Microstructural Aspects of the Captek™ Alloy for Porcelain-Fused-to-Metal Restorations

CARLO ZAPPALA, MD, DDS*
ITZHAK SHOHER, DMD, MSτ
PAULO BATTAINI, PHD+

Captek™ (Precious Chemical USA Inc., Apopka, Florida) is a new, innovative development in dental materials. It is a dental alloy that can be defined as a composite material because it is internally composed of two different alloys. Captek™ is a high gold content alloy (88% by weight) and is used in porcelain-fused-to-metal dental crowns and bridges. Composite metals containing metallic matrix and high module of elastic metallic filler can be structured to have better properties than single-component metals.[1] Composite combinations exist in traditional dental materials, such as polymers with ceramic particles, glass powders with acid composites (cements), and metallic powders with metal composites (amalgams).[2] This study examines the main chemical and physical aspects of Captek™ microstructure, its composite characteristics and the differences between Captek™ and traditional gold alloys for similar use.

MATERIALS AND METHODS

Captek™ alloy has two main components: 'P' and Captek G™.' They come in elastic sheets having an average thickness of about 0.3 mm. They are manually modeled to form crown copings over refractory dies. Captek P™ is processed in a porcelain furnace at 1075°C for 4 minutes in air. Then Captek G™ is applied over the processed Captek P™ and processed at the same firing cycle, to complete the coping. The composition of the manufacturing company is about 88% gold (Au), 4% platinum (Pt), and 4% palladium (Pd). A detailed description of the use of Captek™ is given in a working manual.[3]

For this study, six dental copings were fabricated. Three were subjected to a complete porcelain firing cycle. Two sheets 10x20x0.4 mm were made, as well as two disks 1.3 cm in diameter and 0.8 mm thick. The latter were used in electrochemical corrosion tests. The crowns and plates were embedded in cold curing resin and sectioned with a diamond blade. The cut surfaces were ground with silicon carbide paper and polished down to 1-micron diamond paste for metallographic examination.

Whenever indicated, for better examination of the microstructure, the polished surfaces were chemically etched (N.61),[4] or the embedding resin was eliminated and the sample was thermal etched at 600°C for 1 minute at 10^{-2}atm.

The microstructural studies were done using a Leitz Metallux II (Ernst Leitz, Wetzlar, Germany) Optical Metallographic Microscope, a Cambridge Stereoscan 240 Scanning Electron Microscope (SEM) (Leo Electron Microscopy Ltd., Cambridge, England) equipped with a Robinson backscattered electron detector, and an energy dispersion x-ray spectrometer (EDS) Link AN10000 (Link Analytical Ltd., Bucks England).

The phase transformations were studied with a differential scanning calorimeter (DSC) Polymer Laboratories DSC-1500 (Rheometric Scientific Ltd., Loughborough, England). The instrument was calibrated according to the standards,[5] and data were analyzed according to the standards.[6]

∗Studio di Odontoiatria Estetica, Bergamo, Italy
τPrecious Chemicals Research Center, Tel Aviv, Israel

+Materials Engineer, Castiglione, Olona, Italy

Samples were heated at a controlled rate of 20 Cal per minute in a 50-mL per minute nitrogen flow. Electrochemical corrosion tests were carried out by EG&G potentiostat/galvanostat, model 273A, equipped with a three-electrode electrochemical cell (ASTM model), in a Ringer's solution (9 g/L NaCl, 0.25g/L $CaCl_2$, 6 H_20, 0.4 g/L KCI, 0.2 g/L Na $HC0_3$) at 37°C. Captek™ corrosion samples were abraded with abrasive silicon carbide paper (800 granules) and immersed in the solution for 600 seconds before each test. A gold sample was used as a reference material.

Tests were carried out according to the standard procedures.[7,8] Potentiodynamic tests were carried out from –350 m V Vs. OCP, with a voltage increase of 0.16mV per second. Polarization resistance measurements were carried out starting at –20mV Vs. OCP, up to +20 mV Vs. OCP with a 0.1 mV per second voltage velocity. Two potentiodynamic tests and six polarization resistance measurements were done for both Captek™ and gold.

RESULTS

After heating at 650°C for 4 minutes for the complete elimination of the binders that connect the microspheres, the Captek G™ sheet showed microspheres ranging from 5 to 100 microns in diameter, made up mainly of atomized gold powder (Figure1). The EDS microanalysis detected about 2% weight silver (Ag). After similar heating to 650°C, the Captek P™ sheet showed microflakes of up to 80 microns and atomized gold microspheres (Figure 2). Theses were of the same composition as those in the Captek G™, but smaller in average dimensions (5-40 microns). Microanaylsis of the microflakes by EDS revealed Au, Pt, Pd, and Ag as their main components (Table 1), with a composition of about 38.4% Au, 29.0% Pt, 30.2% Pd, and 2.4% weight Ag.

Figure 3 shows the typical Captek P™ surface after the first baking at 1075°C, and Figure 4 shows Captek™ alloy surface after the final baking of Captek G™.

Figure 5 shows a cross-section of the sample of Figure 3. The EDS analysis at 26 points on different areas along the microflakes and their standard deviations (% weight): Au (76.3 ± 6.8), Pt (12.2 ± 4.2), Pd (9.4±3.0), and Ag (2.1 ± 0.3).

Figures 6 and 7 show the typical microstructural view of all Captek™ sheets and crowns after chemical and thermal etching.

No change in microstructure was detected after dental porcelain baking cycles. The DSC curve of a sample in Captek P™ after the previous baking at 1075°C is shown in Table 2, and a comparison of the potentiodynamic curves of Captek™ alloy and gold is presented in Table 3. Table 1 summarizes the data relative to the polarization resistance tests.

DISCUSSION

The microstructure analysis of Captek P™ demonstrates that its baking at 1075°C forms an apparently homogeneous composition. At a temperature of 1075°C the gold microspheres melt and create microbrazings between the Au-Pt-pd alloy microflakes. These microbrazings are completed in the 4-minute baking by homogenization through solid state diffusion. In the limits of its spatial desolution,[9] EDS microanalysis does not reveal points with gold concentration in the range of the gold with atomized microspheres. The chemical homogeneity is also supported by the DSC analysis, which indicates, after Captek P™ baking at 1075°C, a solidus temperature and a liquidus temperature in good accordance with the literature data,[10] relative to a ternary alloy, Au-Pt-Pd, of Captek P™ composition. The same DSC analysis does not show any phase transformation under 1290°C (see Table 2). Captek P™ structure after baking is characterized by a capillary network, with the microflakes exhibiting preferential orientation parallel to the crown or sheet surface (see Figure 5).

The processing of Captek G™ forms the composite alloy in which both P and G components are distinctly present, as confirmed by both the optical and the electron microscope examinations. The capillary infiltration process forms Captek G™ layers on the inner and outer surfaces of the coping of identical thickness of about 35 microns each. The thickness of these layers depends on the relation between the amounts of the Captek P™ and G used. The fact that the two components, P and G, exist in Captek™ composite metal has important implications. The coefficient of thermal expansion between 20°C and 500°C of G is close to that of pure gold, $15.5X10^{-6}$ /°C.[11] For P, as calculated by linear combination of the coefficients of Au, Pt, and Pd, and their atomic concentration percentage in the composition, it is about $14.5X10^{-6}$.°C. As their mutual composite cools, after heating, internal stress develops between the components. Captek G™ compresses over Captek P™ structure. These stresses are partially resorbed by the Captek G™, a process that translates into the formation of twinned structure inside its crystal grains (see Figure 7).

This interaction between the two components and their different elasticity moduli, due to their differing composition, produces a structure strengthening similar to that obtained in other composite materials. The absence of surface oxides and the internal stress absorption during the baking phases of the porcelain produce the major dimensional stability of the metallic crowns, particularly along the border zones, as noticed by the users of this alloy. Surface metal oxides increase the metal's sag.[12,13] The absence of such oxides in Captek™ improves its thermal stability.

Test results with Captek™-ceramic crowns under impact had no major porcelain breakage occur at or near the ceramometal interface even with successive impact hits that crushed the incisal porcelain.[14] This attributed to the effect of the soft outer layer of the coping that originates from Captek G™. This layer contributes to stress dispersion in the ceramometal interface and consequently to high porcelain fracture resistance. Further studies should be done to see the effect of prolonged processing time on the properties of Captek™. This may lead to further improvement of its properties.

Electrochemical corrosion resistance tests indicate that Captek™ behaves in a manner similar to pure gold (see Table 3). The removal of the outer Captek G™ layer does not increase the galvanic corrosion between Captek P™ and G components. The electrochemical nobility of Captek™ [E(I = 0)] is higher than that of gold, probably due to a higher surface passiveness during the stabilization time. This result is attributed to the presence of the three elements: Au, Pt, and Pd. The corrosion behavior of Captek™ is therefore in line with the literature data regarding the corrosion resistance of gold, platinum and palladium, and of their respective alloys.[15,16]

CONCLUSION

The Captek™ alloy for ceramometal restorations has a composite microstructure formed by the interconnection of high gold content alloys. Captek P™ is present in the finished metal composite structure. Thus, Captek™ differs from all other commercially available alloys.

Captek's™ composite microstructure does not make it more vulnerable to corrosion; it behaves similar to pure gold. Furthermore, the composite microstructure improves its mechanical properties and its sag, compared with classic alloys of similar overall composition. Further studies are underway to evaluate the clinical implications of the more favorable properties of Captek™.

REFERENCES

1. Composites. In: . Engineered materials handbook. Vol. 1. 1987 ASM Handbook, 1987
2. Medical and dental materials. In: Cahn RW, Haasen P, Kramer EJ, eds. Materials science and technology. Vol. 14. VCH, 1992
3. Captek™ training manual. N. Attleboro, MA: Leach & Dillon.
4. ASTM E407-70. Standard methods for microetching metals and alloys. ASTM, 1995.
5. ASTM E967-92. Standard practice for temperature calibration of differential scanning calorimeters and differential thermal analyzers. ASTM, 1995.
6. ASTM E794-85 Standard test method for melting and crystallization temperatures by thermal analysis. ASTM, 1995.
7. ASTM G59-91. Practice for conducting potentiodynamic anodic polarization measurements. ASTM, 1995.

8. ASTM G59-91. Practice for conducting poteniodynamic polarization resistance measurements. ASTM, 1995.
9. Reed SJB. Electron microprobe analysis. New York: Cambridge University Press, 1993.
10. Savitskii YEM. Handbook of precious metals. New York: Hemisphere, 1989.
11. Touloukian YS, ed. Thermophysical properties of high temperature solid materials. New York: MacMillan, 1995.
12. Buchanan WT, et al. J Prosthet Dent 1984; 51:502-504.
13. Dedrich DN, et al. J Prosthet Dent 1984;51;628-630.
14. Shoher I, Whiteman A. Captek-a new capillary technology for ceramometal restoration. Quintessence Int 1995;18:9-19.
15. German RM, et al. Precious metals. Pergamon Press, 1981.
16. Johnson DL, et al. J Dent Res 1983; 62:1221-1225.