High performance, nanostructures of the medical Ti-Cu-Sn alloy and dental implant development

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With a continuously increasing population in the aged group, large demands of metallic biomaterials are expected for many years to come. In recent years, Ti-base alloys have received much attention due to their excellent biocompatibility, good osseointegration, low density, superior corrosion resistance, and good balance of mechanical properties. E.g, Ti is clinically used for dental implants and dentures. CP-Ti alloy is considered to be a difficult metal to manufacture, mainly because of its high melting temperature (1670°C) and high chemical activation energy at high temperature. Another obstacle is its poor machinability, which prevents practical application of CP-Ti in dentistry, as working (e.g. cutting, grinding, and polishing) of dental prostheses in dental laboratories or chair-side is essential. However, Ti6Al4V is the most commonly used alloy because of its superior physical and mechanical properties in comparison to CP-Ti alloy. The harmful elements V and Al in Ti6Al4V tend to be released into the human body. Another, bacterial infection after implant placement is still a significant rising complication. Therefore, the development of a high-performance, antibacterial of new titanium alloys on high-value medical device become imperative.

The microstructure of the Ti7CuXSn alloy sample is depicted in the SEM micrographs in Fig. 1. The compositions of various phases in the microstructure are shown in Table 1. Fig. 1a shows the α-martensite structure of the typical Ti7Cu Ti alloy is combined with a basket-weave structure of acicular α-Ti (dark colour) and Ti_2Cu (light colour). In Ti7Cu alloy, the average size of cellular grain sizes, lamellar spacings and grain sizes of Ti_2Cu phases (fv) were 427±36.8μm, 41.9±6.8um and 1.74±0.6%, respectively. It is clearly that the addition of Sn plays an important role to promote the formation of the supersaturated solid solution upon solidification. In particular, with a 5 wt% content of Sn, lamellar eutectoid areas with largely nano $(Ti, Sn)_2Cu$ (grain size, 0.15±0.10μm) distributed throughout them were observed in the solidified structure (Fig. 1c).

Comparing the bar graph in Fig. 2 shows the microhardness of Ti7CuXSn samples. The microhardness of the Ti7Cu specimen is about 354.8 Hv (>186.8 Hv of CP-Ti). It is clear that the microhardness of the Ti7Cu alloy increases, obviously due to the formation of a hard Ti_2Cu phase in a martensite structure (Fig.1a). From a comparison of microhardness and Sn content, it can be observed that the microhardness of the Ti7CuXSn alloy increased with increases in the weight percent of Sn added into the Ti7Cu alloy. The microhardness of these Ti7CuXSn alloys is enhanced by 13.5–21.6% over that of the Ti7Sn alloy.

The surfaces of films formed on Ti7Cu 5Sn has porous microstructure after MAO process (Fig. 3). The EDS analysis revealed that the Ti7Cu5Sn sample mainly consisted of Ca, P, Ti and O. The Ca/P ratio (1.72) is very close to the value of normal human bone. In XRD analysis, the coating was mainly composed of anatase-TiO_2, rutile-TiO_2, and HA ($Ca10(PO4)6(OH)_2$) phase. It was also shown that a titanium oxide surface had a greater number of osteoblasts with higher cell activity. Fig.4 shown that the novel Ti7Cu5Sn dental implant, eg., implant design, color anodizing treatment and dental implants.

In the word, this study successfully developed a high-performance, nanostructures and antibacterial of novel Medical Ti7Cu5Sn titanium alloys, and replacing the traditional Ti6Al4V and pure titanium. Also, won a biotech gold medal in the 2012 Taipei International Invention Show & Technomart (INST), and applied for the Taiwan (I 440722) and China patents (ZL 201310016723.6).

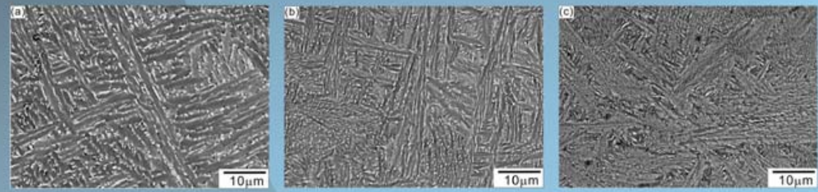

Fig. 1 BSE micrographs of the as-cast alloy: (a) Ti7Cu, (b) Ti7Cu2.5Sn, (c) Ti7Cu5Sn.

Table 1 The values of cellular grain size, lamellar spacing and grain size of Ti_2Cu for theTi7CuXSn

Specimens	Cellular grain size (μm)	Lamellar spacing (μm)	Grain size of Ti_2Cu (μm)
Ti7Cu	427±36.8	41.9±6.8	1.74±0.6
Ti7Cu2.5Sn	163±21.8	5.1±2.1	0.18±0.13
Ti7Cu5Sn	98±18.8	3.5±0.2	0.15±0.10

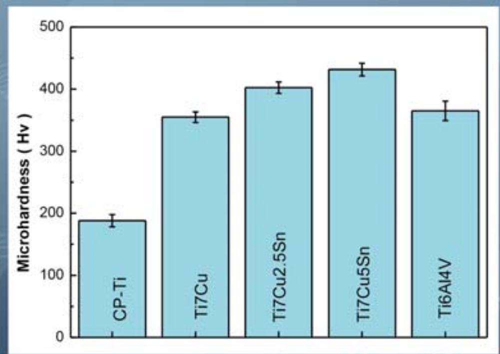

Fig. 2 Microhardness of as-cast Ti7CuXSn alloys compared with that of CP-Ti and Ti6Al4V.

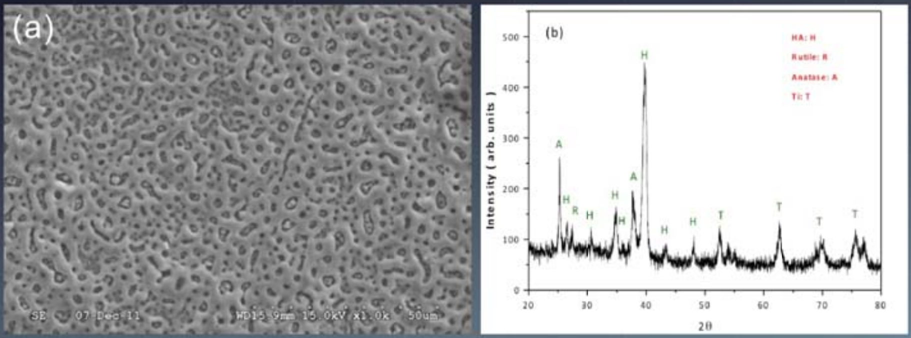

Fig. 3 HA coating layer formed on Ti7Cu5Sn alloy after MAO process: (a) SEM, (b) XRD.

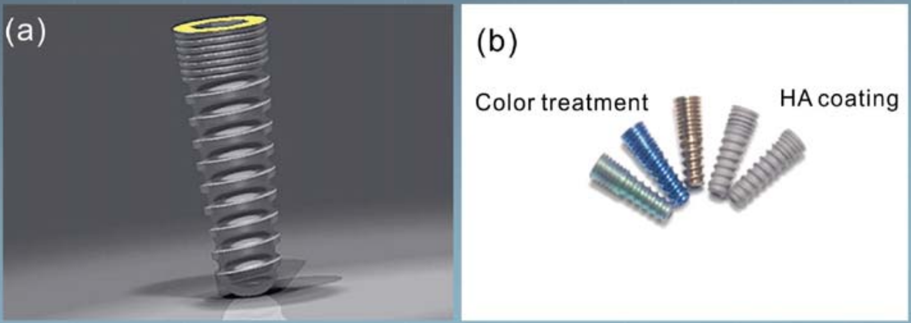

Fig. 4 Implant designs used in Ti7Cu5Sn alloy, (a) implant design, (b) dental implants.