Acta Biomaterialia 8 (2012) 2856–2862

Contents lists available at SciVerse ScienceDirect

Acta Biomaterialia

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

Effects of chromium and nitrogen content on the microstructures and mechanical properties of as-cast Co–Cr–Mo alloys for dental applications

Keita Yoda [a], Suyalatu [b], Atsushi Takaichi [a], Naoyuki Nomura [b,*], Yusuke Tsutsumi [b], Hisashi Doi [b], Shingo Kurosu [c], Akihiko Chiba [c], Yoshimasa Igarashi [a], Takao Hanawa [b,d]

[a] Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8510, Japan
[b] Institute of Biomaterials and Bioengineering, Tokyo Medical and Dental University, 2-3-10 Kanda-surugadai, Chiyoda-ku, Tokyo 101-0062, Japan
[c] Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8057, Japan
[d] Graduate School of Engineering, The University of Tokyo, Bunkyo-ku, Tokyo 113-8650, Japan

ARTICLE INFO

Article history:
Received 9 December 2011
Received in revised form 2 March 2012
Accepted 12 March 2012
Available online 17 March 2012

Keywords:
Co–Cr alloy
Nitrogen addition
Microstructure
Mechanical properties
Dental casting

ABSTRACT

The microstructure and mechanical properties of as-cast Co–(20–33)Cr–5Mo–N alloys were investigated to develop ductile Co–Cr–Mo alloys without Ni addition for dental applications that satisfy the requirements of the type 5 criteria in ISO 22674. The effects of the Cr and N contents on the microstructure and mechanical properties are discussed. The microstructures were evaluated using scanning electron microscopy with energy-dispersive X-ray spectroscopy (EDS), X-ray diffractometry (XRD), and electron back-scattered diffraction pattern analysis. The mechanical properties were evaluated using tensile testing. The proof strength and elongation of N-containing 33Cr satisfied the type 5 criteria in ISO 22674. ε-phase with striations was formed in the N-free (20–29)Cr alloys, while there was slight formation of ε-phase in the N-containing (20–29)Cr alloys, which disappeared in N-containing 33Cr. The lattice parameter of the γ-phase increased with increasing Cr content (i.e. N content) in the N-containing alloys, although the lattice parameter remained almost the same in the N-free alloys because of the small atomic radius difference between Co and Cr. Compositional analyses by EDS and XRD revealed that in the N-containing alloys Cr and Mo were concentrated in the cell boundary, which became enriched in N, stabilizing the γ-phase. The mechanical properties of the N-free alloys were independent of the Cr content and showed low strength and limited elongation. Strain-induced martensite was formed in all the N-free alloys after tensile testing. On the other hand, the proof strength, ultimate tensile strength, and elongation of the N-containing alloys increased with increasing Cr content (i.e. N content). Since formation of ε-phase after tensile testing was confirmed in the N-containing alloys the deformation mechanism may change from strain-induced martensite transformation to another form, such as twinning or dislocation slip, as the N content increases. Thus the N-containing 33Cr alloy with large elongation is promising for use in dentures with adjustable clasps through one piece casting.

1. Introduction

Cobalt–chromium–molybdenum (Co–Cr–Mo) alloys have been widely used for removable partial denture frameworks because of their excellent strength, corrosion resistance, and castability [1–3]. Partial denture frameworks consist of a major connector and a clasp, which are usually integrated through one piece casting. However, different mechanical properties are required for the two parts. High resilience and no permanent deformation (i.e. high Young's modulus and high yield strength) are required for the major connector when occlusal force is applied [4–6]. On the other hand, high ductility is required to repeatedly reactivate the clasp.

Gold–platinum alloys (Au–Pt) can satisfy the above requirements and have been used because their mechanical properties and corrosion resistance match the demands of this application. Unfortunately, their use is becoming limited by cost considerations due to the recent rise in the price of gold. Co–Cr–Mo alloys also have promising properties for use as the major connector because of their high Young's modulus and strength. However, it is difficult to design Co–Cr–Mo alloy clasps with a deep undercut because they have less deflection (i.e. a higher Young's modulus) than gold alloys and the undercut is thus half as deep as that of a gold alloy. Although these clasps can firmly brace the denture with less deflection, the retentive force decreases gradually owing to plastic deformation during usage [7,8]. The loosened clasp must then be adjusted [9], however fracture often occurs because of the limited ductility [10,11]. Therefore, improving the ductility of Co–Cr–Mo

* Corresponding author. Tel./fax: +81 352808007.
E-mail address: nnomura.met@tmd.ac.jp (N. Nomura).

1742-7061/$ - see front matter
http://dx.doi.org/10.1016/j.actbio.2012.03.024