

Functionalizing machinable glass-ceramic for jewellery items produced by hot pressing

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The use of coloured gold alloys (e.g. red, white, green) in the manufacture of jewellery pieces is currently generalized and one can often see jewellery items that combine several colours [1]. Still, colour combinations provided by gold alloys and other metallic materials are somewhat limited. Nowadays, technical ceramics are easily available on the market in a wide range of colours and with almost any shape. Integrating “coloured” technical ceramics with gold or with other precious metals in the production of jewellery items opens a new array of options that is still waiting to be explored by jewellery designers and manufacturers. Due to several constraints of the jewel manufacturing process, bonding between the metal and the ceramic parts of the jewels is achieved just by mechanical interlocking, which does not provide adequate mechanical strength for practical use. Joints with higher mechanical strength may only be achieved when metal and ceramic are chemically bonded.

The present work is centred on the development of a novel technique, tailored to enable chemical bonding between the ceramic and metal parts of jewels produced by hot pressing. The process involves the functionalization of the ceramic part in order to induce the formation of a metallic multi-layered coating, with a global chemical composition similar to that of an active brazing alloy (ABA). In the course of hot pressing processing, the coating melts due to solid state diffusion. The melted coating will then react with the ceramic substrate and the metal powders, originating the formation of reaction products that due to their semi-metallic nature enable chemical bonding between the ceramic and the metal parts of the jewel.

Macor[®], which is a machinable fluorosilicate glass-ceramic, was coated with 3 different metallic layers (Fig. 1a): a Ti layer (1.2 µm), followed by a Ag layer (15 µm) and finally by a Cu layer (10 µm). The Ti layer was deposited by sputtering and the Ag and Cu layers were electroplated. The thickness of each layer was calculated so that the global composition of the multi-layered coating was around 63Ag-35.3Cu-1.7Ti (wt.%), which is the chemical composition of Cusil-ABA filler. Our previous work [2] demonstrated that Cusil-ABA is an adequate filler for brazing Macor[®].

Coated Macor[®] samples were heated to 850 °C in vacuum (10⁻² mbar) in order to assess the reaction of the multi-layered coating with the glass-ceramic, without the interference of the Au alloy (80Au-10Ag-10Cu, wt.%) powders. Scanning electron microscopy (SEM) observations and energy dispersive x-ray spectroscopy (EDS) analysis, revealed that eutectic structure, which denotes melting of the coating, was developed and that Ti reacted with Macor[®] forming a continuous Ti-rich reaction layer (Fig. 1b). The reaction layer prevents partial delamination of the coating near the glass-ceramic, which may occur as the result of sample preparation operations for microstructural and chemical characterization.

Hot pressing of the Au alloy powders mixture, with the coated glass-ceramic sample placed roughly at the geometrical centre of the cavity of the die, was carried out in vacuum, at 850 °C, with a dwelling stage of 20 minutes and an applied pressure of 20 MPa at the processing temperature. As it can be observed in Figure 2, hot pressing produced a fully sintered Au alloy matrix joined to the glass-ceramic sample by 3 continuous bonding reaction layers, each less than 1 µm thick. According to EDS analysis, layer adjacent to Macor[®] is mainly composed of Ti, Si and Au, while Au and Ti are the main elements detected in layer formed near the

Au alloy matrix. The functionalizing method presented in this work proved to be adequate for this specific system of materials.

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[1] Henriques B. *et al.*, *Gold Bull.*, **46**, 117–125, 2013.

[2] Guedes A. *et al.*, *Mater. Sci. Eng.*, **A301**, 118–124, 2001.

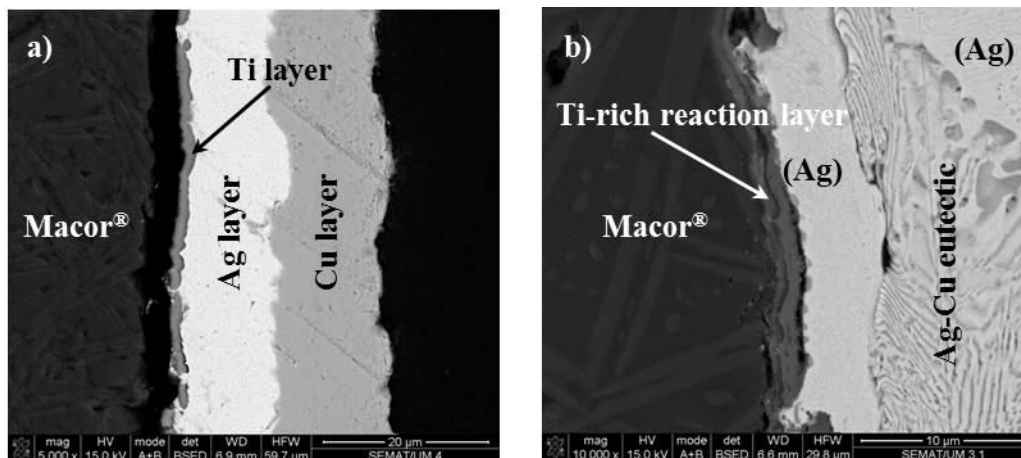


Figure 1. SEM images of the multi-layered coating. a) as-deposited, showing a zone of delamination; b) after heating to 850 °C, with no dwelling stage.

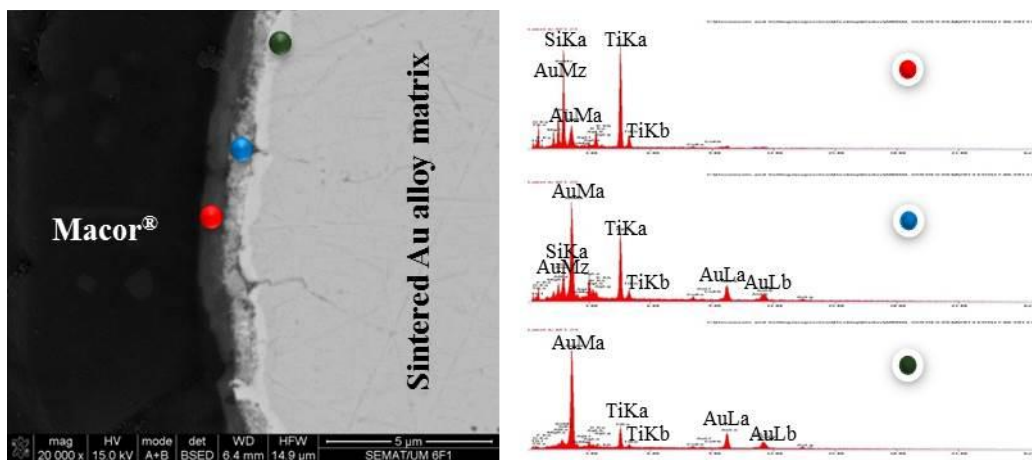


Figure 2. SEM image of the glass-ceramic sample joined to the sintered Au alloy matrix and EDS spectra of the bonding reaction layers, after hot pressing at 850 °C for 20 minutes, under an applied pressure of 20 MPa.