70 optical microscope with a Diagnostic Instruments SPOT digital camera.

Figure 1 shows green and sintered hybrid parts made from a combination of AA6061 + 2% Sn and AA6061 + 2% Sn + 10%AlN. Figure 1(a) shows the top layer (AA6061 + 2% Sn) in both green and sintered form, whilst figure 1 (b) shows the bottom layer (AA6061 + 2% Sn + 10%AlN) in both green and sintered form. The parts were sintered at 630°C for 2 hours in nitrogen. Optical microstructures are shown in figure 2. As can be seen from figure 1 and figure 2, even though two different mixtures were used, there is no lamination or warpage. As the two mixtures that were used have different optimal sintering conditions and densification kinetics, a different powder loading was used for each half to match the shrinkage from the green part to the sintered part. To do this, the green and sintered dimensions of the individual materials were measured to determine the shrinkage factor. Then, two feedstock mixtures with a similar shrinkage factor were chosen to prepare the hybrid material. A lower powder loading of 61 volume percent was used for the AA6061 + 2% Sn + 10%AlN containing mixture as the AlN particles will retard densification, while a powder loading of 63 volume percent was used for the mixture containing AA6061 + 2% Sn. The two materials are well bonded together.

The present invention allows the formation of articles having functionally graded surfaces. For example, aluminium has a relatively low wear resistance. The present invention allows the possibility of forming a wear resistant surface on an aluminium article by co-injection moulding of aluminium and a ceramic reinforced aluminium composite.

Those skilled in the art will appreciate that the present invention may be susceptible to variations and modifications other than those specifically described. It will be understood that the present invention encompasses all such variations and modifications that fall within its spirit and scope.

CLAIMS.

1. A method of forming an article by metal injection moulding comprising the steps of:

- forming a first mixture containing an aluminium powder or an aluminium alloy powder, a binder, optionally a sintering aid and optionally ceramic particles;

- forming a second mixture containing an aluminium powder or an aluminium alloy powder, a binder, optionally a sintering aid and optionally ceramic particles;

- the first mixture being of different composition to the second mixture;

- injection moulding the first mixture and the second mixture to form a green body;

- removing the binder from the green body; and

- sintering the green body to form the article

-wherein a powder loading of the first mixture and a powder loading of the second mixture are controlled so that the first mixture and the second mixture exhibit similar or identical shrinkage during sintering.

2. A method as claimed in claim 1 wherein the sintering step is conducted in the presence of an oxygen getter.

3. A method as claimed in claim 2 wherein the oxygen getter comprises Mg.

4. A method as claimed in claim 3 wherein the Mg is present in the form of a Magnesium-containing alloy powder or Mg blocks.

5. A method as claimed in any one of the preceding claims wherein the first mixture or the second mixture or both the first mixture and the second mixture include a sintering aid.

6. A method as claimed in claim 5 wherein the sintering aid comprises a low melting point metal selected from the group consisting of Sn, Pb, or In.

7. A method as claimed in claim 6 wherein the sintering aid comprises Sn.

8. A method as claimed in any one of the preceding claims wherein the sintering step is conducted in an atmosphere containing nitrogen.

9. A method as claimed in claim 8 wherein the atmosphere is essentially nitrogen.

10. A method as claimed in any one of the preceding claims wherein the sintering step is conducted in an atmosphere having a water vapour partial pressure of less than 0.001kPa.

11. A method as claimed in claim 10 wherein the atmosphere has a dew point of less than -60°C.

12. A method as claimed in any one of the preceding claims wherein the first mixture comprises an aluminium or aluminium alloy powder and the second mixture comprise a different aluminium alloy powder, or the first mixture comprises two or more aluminium alloy powders and the second mixture comprises the same two or more aluminium alloy powders but with a different proportion of those powders, or the first mixture comprises a different sintering agent to that used in the second mixture, or the first mixture comprises no ceramic particles and the second mixture comprises ceramic particles (and vice versa), or the first mixture comprises ceramic particles and the second mixture comprise different ceramic particles, or the first mixture comprises or more ceramic particles and the second mixture comprises differing proportions of the same one or more ceramic particles.

13. A method as claimed in any one of the preceding claims wherein the first mixture and the second mixture are sequentially injection moulded.

14. A method as claimed in any one of claims 1 to 13 wherein the first mixture and the second mixture are simultaneously injection moulded through different gates of the injection moulding equipment.

15. A method as claimed in any one of the preceding claims wherein the two mixtures are injection moulded using multi-shot moulding techniques.

16. A method as claimed in any one of the preceding claims further including injection moulding more than two mixtures to form the article.

17. A method of forming an article by metal injection moulding comprising

forming a first mixture containing an aluminium powder or aluminium alloy powder, binder and optionally a sintering agent and optionally ceramic particles, moulding the first mixture, removing the binder and sintering to thereby determine a shrinkage factor for the first mixture,

forming a second mixture containing an aluminium powder or aluminium alloy powder, binder and optionally a sintering agent and optionally ceramic particles, moulding the second mixture, removing the binder and sintering to thereby determine a shrinkage factor for the second mixture,

forming a third mixture having the same powder components as the first mixture mixed with a binder, forming a fourth mixture having the same powder components as the second mixture, controlling the powder loading in the third mixture and the fourth mixture so that the third mixture and the fourth mixture exhibit similar or identical shrinkage characteristics during sintering,

- the third mixture being of different composition to the fourth mixture;

- injection moulding the third mixture and the fourth mixture to form a green body;

- removing the binder from the green body; and

- sintering the green body to form the article.

18. A method of forming an article by metal injection moulding comprising

forming a first mixture containing an aluminium powder or aluminium alloy powder, binder and optionally a sintering agent and optionally ceramic particles, moulding the first mixture, removing the binder and sintering to thereby determine a shrinkage factor for the first mixture,

forming a second mixture containing an aluminium powder or aluminium alloy powder, binder and optionally a sintering agent and optionally ceramic particles, moulding the second mixture, removing the binder and sintering to thereby determine a shrinkage factor for the second mixture,

determining a powder loading of the first mixture and a powder loading of the second mixture that will result in the first mixture and the second mixture exhibiting similar or identical shrinkage properties during sintering,

forming a third mixture having the same powder components as the first mixture mixed with a binder, the third mixture having the determined powder loading

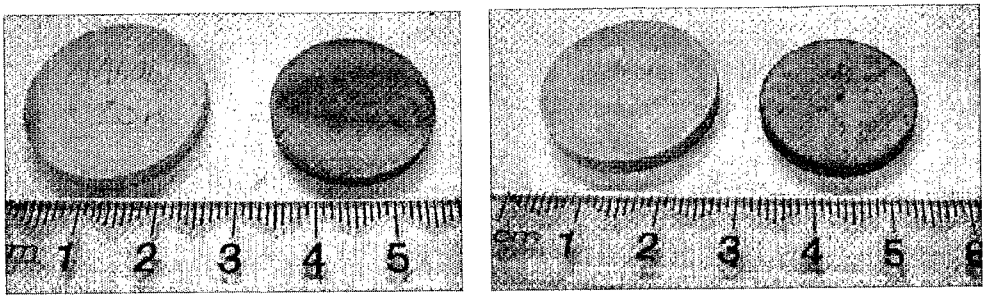
forming a fourth mixture having the same powder components as the second mixture, the fourth mixture having the determined powder loading, whereby the third mixture and the fourth mixture exhibit similar or identical shrinkage characteristics during sintering,

- the third mixture being of different composition to the fourth mixture;

- injection moulding the third mixture and the fourth mixture to form a green body;

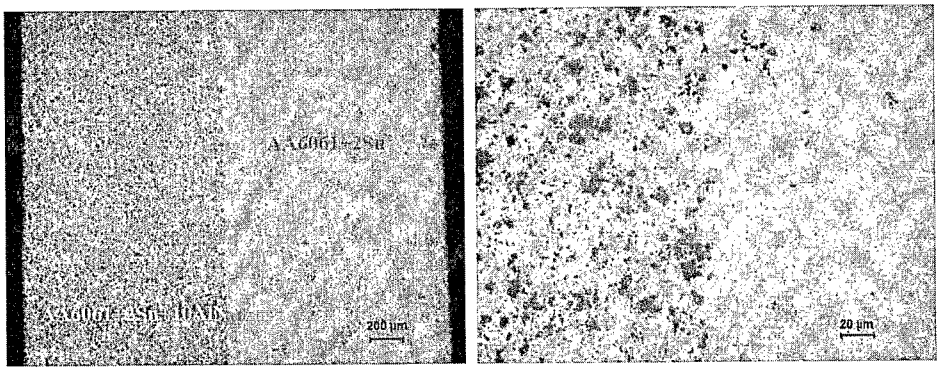
- removing the binder from the green body; and

- sintering the green body to form the article.



(a) (b)

FIGURE 1



(a) (b)

FIGURE 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/001321

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

B22F 3/16 (2006.01) ***B22F 7/00*** (2006.01)
B22F 3/10 (2006.01) ***B28B 1/24*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC; WPI: (B22F 3/- OR B22F 7/- OR B28B 1/24) and ((inject+) and m[o,ou]ld+) and metal+) and (alumin+ or Al) and (sinter+ or heat+ or calcin+)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	WO 2008/017111 A1 (THE UNIVERSITY OF QUEENSLAND) 14 February 2008 See whole document	1-18
X	WO 2005/066380 A1 (EX ONE CORPORATION) 21 July 2005 See page 13 line 20, claims example 4, page 12 lines 9 and 18	1-18
X	US 5445788 A (TURENNE, SYLVAIN ET AL) 29 August 1995 See column 2 lines 38-42, Table 1, examples, column 4 lines 48-53	1-18
X	US 6171360 B1 (SUZUKI, KATSUNORI ET AL) 9 January 2001 See column 4 lines 22-35, column 6 lines 20-30, column 7 lines 34-38, examples	1-18

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 October 2008	17 OCT 2008
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **GREGORY DIVEN** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2992

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/001321

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/0170137 A1 (YEO, CHEE-TIAN ET AL) 11 September 2003 See paragraphs 0012, 0013, 0016, 0015, 0025, 0023, claim 13	1-18
X	US 5432224 A (RYUHGOH, JIROH ET AL) 11 July 1995 See column 8, lines 46-62, column 11, lines 60-68, column 10, lines 58-60, column 9 lines 16-19	1-18
X	Patent Abstracts of Japan; JP 02-019401 A (SANYO CHEM IND LTD) 23 January 1990 See abstract	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2008/001321

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	2008017111	NONE					
WO	2005066380	AU	2003304688	CA	2556825	EP	1694875
		US	2007110608				
US	5445788	NONE					
US	6171360	JP	11350005				
US	2003170137	EP	1344593	JP	2003268407	SG	124245
		US	6761852				
US	5432224	EP	0329475	JP	1212271	JP	1278558
		JP	2019401	JP	2145704		

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX