Title	State-of-the-Art Review on Selective Laser Melting of Non-Ferrous Metals
Author(s)	Yap, Chor Yen; Chua, Chee Kai; Dong, Z. L.; Liu, Zhong Hong; Zhang, Dan Qing
Citation	Yap, C. Y., Chua, C. K., Dong, Z. L., Liu, Z. H., & Zhang, D. Q. (2014). State-of-the-Art Review on Selective Laser Melting of Non-Ferrous Metals. Proceedings of the 1st International Conference on Progress in Additive Manufacturing (Pro-AM 2014), 193-201.
Date	2014
URL	http://hdl.handle.net/10220/41677
Rights	© 2014 by Research Publishing Services.

STATE-OF-THE-ART REVIEW ON SELECTIVE LASER MELTING OF NON-FERROUS METALS

C.Y. YAP
NTU Additive Manufacturing Centre, Energy Research Institute @ NTU
Interdisciplinary Graduate School
Nanyang Technological University, 50 Nanyang Avenue
Singapore 639798

C.K. CHUA
NTU Additive Manufacturing Centre, School of Mechanical and Aerospace Engineering
Nanyang Technological University, 50 Nanyang Avenue
Singapore 639798

Z.L. DONG
School of Material Science and Engineering
Nanyang Technological University, 50 Nanyang Avenue
Singapore 639798

Z.H. LIU
NTU Additive Manufacturing Centre, School of Mechanical and Aerospace Engineering
Nanyang Technological University, 50 Nanyang Avenue
Singapore 639798

D.Q. ZHANG
NTU Additive Manufacturing Centre, School of Mechanical and Aerospace Engineering
Nanyang Technological University, 50 Nanyang Avenue
Singapore 639798

ABSTRACT: In the field of Additive Manufacturing (AM), Rapid Prototyping (RP) or 3D Printing, there is an increasing research interest in Selective Laser Melting (SLM) in the past few years. This review focuses on the SLM of non-ferrous metals such as titanium, nickel, aluminium and other metals. Besides discussing the materials that have been tested for SLM, it also tabulates the various mechanical properties reported in research publications for readers to have a good overview of the current research on this technology.

INTRODUCTION

Selective Laser Melting (SLM) is a powder-based Additive Manufacturing (AM), also known as Rapid Prototyping (RP) or 3D Printing, method that uses high-power laser as an energy source to melt and fuse selective regions of powder according to computer aided design (CAD) data. This technique is designed to process metallic powders directly without the need for binders. SLM's competitive advantage over other AM or RP methods lies in its ability to make near full-density, functional parts with metallic materials. Moreover, it is able to create very find structures with laser spots as small as 20 µm in diameter. Hence, there is much research and industrial interest in this technology.Other AM technologies such as LaserCusing and Direct Metal Laser Sintering (DMLS) are very similar to SLM (Chua et al., 2010).

Proc. of the Intl. Conf. on Progress in Additive Manufacturing
Edited by Chua Chee Kai, Yeong Wai Yee, Tan Ming Jen and Liu Erjia

ISBN: 978-981-09-0446-3 :: doi:10.3850/978-981-09-0446-3_035

SLM of steel and other iron-based metals has been extensively studied by various research groups around the world. According to Web of Science, there were hundreds of research publications regarding the SLM of ferrous metals from 2003 to 2013. Variants of steel studied includes 316L stainless steel (Zhang et al., 2013a), 904L stainless steel (Yadroitsev et al., 2012), 15-5 precipitation hardening steel (Rafi et al., 2013) and M2 high speed tool steel (Liu et al., 2013).

On the other hand, research on SLM of non-ferrous metalsis increasing rapidly in the past three to five years. Such a trend is clearly illustrated by **Figure 1**. The research on non-ferrous metals such as copper, aluminium and tungsten is still at its early stages. There are much room for further improvement and many more areas that require studies.

SLM is an emerging metal-processing AM technique with increasing industrial and commercial interests as indicated by Wohlers Report 2013 and the increasing number of research publications indexed by Web of Science and ScienceDirect in the past 10 years. This review focuses on research publications from 2003 on SLM and similar techniques such as laserCusing and DMLS. It is organized according to the different metals used. Properties of non-ferrous metals process by SLM will also be compiled and tabulated for the ease of comparison.

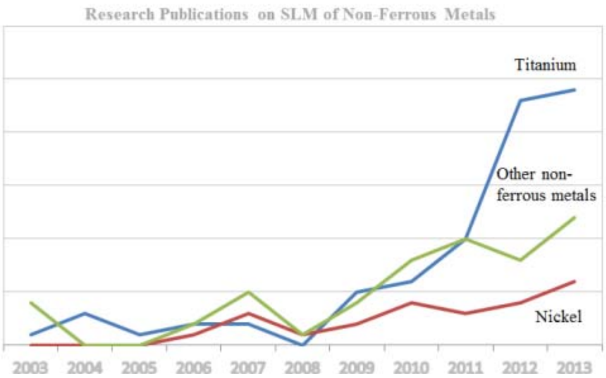

Figure 1 Research publications on SLM of non-ferrous metals, from 2003 to 2013, indexed by Web of Science and ScienceDirect.

NON-FERROUS METALS IN SLM

Titanium and Titanium-Based Alloys

In the last decade, the number of publications of SLM of titanium is second to that of SLM of steel and other iron-based metals. But more importantly, it has a higher rate of. Almost all of these papers are based on commercially pure titanium (cpTi) or Ti-6Al-4V alloy (Ti64). Initial research efforts in cpTi were led by Shiomi'sresearch group (Abe et al., 2003) and papers on SLM of Ti64 appeared in 2007 (Vandenbroucke and Kruth, 2007). More recently, SLM of other titanium based alloys such as Ti-6Al-7Nb (Chlebus et al., 2011), Ti-24Nb-4Zr-8Sn (Zhang et al., 2011), Ti-13Zr-Nb (Zielinski et al., 2012) and Ti-13Nb-13Zr (Speirs et al., 2013) have also been investigated. The goals were to replace the controversial Vanadium with Niobium and to find a low modulus biocompatible implant material for biomedical applications.

In the area of process improvement, Van Bael et al.(2011) demonstrated a micro-CT-based protocol that can enhance the robustness and controllability of the SLM process and Ferrar et al. (2012) studied the effects of the gas flow during the fabrication and concluded that gas flow uniformity is an important parameter in production consistency. Recently, Zhang et al.(2013b) investigated the SLM of cpTi in vacuum, instead of inert atmosphere, and found the surface roughness of the SLM product improved significantly.Hussein et al.(2013) looked into the design of support structure so as to reduce the required volume fraction for overhanging structures during the SLM process. This could significantly reduce the amount of materials needed for support structure and lower the overall cost of the SLM process as more powders can be reused. Generally, research on SLM of titanium alloys has been successful with all alloys reaching relative densities of 99 % and above. The strength and hardness of each alloy have also been studied.

Nickel-Based Alloys

Nickel-based alloys are the second most studied group of non-ferrous metals for the SLM process. Most of the publications on nickel-based alloys are on Inconel, a family of nickel-based super-alloys typically used in high-temperature applications. Nickel-based alloys studied for the SLM process include Inconel 625(Bertrand and Smurov, 2007; Mumtaz and Hopkinson, 2009), Inconel 718(Amato et al., 2012; Kelbassa et al., 2008), Chromel(Osakada and Shiomi, 2006), Hastelloy X(Tomus et al., 2013; Wang, 2011), Nimonic 263 (Vilaro et al., 2012), IN738LC (Rickenbacher, 2013) and shape memory alloy (SMA) Nitinol(Clare et al., 2007; Meier et al., 2010). Pure nickel has also been examined by (Li et al., 2011). Of all the alloys mentioned, only Inconel 625 has been extensively studied for the SLM process by Smurov's group (Bertrand and Smurov, 2007; Yadroitsev et al., 2010; Yadroitsev et al., 2009; Yadroitsev and Smurov, 2010; Yadroitsev et al., 2007) and Mumtaz and Hopkinson(2009, 2010).

Other Metals

Besides titanium and nickel, other non-ferrous metals such as aluminium, copper, cobalt-chrome, magnesium, tungsten and gold have also been studied for the SLM process. However, as publications on each of these metals are significantly fewer they are grouped together in this section.

Most of the papers on SLM of aluminium alloys are based on AlSi10Mg(Kempen et al., 2011; Manfredi et al., 2013; Vilaro et al., 2008). There are few reports on SLM of pure aluminium(Jerrard et al., 2010; Savalani et al., 2011), Al6061(Loh et al., 2013; Wong et al., 2007), AlSi12 (Ameli et al., 2013; Louvis et al., 2011) and AlMg(Olakanmi et al., 2009; Savalani et al., 2011). Thus far, only relative densities of SLM AlSi10Mg and Al6061 have been reported in literatures.
In the SLM of copper, pure copper (Pogson et al., 2003) and standard copper alloys such as C18400 (Zhang et al., 2013c) have been studied. Copper-based metals of various compositions have also been examined and reported. These includecopper with Cu10Sn and Cu84.4P powders (Gu and Shen, 2006), Cu10Sn with Cu8.4P and Ni powders (Gu et al., 2009) and CuNi alloys (Sustarsic et al., 2009; Yadroitsev et al., 2010). Laser AM of cobalt-chrome alloy has been studied by various groups, mainly for dental applications(Ayyildiz et al., 2013; Faure et al., 2012).

First papers on SLM of magnesium started in 2010 by Man's group(Ng et al., 2010; Savalani et al., 2010) and Zhang et al.(2012)reported the SLM of Mg-Al alloy. Pure tungsten has also been studied for the SLM process by Bertrand and Smurov(2007) and Deprez et al.(2013). A number of publications based on SLM of tungsten-based alloys were also made by D.Q. Zhang et alsuch as W-Ni-Fe (Zhang et al., 2010) and W-Ni-Cu (Zhang et al., 2013d).

For precious metals, Khan and Dickens(2010)and Jhabvala et al.(2010)have studied the SLM of gold. Gebhardt(2011)examined the SLM of silver both numerically and experimentally and Fateri et al. (2012) studied the buckling deformation of SLM parts using silver. More recently, Pauly et al.(2013) presented SLM as a feasible processing technique for the production of bulk metallic glass which has many desirable characteristics such as near-theoretical strength, low Young's modulus and high elasticity.

PROPERTIES OF SLM NON-FERROUS METALS

Relative Density

Relative density is often used as an indicator of the quality of the SLM parts. It is the ratio of the density attained with SLM and the theoretical density of the bulk material. SLM of non-ferrous metals has been rather successful in terms of the relative density attained by various researchers. Notably, SLM of titanium, Ti-6Al-7Nb alloy, Inconel 718 and cobalt-chromium alloy have produced relative densities higher than 99.9%. However, relative densities achieved by SLM of copper, magnesium, tungsten and gold remain poor, providing ample room for improvements.Table 1 summarizes the reported maximum density of the various SLM non-ferrous metals.

Table 1 Highest reported relative density of SLM non-ferrous metals.

Material	Highest relative density	Reference
cpTi	99.50 %	(Gu et al., 2012)
cpTi	99.90 % (vacuum)	(Zhang et al., 2013b)
Ti-6Al-4V	99.80 %	(Vandenbroucke and Kruth, 2007)
Ti-6Al-7Nb	99.95 %	(Chlebus et al., 2011)
Ti-24Nb-4Zr-8Sn	99.50 %	(Zhang et al., 2011)
Inconel 625	95.00 %	(Yadroitsev et al., 2007)
Inconel 718	99.98 %	(Sanz and Navas, 2013)
Chomel	88.00 %	(Osakada and Shiomi, 2006)
Hastelloy X	99.75 %	(Wang, 2011)
Nimonic 263	99.70 %	(Vilaro et al., 2012)
Al6061	96.50 %	(Jerrard et al., 2010)
AlSi10Mg	99.50 %	(Buchbinder et al., 2011)
Cu	82.20 %	(Tang et al., 2003)
Cu + Cu10Sn + Cu8.4P	84.00 %	(Gu and Shen, 2007)
Cu based powder	95.00 %	(Wu et al., 2007)
Cu10Sn + Cu8.4P + Ni	95.20 %	(Gu et al., 2009)
CuNi15	92.00 %	(Sustarsic et al., 2009)
C18400	96.74 %	(Zhang et al., 2013c)
Mg + 9wt. % Al	82.00 %	(Zhang et al., 2012)
Tungsten	89.92 %	(Deprez et al., 2013)
24 Carat Gold	89.60 %	(Khan and Dickens, 2010)
CoCr	99.94 %	(Sanz and Navas, 2013)

Strength

The strength of SLM metal parts is of paramount importance for their respective applications. It is often reported that SLM components are stronger compared to their cast counterparts. It is commonly agreed that the rapid cooling in the SLM process causes the growth of fine dendritic features, resulting in an increase in strength and a decrease in ductility. The highest reported UTS for non-ferrous metals is that of Ti-6Al-7Nb, at 1515 MPa. The most ductile SLM non-ferrous metal is the Hastelloy X, a nickel-based alloy, with an elongation of 35% at failure.

By comparing the strength of these SLM metals with their respective relative densities, it is evident that high porosity results in compromised structure, leading to a much lower strength and ductility, as reported by Tang et al.(2003) who obtained low strength of 29 MPa for copper parts with 82.2 % relative density. Table 2 shows the strengths of various SLM metals.

Table 2 Highest reported tensile strengths of SLM non-ferrous metals.

Material	UTS (MPa)	YS (MPa)	Elongation (%)	Reference
cpTi	654	522	17.0	(Barbas et al., 2012)
Ti-6Al-4V	1250	1125	6.00	(Vandenbroucke and Kruth, 2007)
Ti-6Al-7Nb	1515	1440	1.40	(Chlebus et al., 2011)
Ti-24Nb-4Zr-8Sn	665	563	13.8	(Zhang et al., 2011)
Inconel 625	1030	800	10.0	(Yadroitsev et al., 2007)
Inconel 718	1148	907	25.9	(Wang et al., 2012)
IN738LC	1184	933	8.40	(Rickenbacher, 2013)
Hastelloy X	930.5	814	35.0	(Wang, 2011)
Nimonic 263	1085	818	24.0	(Vilaro et al., 2012)
AlSi10Mg	400	220	11.0	(Buchbinder et al., 2011)
Cu	29	-	-	(Tang et al., 2003)
CuNi15	400	-	-	(Sustarsic et al., 2009)

Surface Roughness

One of the limitations of the SLM process is the surface roughness and it is common to achieve roughness of about 5 to 20 µm. Post processing such as sand-blasting or shot-peening are often needed to achieve a smooth and shiny surface for applications that require low roughness. **Table 3** shows the lowest report figures for surface roughness, R_a, of non-ferrous metals process by SLM.

Table 3 Lowest report R_a of SLM non-ferrous metals.

Material	Surface Roughness, R_a (µm)	Reference
Ti64	3.96	(Cooper et al., 2012)
cpTi	5.00	(Zhang et al., 2013b)
Inconel 625	4.00 (top surface)	(Mumtaz and Hopkinson, 2009)
Hastelloy X	6.00	(Wang et al., 2011)
AlSi10Mg	14.35	(Calignano et al., 2013)
Mg	20.0	(Savalani et al., 2010)
Cu	13.0	(Tang et al., 2003)
CuNi15	9.00	(Sustarsic et al., 2009)

Micro-hardness

Table 4 shows the micro-hardness of SLM metal parts in units of HV for the ease of comparison. By comparing the results for Inconel 718, micro-hardness of SLM components can be increased by aging treatment. Jerrard et al.(2010)also found that hardness of the SLM Al6061 can be significantly improved when copper powder is added to the Al6061 powder at 30 wt.%. This phenomenon is attributed to the formation of $AlCu_2$reinforcement particulates *in-situ*during the SLM process. Similar results can also be obtained by adding ceramic powders to metallic powders in SLM to form ceramic particulate reinforced metal matrix composites (MMCs) as reported by Gu and Zhang(2013).

Table 4 Highest reported micro-hardness of SLM non-ferrous metals.

Material	Micro-hardness (HV)	Reference
cpTi	308	(Zhang et al., 2013b)
Ti-6Al-4V	613	(Bertol et al., 2010)
Ti-6Al-7Nb	464	(Chlebus et al., 2011)
Ti-24Nb-4Zr-8Sn	225	(Zhang et al., 2011)
Inconel 718	365	(Wang et al., 2012)
Inconel 718	470 (after aging treatment)	(Sanz and Navas, 2013)
Chomel	740	(Osakada and Shiomi, 2006)
Nimonic 263	370	(Vilaro et al., 2012)
Al6061	50	(Jerrard et al., 2010)
Al6061 + 30wt. % Cu	200	(Jerrard et al., 2010)
AlSi10Mg	149	(Buchbinder et al., 2011)
CuNi15	116 (from 110 HB)	(Sustarsic et al., 2009)
Mg + 9wt. % Al	75	(Zhang et al., 2012)
24 Carat Gold	29.3	(Khan and Dickens, 2012)
CoCr	482	(Ayyildiz et al., 2013)

CONCLUSION

Research in the SLM of non-ferrous metals has increased sharplyin recent years. This is mainly due to SLM’s unique advantage increating functional and near full-density parts. Moreover, there are plenty of room for exploration and improvement as only the more common non-ferrous metals have been examined. Process optimization for SLM of various metals remains unresolved. Moreover, mechanical properties of some these SLM materials also require further studies. For instance, dynamic properties such as fatigue strength and fracture toughness of SLM metals are seldom reported but these properties are important for industrial applications. Hence, this field is likely to generate increasing research interests in the foreseeable future

ACKNOWLEDGMENTS

The author would like to acknowledge Interdisciplinary Graduate School of Nanyang Technological University for the graduate scholarship.

REFERENCES

Abe, F., Santos, E.C., Kitamura, Y., Osakada, K., Shiomi, M., 2003. Influence of forming conditions on the titanium model in rapid prototyping with the selective laser melting process. Proc. Inst. Mech. Eng. Part C-J. Eng. Mech. Eng. Sci. 217, 119-126.

Amato, K.N., Gaytan, S.M., Murr, L.E., Martinez, E., Shindo, P.W., Hernandez, J., Collins, S., Medina, F., 2012. Microstructures and mechanical behavior of Inconel 718 fabricated by selective laser melting. Acta Materialia 60, 2229-2239.

Ameli, M., Agnew, B., Leung, P.S., Ng, B., Sutcliffe, C.J., Singh, J., McGlen, R., 2013. A novel method for manufacturing sintered aluminium heat pipes (SAHP). Applied Thermal Engineering 52, 498-504.

Ayyildiz, S., Soylu, E.H., Ide, S., Kilic, S., Sipahi, C., Piskin, B., Gokce, H.S., 2013. Annealing of Co-Cr dental alloy: effects on nanostructure and Rockwell hardness. J. Adv. Prosthodont. 5, 471-478.

Barbas, A., Bonnet, A.S., Lipinski, P., Pesci, R., Dubois, G., 2012. Development and mechanical characterization of porous titanium bone substitutes. Journal of the Mechanical Behavior of Biomedical Materials 9, 34-44.

Bertol, L.S., Kindlein, W., da Silva, F.P., Aumund-Kopp, C., 2010. Medical design: Direct metal laser sintering of Ti-6Al-4V. Materials & Design 31, 3982-3988.

Bertrand, P., Smurov, I., 2007. Laser assisted direct manufacturing - art. no. 67320H, In: Panchenko, V., Louchev, O., Malyshev, S. (Eds.), International Conference on Lasers, Applications, and Technologies 2007: Laser-Assisted Micro- and Nanotechnologies. Spie-Int Soc Optical Engineering, Bellingham, pp. H7320-H7320.

Buchbinder, D., Schleifenbaum, H., Heidrich, S., Meiners, W., Bultmann, J., 2011. High Power Selective Laser Melting (HP SLM) of Aluminum Parts, In: Schmidt, M., Zaeh, M., Graf, T., Ostendorf, A. (Eds.), Lasers in Manufacturing 2011: Proceedings of the Sixth International Wlt Conference on Lasers in Manufacturing, Vol 12, Pt A, pp. 271-278.
Calignano, F., Manfredi, D., Ambrosio, E.P., Iuliano, L., Fino, P., 2013. Influence of process parameters on surface roughness of aluminum parts produced by DMLS. International Journal of Advanced Manufacturing Technology 67, 2743-2751.
Chlebus, E., Kuznicka, B., Kurzynowski, T., Dybala, B., 2011. Microstructure and mechanical behaviour of Ti-6Al-7Nb alloy produced by selective laser melting. Materials Characterization 62, 488-495.
Chua, C.K., Leong, K.F., Lim, C.S., 2010. Rapid Prototyping: Principles and Applications, 3rd ed. World Scientific Publishing Co. Pte. Ltd., Singapore.
Clare, A.T., Chalker, P.R., Davies, S., Sutcliffe, C.J., Tsopanos, S., 2007. Selective laser melting of high aspect ratio 3D nickel–titanium structures two way trained for MEMS applications. International Journal of Mechanics and Materials in Design 4, 181-187.
Cooper, D.E., Stanford, M., Kibble, K.A., Gibbons, G.J., 2012. Additive Manufacturing for product improvement at Red Bull Technology. Materials & Design 41, 226-230.
Deprez, K., Vandenberghe, S., Van Audenhaege, K., Van Vaerenbergh, J., Van Holen, R., 2013. Rapid additive manufacturing of MR compatible multipinhole collimators with selective laser melting of tungsten powder. Med Phys 40, 012501.
Fateri, M., Hötter, J.-S., Gebhardt, A., 2012. Experimental and Theoretical Investigation of Buckling Deformation of Fabricated Objects by Selective Laser Melting. Physics Procedia 39, 464-470.
Faure, S.P., Mercier, L., Didier, P., Roux, R., Coulon, J.F., Garel, S., Trenit, J., Buard, H., Razan, F., Asme, 2012. LASER SINTERING PROCESS ANALYSIS: APPLICATION TO CHROMIUM-COBALT ALLOYS FOR DENTAL PROSTHESIS PRODUCTION. Amer Soc Mechanical Engineers, New York.
Ferrar, B., Mullen, L., Jones, E., Stamp, R., Sutcliffe, C.J., 2012. Gas flow effects on selective laser melting (SLM) manufacturing performance. Journal of Materials Processing Technology 212, 355-364.
Gebhardt, A., 2011. Numerical and Experimental Investigation of Selective Laser Melting of Silver, Fraunhofer Direct Digital Manufacturing Conference.
Gu, D., Shen, Y., 2007. Effects of dispersion technique and component ratio on densification and microstructure of multi-component Cu-based metal powder in direct laser sintering. Journal of Materials Processing Technology 182, 564-573.
Gu, D., Zhang, G., 2013. Selective laser melting of novel nanocomposites parts with enhanced tribological performance. Virtual and Physical Prototyping 8, 11-18.
Gu, D.D., Hagedorn, Y.C., Meiners, W., Meng, G.B., Batista, R.J.S., Wissenbach, K., Poprawe, R., 2012. Densification behavior, microstructure evolution, and wear performance of selective laser melting processed commercially pure titanium. Acta Materialia 60, 3849-3860.
Gu, D.D., Shen, Y.F., 2006. Development and characterisation of direct laser sintering multicomponent Cu based metal powder. Powder Metallurgy 49, 258-264.
Gu, D.D., Shen, Y.F., Lu, Z.J., 2009. Microstructural characteristics and formation mechanism of direct laser-sintered Cu-based alloys reinforced with Ni particles. Materials & Design 30, 2099-2107.
Hussein, A., Hao, L., Yan, C.Z., Everson, R., Young, P., 2013. Advanced lattice support structures for metal additive manufacturing. Journal of Materials Processing Technology 213, 1019-1026.
Jerrard, P., Hao, L., Dadbakhsh, S., Evans, K., 2010. Consolidation behaviour and microstructure characteristics of pure aluminium and alloy powders following Selective Laser Melting processing, Proceedings of the 36th International MATADOR Conference. Springer, pp. 487-490.
Jhabvala, J., Boillat, E., Antignac, T., Glardon, R., 2010. On the effect of scanning strategies in the selective laser melting process. Virtual and Physical Prototyping 5, 99-109.
Kelbassa, I., Albus, P., Dietrich, J., Wilkes, J., 2008. Manufacture and repair of aero engine components using laser technology, Proceedings of the 3rd Pacific International Conference on Application of Lasers and Optics. Wiley.
Kempen, K., Thijs, L., Yasa, E., Badrossamay, M., Verheecke, W., Kruth, J., 2011. PROCESS OPTIMIZATION AND MICROSTRUCTURAL ANALYSIS FOR SELECTIVE LASER MELTING OF AlSi10Mg.
Khan, M., Dickens, P., 2010. Selective Laser Melting (SLM) of pure gold. Gold Bulletin 43, 8.
Khan, M., Dickens, P., 2012. Selective laser melting (SLM) of gold (Au). Rapid Prototyping Journal 18, 81-94.
Li, R., Liu, J., Shi, Y., Wang, L., Jiang, W., 2011. Balling behavior of stainless steel and nickel powder during selective laser melting process. The International Journal of Advanced Manufacturing Technology 59, 1025-1035.
Liu, Z.H., Zhang, D.Q., Chua, C.K., Leong, K.F., 2013. Crystal structure analysis of M2 high speed steel parts produced by selective laser melting. Materials Characterization 84, 72-80.
Loh, L., Liu, Z., Zhang, D., Yeong, W., Chua, C., 2013. Effect of laser beam profile on melt track in Selective Laser Melting, High Value Manufacturing: Advanced Research in Virtual and Rapid Prototyping: Proceedings of the 6th International Conference on Advanced Research in Virtual and Rapid Prototyping, Leiria, Portugal, 1-5 October, 2013. CRC Press, p. 83.
Louvis, E., Fox, P., Sutcliffe, C.J., 2011. Selective laser melting of aluminium components. Journal of Materials Processing Technology 211, 275-284.

Manfredi, D., Calignano, F., Ambrosio, E.P., Krishnan, M., Canali, R., Biamino, S., Pavese, M., Atzeni, E., Iuliano, L., Fino, P., Badini, C., 2013. Direct Metal Laser Sintering: an additive manufacturing technology ready to produce lightweight structural parts for robotic applications. Metall. Ital., 15-24.
Meier, H., Haberland, C., Frenzel, J., Zarnetta, R., 2010. Selective Laser Melting of NiTi shape memory components. Crc Press-Taylor & Francis Group, Boca Raton.
Mumtaz, K., Hopkinson, N., 2009. Top surface and side roughness of Inconel 625 parts processed using selective laser melting. Rapid Prototyping Journal 15, 96-103.
Mumtaz, K., Hopkinson, N., 2010. Selective laser melting of Inconel 625 using pulse shaping. Rapid Prototyping Journal 16, 248-257.
Ng, C.C., Savalani, M.M., Man, H.C., Gibson, I., 2010. Layer manufacturing of magnesium and its alloy structures for future applications. Virtual and Physical Prototyping 5, 13-19.
Olakanmi, E.O., Cochrane, R.F., Dalgarno, K.W., Tms, 2009. Spheroidisation and oxide disruption phenomena in direct Selective Laser Melting (SLM) of pre-alloyed Al-Mg and Al-Si powders. Minerals, Metals & Materials Soc, Warrendale.
Osakada, K., Shiomi, M., 2006. Flexible manufacturing of metallic products by selective laser melting of powder. International Journal of Machine Tools and Manufacture 46, 1188-1193.
Pauly, S., Löber, L., Petters, R., Stoica, M., Scudino, S., Kühn, U., Eckert, J., 2013. Processing metallic glasses by selective laser melting. Materials Today 16, 37-41.
Pogson, S., Fox, P., Sutcliffe, C., O'Neill, W., 2003. The production of copper parts using DMLR. Rapid Prototyping Journal 9, 334-343.
Rafi, H.K., Starr, T.L., Stucker, B.E., 2013. A comparison of the tensile, fatigue, and fracture behavior of Ti-6Al-4V and 15-5 PH stainless steel parts made by selective laser melting. International Journal of Advanced Manufacturing Technology 69, 1299-1309.
Rickenbacher, L., 2013. High temperature material properties of IN738LC processed by selective laser melting (SLM) technology. Rapid Prototyping Journal 19, 282-290.
Sanz, C., Navas, V.G., 2013. Structural integrity of direct metal laser sintered parts subjected to thermal and finishing treatments. Journal of Materials Processing Technology 213, 2126-2136.
Savalani, M.M., Chung, C.C., Poon, C., Yeung, W., 2011. Selective Laser Melting of Aluminum and its alloys, NZ Rapid Product Development Conference, Auckland, New Zealand.
Savalani, M.M., Ng, C.C., Man, H.C., 2010. Selective laser melting of Magnesium for Future Applications in Medicine, International Conference on Manufacturing Automation, Hong Kong.
Speirs, M., Van Humbeeck, J., Schrooten, J., Luyten, J., Kruth, J.P., 2013. The effect of pore geometry on the mechanical properties of selective laser melted Ti-13Nb-13Zr scaffolds, In: Mitsuishi, M., Bartolo, P. (Eds.), First Cirp Conference on Biomanufacturing. Elsevier Science Bv, Amsterdam, pp. 79-82.
Sustarsic, B., Dolinsek, S., Jenko, M., Leskovsek, V., 2009. Microstructure and Mechanical Characteristics of DMLS Tool-Inserts. Materials and Manufacturing Processes 24, 837-841.
Tang, Y., Loh, H., Wong, Y., Fuh, J., Lu, L., Wang, X., 2003. Direct laser sintering of a copper-based alloy for creating three-dimensional metal parts. Journal of Materials Processing Technology 140, 368-372.
Tomus, D., Jarvis, T., Wu, X., Mei, J., Rometsch, P., Herny, E., Rideau, J.F., Vaillant, S., 2013. Controlling the Microstructure of Hastelloy-X Components Manufactured by Selective Laser Melting. Physics Procedia 41, 816-820.
Van Bael, S., Kerckhofs, G., Moesen, M., Pyka, G., Schrooten, J., Kruth, J.P., 2011. Micro-CT-based improvement of geometrical and mechanical controllability of selective laser melted Ti6Al4V porous structures. Materials Science and Engineering a-Structural Materials Properties Microstructure and Processing 528, 7423-7431.
Vandenbroucke, B., Kruth, J.P., 2007. Selective laser melting of biocompatible metals for rapid manufacturing of medical parts. Rapid Prototyping Journal 13, 196-203.
Vilaro, T., Abed, S., Knapp, W., 2008. Direct manufacturing of technical parts using selective laser melting: example of automotive application, Proc. of 12th European Forum on Rapid Prototyping.
Vilaro, T., Colin, C., Bartout, J.D., Nazé, L., Sennour, M., 2012. Microstructural and mechanical approaches of the selective laser melting process applied to a nickel-base superalloy. Materials Science and Engineering: A 534, 446-451.
Wang, F., 2011. Mechanical property study on rapid additive layer manufacture Hastelloy® X alloy by selective laser melting technology. The International Journal of Advanced Manufacturing Technology 58, 545-551.
Wang, F., Wu, X., Clark, D., 2011. On direct laser deposited Hastelloy X: dimension, surface finish, microstructure and mechanical properties. Materials Science and Technology 27, 344-356.
Wang, Z., Guan, K., Gao, M., Li, X., Chen, X., Zeng, X., 2012. The microstructure and mechanical properties of deposited-IN718 by selective laser melting. Journal of Alloys and Compounds 513, 518-523.
Wong, M., Tsopanos, S., Sutcliffe, C., Owen, E., 2007. Selective laser melting of heat transfer devices. Rapid Prototyping Journal 13, 291-297.
Wu, W.H., Yang, Y.Q., Huang, Y.L., 2007. Direct manufacturing of Cu-based alloy parts by selective laser melting. Chinese Optics Letters 5, 37-40.
Yadroitsev, I., Gusarov, A., Yadroitsava, I., Smurov, I., 2010. Single track formation in selective laser melting of metal powders. Journal of Materials Processing Technology 210, 1624-1631.
Yadroitsev, I., Shishkovsky, I., Bertrand, P., Smurov, I., 2009. Manufacturing of fine-structured 3D porous filter elements by selective laser melting. Applied Surface Science 255, 5523-5527.

Yadroitsev, I., Smurov, I., 2010. Selective laser melting technology: From the single laser melted track stability to 3D parts of complex shape. Physics Procedia 5, 551-560.

Yadroitsev, I., Thivillon, L., Bertrand, P., Smurov, I., 2007. Strategy of manufacturing components with designed internal structure by selective laser melting of metallic powder. Applied Surface Science 254, 980-983.

Yadroitsev, I., Yadroitsava, I., Bertrand, P., Smurov, I., 2012. Factor analysis of selective laser melting process parameters and geometrical characteristics of synthesized single tracks. Rapid Prototyping Journal 18, 201-208.

Zhang, B., Liao, H., Coddet, C., 2012. Effects of processing parameters on properties of selective laser melting Mg–9%Al powder mixture. Materials & Design 34, 753-758.

Zhang, B.C., Dembinski, L., Coddet, C., 2013a. The study of the laser parameters and environment variables effect on mechanical properties of high compact parts elaborated by selective laser melting 316L powder. Materials Science and Engineering a-Structural Materials Properties Microstructure and Processing 584, 21-31.

Zhang, B.C., Liao, H.L., Coddet, C., 2013b. Selective laser melting commercially pure Ti under vacuum. Vacuum 95, 25-29.

Zhang, D., Liu, Z., Chua, C., 2013c. Investigation on forming process of copper alloys via Selective Laser Melting, High Value Manufacturing: Advanced Research in Virtual and Rapid Prototyping: Proceedings of the 6th International Conference on Advanced Research in Virtual and Rapid Prototyping, Leiria, Portugal, 1-5 October, 2013. CRC Press, p. 285.

Zhang, D.Q., Cai, Q.Z., Liu, J.H., He, J., Li, R.D., 2013d. Microstructural evolvement and formation of selective laser melting W-Ni-Cu composite powder. International Journal of Advanced Manufacturing Technology 67, 2233-2242.

Zhang, D.Q., Cai, Q.Z., Liu, J.H., Zhang, L., Li, R.D., 2010. Select laser melting of W–Ni–Fe powders: simulation and experimental study. The International Journal of Advanced Manufacturing Technology 51, 649-658.

Zhang, L.C., Klemm, D., Eckert, J., Hao, Y.L., Sercombe, T.B., 2011. Manufacture by selective laser melting and mechanical behavior of a biomedical Ti-24Nb-4Zr-8Sn alloy. Scripta Materialia 65, 21-24.

Zielinski, A., Sobieszczyk, S., Serbinski, W., Seramak, T., Ossowska, A., 2012. Materials Design for the Titanium Scaffold Based Implant, In: Labanowski, J., Zielinski, A. (Eds.), Environmental Degradation of Engineering & Materials Engineering and Technologies. Trans Tech Publications Ltd, Stafa-Zurich, pp. 225-232.