Journal of Physics:
Conference Series

PURPOSE-LED PUBLISHING™

PAPER • **OPEN ACCESS**

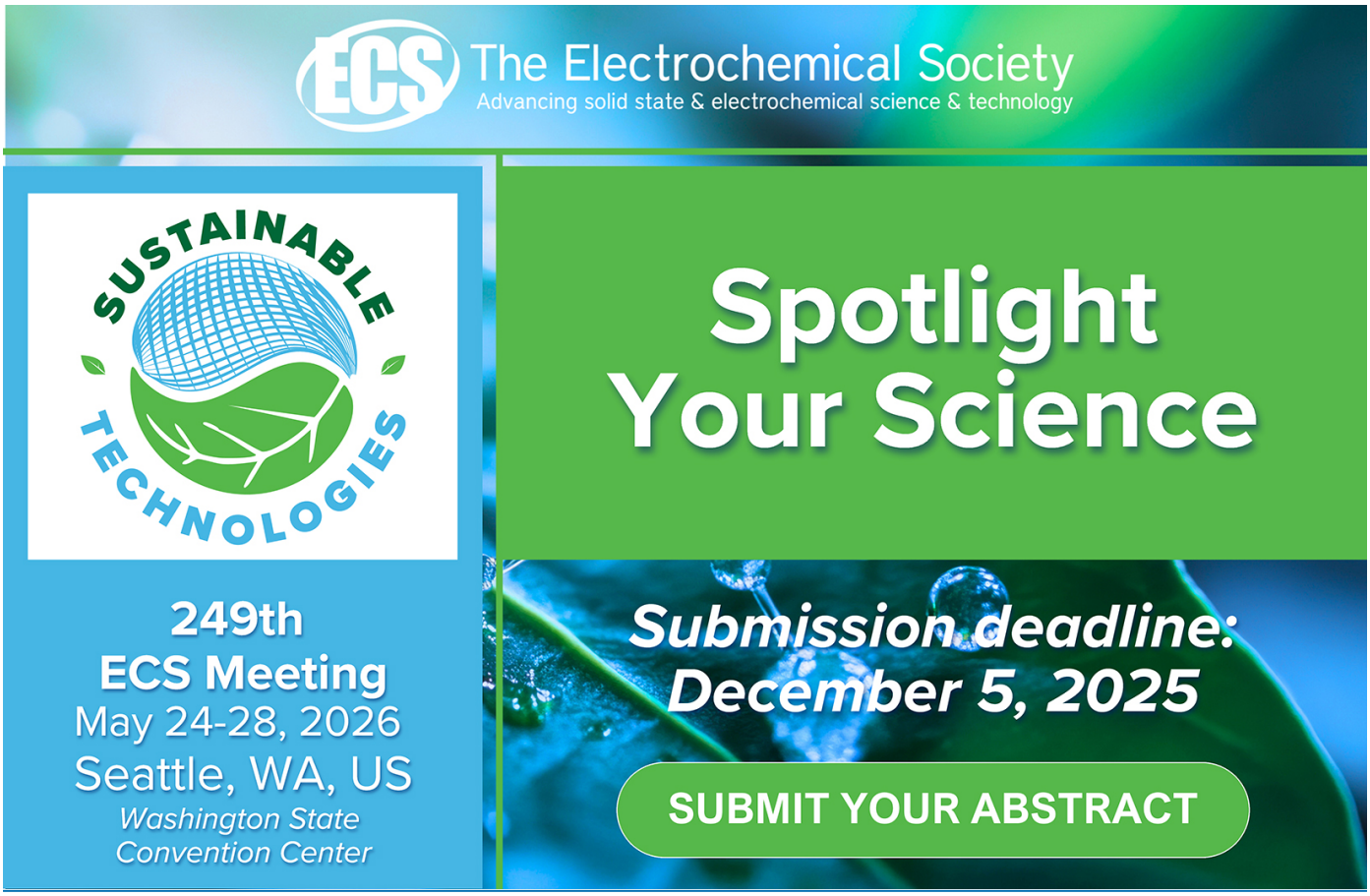
Aluminum smelting by physical process of electromagnetic wave generation with microwave oven

To cite this article: N Y Perez Rangel *et al* 2021 *J. Phys.: Conf. Ser.* **2046** 012075

View the article online for updates and enhancements.

You may also like

- Oxidation of HighPurity Aluminum and 5052 AluminumMagnesium Alloy at Elevated Temperatures
C. N. Cochran and W. C. Sleppy
- Evaluation of Sealing Process on the Surface Properties of Nanoporous Aluminum Oxide Layers Electrochemically Growth on 1050 Aluminum Alloy Surface
V M Dumitrascu, L Benea and N L Simionescu
- Investigation of Metal Cation Effects on Corrosion Behavior of Aluminum Alloys
Masatoshi Sakairi, Md. Saiful Islam and Li Li



This content was downloaded from IP address 8.243.64.131 on 26/09/2025 at 13:55

Aluminum smelting by physical process of electromagnetic wave generation with microwave oven

N Y Perez Rangel[1], **E Florez Solano**[1], **and E Espinel Blanco**[2]
[1] Grupo de Investigación en Ingenierías Aplicadas para la Innovación, Gestión y Desarrollo (INGAP), Universidad Francisco de Paula Santander, Seccional Ocaña, Colombia
[2] Grupo de Investigación en Tecnología y Desarrollo en Ingeniería (GITYD), Universidad Francisco de Paula Santander, Seccional Ocaña, Colombia

E-mail: nperezr@ufpso.edu.co

Abstract. In Colombia, there is a demand for quantities of metal parts of iron, steel, and aluminum for different purposes, which requires the demand for large quantities of energy leading to a high emission of gaseous pollutants; the need to start recycling and reuse, as in the case of aluminum, which is used in products such as foods used in soda cans, beers, fruit syrup, tuna, grains, etc. In addition, there are other residues such as aluminum chips that are generated from machining processes, everything is based on the preservation of the environment. This project presents a new microwave oven technique to transform aluminum chip into blocks or sheets of aluminum to be reused, from the recycling of aluminum shavings and scrap produced mainly by machine-tool shops and machining centers, when, after carrying out the washing processes prior to casting, microwave irradiation is used as a physical property of material state transformation by implementing high frequencies that allow heat to be produced by high frequency vibrations, All this in order to perform the fusion process in less time and obtain aluminum with better mechanical properties.

1. Introduction

The casting process is a direct method that allows the creation of parts using liquid metal, with the advantage of manufacturing any type of part without delimiting aspects such as shape, size and quantity to produce [1]. This process consists in bringing the material to be used to its melting point in order to obtain its liquid state, which will subsequently be emptied into molds or extruded according to the application for the part to be manufactured.

It should not be forgotten that the structural arrangement is important since the mechanical properties that will characterize the part produced depend on it, a factor in this process is temperature, given that the above conditions are directly related to this factor [2].

Aluminum is a material that due to mechanical properties such as strength, tenacity and its high strength/weight ratio is being highly demanded in the current market [3], taking into account the environmental impact of primary aluminum production, the need to recycle and contribute to the environment arises, knowing that in order to produce one tone of primary aluminum, 4 tones of bauxite, which is the material from which aluminum comes, must be extracted, the secondary aluminum comes from the recycling of aluminum which has already completed a cycle or which is the product of metallurgical processes in the form of chips, the latter in most cases ends up in sanitary landfills without

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

a final disposition and contaminating. Another important aspect to consider is the fact that energy consumption and production of carbon dioxide to the environment is lower when secondary aluminum is produced than primary aluminum.

The aluminum chip has been studied for its difficult fusion between the small particles that make it, mechanical properties and wear have been evaluated [4], obtaining favorable results that provide the basis for further work in this sector and contributing to the conservation of the environment. To obtain the melting and smelting of aluminum we find different processes such as gravity casting [5], agitation casting [6], direct extrusion [7-9] and friction extrusion [10], which allow to obtain the aluminum in block, bars or sheets according to their application because they are preferred in sectors such as transport (tankers, military vehicles, railway systems, aviation), construction (beams, light bridges, armored plates).

Currently the technique of using 2.45 GHz microwave energy as a method to produce the required temperature capable of melting metals in conventional microwave ovens is growing, this is shown in review articles such as: Parametric review of microwave material processing and applications [11] and A review of the literature on the exposure time of microwave welding of different materials [12], where we can see the steps to make the casting of different metals using microwaves. Different processes with microwaves [13-18] have also been carried out with quite favorable results, among them a reduction in casting times and improvements in mechanical properties due to the short time used for this process.

In detailing the literature, it is possible to melt metals in microwave ovens, but it does not specify the conditions to be done casting, such as details of the crucible to melt the metal, in the case of aluminum chip there is no information demonstrating its use in the process using this technique, which causes this process to have its limitations and open the way for further research. The present work was carried out with the purpose of obtaining aluminum smelters from chips by conventional microwave oven, in which the melting of the aluminum chip is achieved and subsequently subjected to hardness and metallography tests to assess the final condition of the molten aluminum.

2. Materials and methods

Recycled aluminum chip will be used to make its transformation and obtain compact aluminum blocks that will be used in machining processes; in this way waste produced by machine tool workshops is recycled and reused, contributing to the environment by reducing the emission of carbon dioxide (CO_2) and reducing the expenditure of electrical energy, causing an increase in the performance in the process of melting aluminum chip.

Taking into account different laboratory experiences to achieve melting of aluminum chip in a microwave oven, it is necessary to bear in mind the removal of a layer of alumina contaminants that forms on the surface of chip particles from oxidation with the environment to be removed through caustic soda-based chemical pretreatment, then proceed to place the aluminum chip in a silicon carbide crucible that will be contained hermetically in alumina refractory brick, this system will be subsequently placed inside the microwave oven.

Finally, the sample is removed from the furnace and placed in a hydraulic press which exerts pressure and solidifies the already melting aluminum as shown in Figure 1; the state of the aluminum is verified by means of metallography and hardness tests which reveal the mechanical properties of the formed material [2].

3. Results

After following step by step the scheme set out above in Figure 1, Figure 2 shows the process performed on aluminum from its initial chip state to the solid sample, where you can see the complete melting of the aluminum chip particles and the compaction of the same, which generates great expectation to work in leaps and bounds in the metal smelting sector through the microwave oven, thus obtaining a significant performance in the melting time and energy consumption, knowing that when implementing the microwave oven the times to obtain molten aluminum decrease by 60% as well as the energy

consumption demanded for the process, all this compared to traditional melting in muffle furnace and crucible furnace.

The samples obtained by melting in a microwave oven can be seen in (Figure 3; Figure 3(a) to Figure 3(c)), where the union of the aluminum chip that gives way to a solid piece of aluminum is observed.

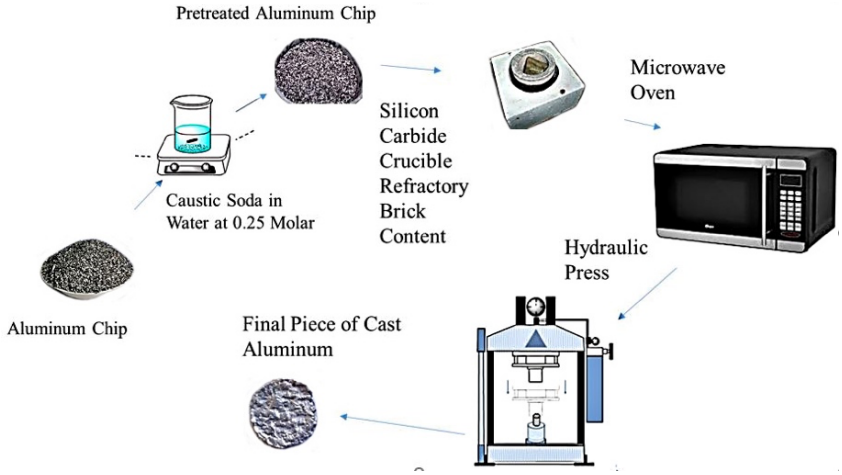


Figure 1. Schematic of the process of casting aluminum chip in microwave oven.

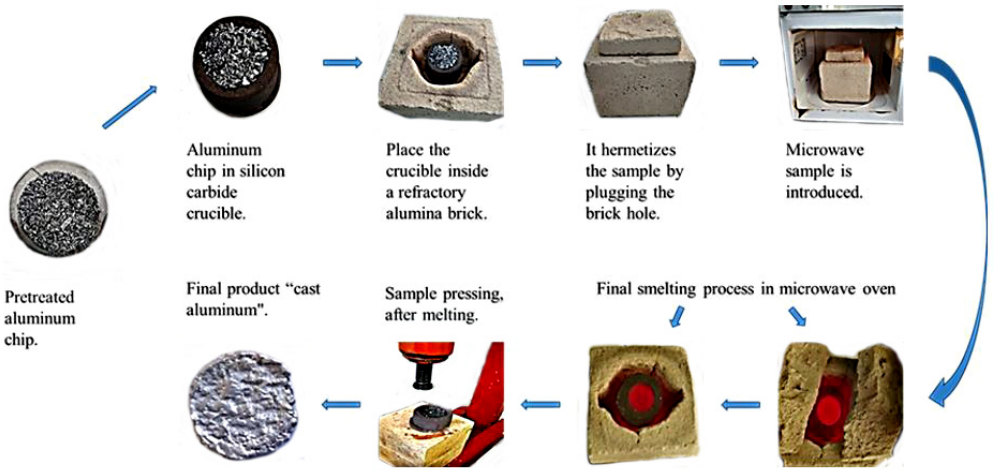


Figure 2. Step-by-step scheme that was carried out for the smelting of aluminum chip in microwave oven.



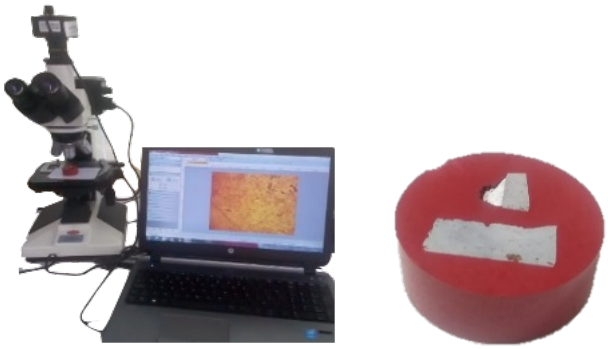
(a) (b) (c)

Figure 3. Samples of aluminum chip smelting with microwave oven. (a) sample 1; (b) sample 2; (c) sample 3.

Aluminum for its good mechanical properties, light weight and corrosion resistance is implemented in many industrial processes such as aeronautics, construction, among others. What makes the development of this smelting process through microwave irradiation generate a positive impact and allow the recycling of aluminum in all its forms.

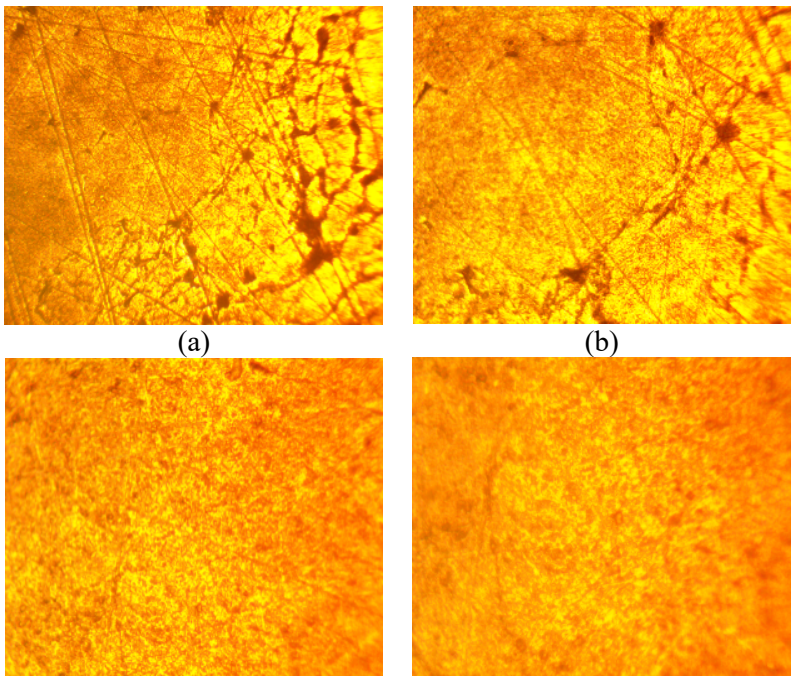
3.1. Metallographic analysis

Metallographic analysis was performed by preparing the sample as indicated in ASTM E112-13 standard [19], obtaining the metallographic images using an Optika B-157ALC microscope (see Figure 4; Figure 4(a), Figure 4(b)), in which the microstructure of the aluminum can be observed after the casting process. Microscopically you can detail the cohesion between chip particles to give way to the formation of the compact sample, which can be used in industrial or commercial processes. Below are the metallographic images (as seen in Figure 5; Figure 5(a) to Figure 5(d)).



(a) (b)

Figure 4. Metallography test: (a) metallographic microscope; (b) test piece in already polished resin.



(a) (b)

(c) (d)

Figure 5. Metallographic images at different zoom: (a) zoom 50x; (b) zoom 100x; (c) zoom 400x; (d) zoom 600x.

3.2. Hardness analysis

The hardness analysis was performed using a Mitutoyo HR-300 hardness tester, applying the ASTM E10-18 standard [20], (see Figure 6; Figure 6(a), Figure 6(b)), where the final conditions of the product obtained are evaluated, which makes it possible to make a comparison with the characteristics of aluminum specified in the market. The test results are shown below in Table 1.



(a) (b)

Figure 6. Test pieces for hardness: (a) front cut; (b) back cut.

Table 1. Hardness test results.

Substrate	Value 1	Value 2	Value 3	Value 4	Average
Sample 1	46.7	52.8	49.2	46.5	48.8
Sample 2	44.2	27.3	45.3	58.0	43.7

4. Conclusions

In this investigation it can be concluded that the sample was made with recycled and melted aluminum chip by irradiation of conventional 2.45 GHz microwave oven. The high vibrations produced by the magnetron of the microwave oven with a high frequency of 2.45 GHz, cause the material of silicon carbide to vibrate in such a way that temperatures are obtained around 700 °C, achieving the casting of the aluminum chip.

Through the metallography test you can see the uniformity of the casting, which means that the small particles of aluminum chips reached their melting point, and a compact sample was produced. We can also observe an average hardness ranging from 43.7 to 48.8 Brinell hardness (HB), which compared to the normalized primary aluminum hardness ranging from 23.27 to 65 Brinell hardness (HB), we can affirm that it is in the stipulated ranges for this material, which makes it some aluminum in condition to perform any function within the commercial market for which it is required.

References

[1] Radha Raman M, Apurbba Kumar S 2016 On mechanism of in-situ microwave casting of aluminium alloy 7039 and cast microstructure *Materials and Design* **112** 97

[2] Perez-Rangel N Y, Florez Solano E, Hoyos Palacio L M 2019 Exploitation of chip and scrap aluminium for the development of aluminum sheets and bars *Journal of Physics: Conference Series* **1587(1)** 012027:1

[3] Brough D, Jouhara H 2020 The aluminium industry: a review on state-of-the-art technologies, environmental impacts, and possibilities for waste heat recovery *International Journal of Thermofluids* **1(2)** 100007

[4] Sumair M, Rahman U, Jayahari L 2018 Study of mechanical properties and wear behaviour of aluminium 6061 matrix composites reinforced with steel machining chips *Materials Today: Proceedings* **5(9)** 20117

[5] Sathish T, Karthick S 2019 Gravity die casting-based analysis of aluminum alloy with AC4B nano-composite *Materials Today: Proceedings* **33** 2555
[6] Gowrishankar M C, Hiremath P, Shettar M, Sharma S, Rao S U 2020 Experimental validity on the casting characteristics of stir cast aluminum composites *Journal of Materials Research and Technology* **9(3)** 3340
[7] Todaro I, Squatrito R, Essel S, Zeidler S 2019 High conductive aluminum metal matrix composites with carbón inserts obtained by casting processes *Materials Today: Proceedings* **10** 277
[8] Kolpak F, Schulze A, Dahnke C, Tekkaya A E 2019 Predicting weld-quality in direct hot extrusion of aluminum chips, *Journal of Materials Processing Technology* **214** 16294
[9] Ashwath P, Joel J, Prashantha kumar H G, Anthony Xavior M, Goel A, Nigam T, Rathi M 2018 Processing, and characterization of extruded 2024 series of aluminum alloy *Materials Today: Proceedings* **5(5)** 12479
[10] Mehtedi M E, Forcellese A, Mancia T, Simoncini M, Spigarelli S 2019 A new sustainable direct solid-state recycling of AA1090 aluminum alloy chips by means of friction stir back extrusion process *Procedia CIRP* **79** 638
[11] Kumar Loharkar P, Ingle A, Jhavar S 2019 Parametric review of microwave-based materials processing and its applications *Journal of Materials Research and Technology* **8(3)** 3306
[12] Nandwani S, Vardhan S, Kumar Bagha A 2019 A literature review on the exposure time of microwave-based welding of different materials *Materials Today: Proceedings* **27** 2526
[13] Luo H, Zhang X, Huang S, Shan D, Deng L, He L, He J, Xu Y, Chen H, Liao C 2019 Infrared emissivity and microwave transmission behavior of flaky aluminum functionalized pyramidal frustum shaped periodic structure *Infrared Physics and Technology* **99** 123
[14] Shashank Lingappa M, Srinath M S, Amarendra H J 2017 Melting of 60Sn40Pb alloy using microwave energy and its characterization *Materials Today: Proceedings* **4(2)** 471
[15] Shashank Lingappa M, Srinath M S Amarendra H 2018 Microwaves: a source of energy for melting of bulk zinc *Materials Today: Proceedings* **5(2)** 7782
[16] Singhal C, Murtaza Q, Parvej 2018 Microwave sintering of advanced composites materials: a review *Materials Today: Proceedings* **5(11)** 24287
[17] Samyal R, Kumar Bagha A, Bedi R 2019 Microwave joining of similar/dissimilar metals and its characterizations: a review *Materials Today: Proceedings* **26** 423
[18] Wang Z, He Z, Wang Z, Ning M 2019 Utilization of magnetite as microwave absorber to prepare microwave eatable aggregate for deicing in cementitious composite *Construction and Building Materials* **227** 116664
[19] American Society of Testing Materials (ASTM) 2014 *Standard Test Methods for Determining Average Grain Size, ASTM E112-13* (West Conshohocken: American Society of Testing Materials)
[20] American Society of Testing Materials (ASTM) 2018 *Standard Test Method for Brinell Hardness of Metallic Materials, ASTM E10-18* (West Conshohocken: American Society of Testing Materials)