Materials and Design 32 (2011) 2685–2694

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

A new approach to joining of bulk copper using microwave energy

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ARTICLE INFO

Article history:
Received 21 October 2010
Accepted 11 January 2011
Available online 18 January 2011

Keywords:
C. Joining
F. Microstructure
G. X-ray analysis

ABSTRACT

Metallurgical joining of high thermal conductivity materials like copper has been technically challenging. This paper illustrates a novel method for joining of bulk metallic materials through microwave heating. Joining of copper in bulk form has been carried out using microwave energy in a multimode applicator at 2.45 GHz and 900 W. Charcoal was used as susceptor material to facilitate microwave hybrid heating (MHH). Copper in coin and plate forms have been successfully joined through microwave heating within 900 s of exposure time. A sandwich layer of copper powder with approximately 0.5 mm thickness was introduced between the two candidate surfaces. Near complete melting of the powder particles in the sandwich layer does take place during the microwave exposure leading to metallurgical bonding of the bulk surfaces. Characterisation of the joints has been carried out through microstructure study, elemental analysis, phase analysis, microhardness survey, porosity measurement and tensile strength testing. X-ray diffraction (XRD) pattern indicates that some copper powder particles got transformed into copper oxides. XRD analysis also reveals that the dominant orientation (3 1 1) in starting copper powder got transformed into a preferential orientation (1 1 1) in the joint. A dense uniform microstructure with good metallurgical bonds between the sandwich layer and the interface was obtained. The hardness of the joint area was observed to be 78 ± 7 Hv, while the porosity in the joint was observed to be 1.92%. Strength character of the copper joints shows approximately 29.21% elongation with an average ultimate tensile strength of 164.4 MPa.

1. Introduction

Permanent joining of materials has been one of the prime requirements in most of the manufacturing and assembling industries. The existing techniques like welding, soldering and brazing are being widely practiced in industries; however, they have their own limitations regarding processing time, materials to be joined and characteristics of the joint. Further, ease of processing and environmental hazards, are some of the issues that need to be addressed. Thus a more versatile, faster and cleaner process could have a huge impact on production. Investigations reveal that application of microwave energy as a tool in materials processing is not only a green manufacturing process, but also significantly faster at relatively low investment. Microwave materials processing can give an alternative to high energy consumption heating techniques that are commonly used in industries.

In microwave processing, energy is directly transferred to the material through interaction of electromagnetic waves with molecules leading to volumetric heating. Heat is generated internally within the material, instead of originating from the external sources, and gets transmitted outward. Hence, there is an inverse heating profile, 'inside-out' unlike in a conventional heating 'outside-in'. Several authors have shown the use of microwave energy for wide ranging applications. In one of the premier investigations, Osepchuk has explained the basics of microwave heating and presented a brief history of the applications of microwave energy [1]. Later, the same author further explored the possible areas of applications of microwave power in details [2]. Significance of microwave heating and its applications in processing of ceramics were then analyzed by Sutton in a landmark publication in 1989 [3]. The unique features of processing materials with microwave were lucidly presented. Later, Clarke et al. have shown the potentials and challenges of using microwave energy in materials processing [4]. Subsequently, application of microwave energy in material processing was reported in many areas including the new and unusual application like glazing of sprayed ceramic composite surfaces [5]. Microwave energy has been effectively used in the processing of different materials. However, majority of these applications was limited to processing of microwave absorbing materials (mostly, bio-materials, hydrocarbons etc.), ceramics and ceramic composites. Successful sintering of alumina with nearly full density at 1350 °C after 50 min has been achieved using 2.45 GHz microwave and its comparison with conventional heating shows only 62% density at this temperature [6]. Metals and alloys, on the other hand, remained outside the applications envelop of microwave energy in materials processing for an uncharacteristically longer time.

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doi:10.1016/j.matdes.2011.01.023