Surface Investigation of Gold Coated Ear Piercings by Scanning Electron Microscopy

Isolda Costa, Olandir V. Correa, Sizue O. Rogero and Mitiko Saiki
Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN-SP
CP 11049 – CEP 05422-970, São Paulo, SP, Brazil
icosta@net.ipen.br

Abstract

The surfaces of two commercial gold coated studs used for ear piercing, have been examined by scanning electron microscopy (SEM), before and after immersion in a cell culture medium. The aim of this study was to evaluate the presence of defects in their coating and their relation to the corrosion and toxicity. Coating defects were found in both kinds of studs. These defects allowed the contact between the culture medium and the substrate alloy. Corrosion reactions caused the release of metal ions. The substrates and the metal ions released in a culture medium were analyzed by instrumental neutron activation analysis (INAA). Nickel, one of the elements responsible for allergic reactions, was liberated from the substrates into the cell culture medium. The cytotoxic effect was observed in both kinds of studs.

Keywords: SEM, corrosion, ear piercing studs

Introduction

Commercial ear piercing studs are usually made of austenitic stainless steel or other Ni containing alloys. Allergic contact dermatitis to nickel is a common skin disease caused by absorption of this metal by skin. Nickel sensitisation was initially acknowledged by use of ear perforation. In recent years, nickel contact dermatitis has increased, mainly among the male population, due to their growing habit of wearing earrings (1). In jewellery, gold is used as coating for aesthetic reasons. The coating process used in jewellery usually is carried out by electrodeposition. In practice, it is very difficult to produce defect free coatings. Consequently, very often body fluids contact the substrate material causing its corrosion and hence the dissolution of component elements of the substrate. Scanning electron microscopy (SEM) of the surfaces of gold coated commercial ear piercing studs has shown that defects in coating surfaces are common. Defects might expose the metallic substrate (Ni containing alloys) to body fluids that contain aggressive species which leads to corrosion and leaching of Ni (2-4). The aim of this study was to investigate the presence of defects in two commercial gold coated studs and their corrosion and cytotoxicity response after immersion in a cell culture medium, a solution with the similar characteristics of physiological fluids.

Materials and Methods

The materials tested consisted of two types of commercial studs used for ear piercing: gold coated austenitic stainless steel (St) and gold coated copper-zinc alloy containing Ni (Pf). The composition of the materials used as substrates was determined by instrumental neutron activation analysis (INAA) (4) after removing the gold coating and the results are given in Table 1.

Table Elemental composition of ear piercing studs obtained by INAA.

Element	Substrate of Pf studs	Substrate of St studs
As, $\mu g\ g^{-1}$	8.1 ± 0.5	57.4 ± 0.8
Co, $\mu g\ g^{-1}$	27.4 ± 0.4	2203 ± 11
Cr, %	0.0070 ± 0.0005	16.1 ± 0.2
Cu, %	36.5 ± 1.2	0.35 ± 0.01
Fe, %	9.0 ± 0.2	67.9 ± 0.2
Mn, %	2.34 ± 0.07	1.81 ± 0.02
Mo, %	≤ 0.2	0.394 ± 0.002
Ni, %	6.80 ± 0.07	7.86 ± 0.07
V, $\mu g\ g^{-1}$	≤ 77	987 ± 26
Zn, %	36.4 ± 3.3	≤ 0.7

Figure 1 shows a macrograph of one of the ear piercing investigated in this study.

Figure 1 - Macrograph of an ear piercing stud.

The studs were immersed for 20 days in a cell culture medium, minimum Eagle's medium (MEM), a solution that is made of a mixture of salts enriched with aminoacids, vitamins and other essential components for cell growing. After 20 days of immersion of the studs in MEM, the obtained extract was analysed by INAA to identify the elements released due to corrosion, as described in a previous paper(4). Their surfaces were observed for defects in the coating by SEM before the immersion in MEM. After 20 days of immersion their surfaces were also examined by SEM and analysed by energy dispersive spectroscopy (EDS) for evaluation of the presence of reaction products. Their corrosion and cytotoxicity response has also been evaluated(2). The cytotoxic effect was studied by *in vitro* assay. Different concentrations of the ear piercing extract were added to a mammalian cell culture and the determination of cytotoxicity was performed by quantitative evaluation based on cell viability, according to Rogero et al (3).

Results and Discussion

Observation of the gold coated studs surfaces by SEM, before the immersion test, revealed the presence of defects in the coating of both kinds of studs, figure 2. Prior to corrosion test the surfaces of the St stud, observed by SEM, indicated fewer defects than those of Pf studs. Localised attack was seen at defects in the coatings on both the studs after 20 days of corrosion test, as figure 3 illustrates.

Figure 4 shows a general view of the stem of one of the Pf studs after immersion in MEM culture medium. Corrosion products remained adhered to the studs surfaces, after rinsing of the specimen, and these were related to defects in the coating.

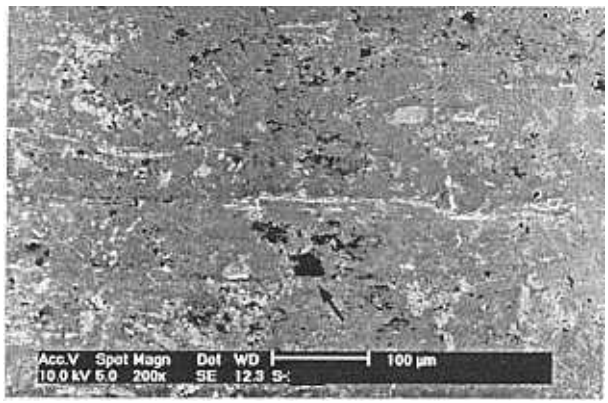

Figure 2 - Arrow points to defect in the coating prior to corrosion test.

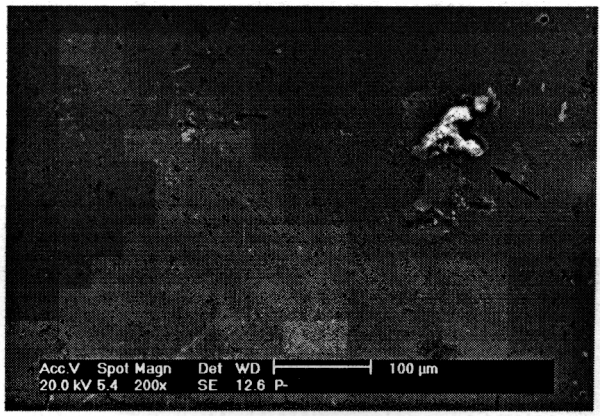

Figure 3 - Localised corrosion at a defect of the coating on St stud. The specimen was immersed for 20 days.

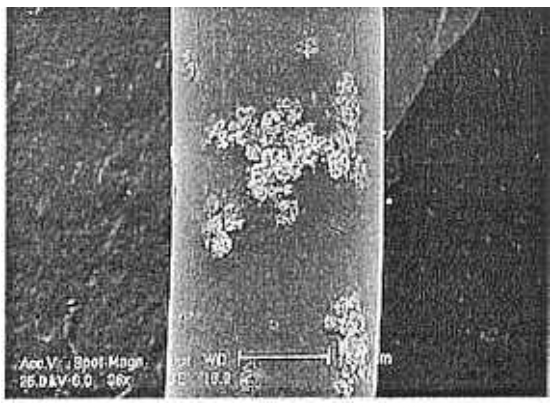

Figure 4 - Stem of Pf stud after immersion in the MEM culture medium, showing corrosion products (ligher areas) on its surface.

The EDS spectrum obtained on the corrosion products showed in figure 4 is presented in figure 5.

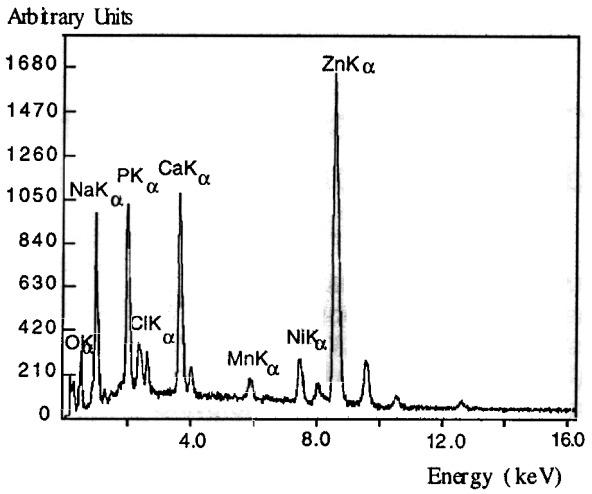

Figure 5 - EDS spectrum of corrosion products on Pf stud

Chlorine was detected by EDS analysis on the corroded area, together with other elements such as phosphorus, calcium and sodium. The phosphorus detected must be related to precipitated phosphate and chlorine to chloride species, both from culture medium. Chlorides are very corrosive species usually associated to localised corrosion. Zinc was also detected in the corrosion reaction products on Pf studs. It is possible that corrosion of the substrate at the defects of the coating is followed by formation of insoluble phosphates with Zn.

SEM observations also showed cracks in some areas and detachment of the external surface of the gold coating due to corrosion (figure 6). Therefore corrosion can lead to the exposure of new areas of the substrate to the physiological medium and further erosion.

High zinc and iron contents were found in the extracts of Pf and St studs respectively. These results showed that there was the corrosion of the substrates and these elements present in high concentrations were liberated into the culture medium. Other elements detected in the extracts were at the same magnitude of those found in the blank.

Cytotoxicity tests were carried out and both types of studs showed cytotoxicity in a cell culture(2), St studs showing a cytotoxic index ($IC_{50\%}$) higher than that of Pf, i.e., Pf was more toxic than St, in this assay.

Ni was detected in the culture medium after the studs had been immersed for 20 days, as table 2 shows. Nickel contact dermatitis is caused by Ni^{2+} ions, which bind to carrier protein and this nickel-protein complex activates immune reactions (3). Despite of the fact that the Ni content of both substrates (Pf and St) were of the same order (table 1), larger contents of Ni (nearly 2.5 times) were leached out into the culture medium from Pf studs comparatively to St studs.

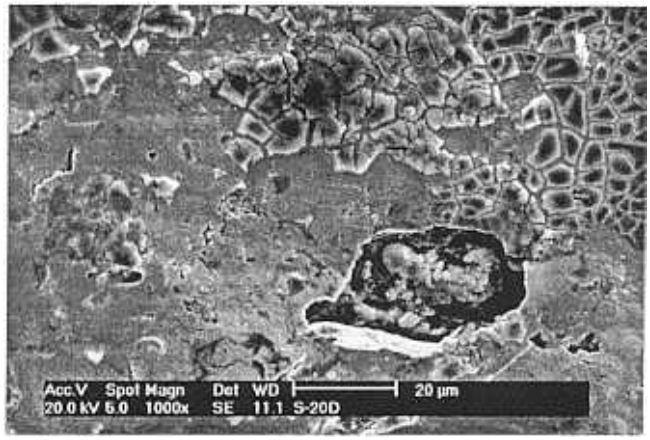

Figure 6 – Cracks in the coating and detachment of the external surface of the gold coating.

Table 2. Concentrations of elements in the extract of studs in cell culture medium and in the blank.

Element	Blank	Culture medium after 20 days immersion of studs	
		Pf	St
Co, ng/mL	12.1 ± 1.2	6.4 ± 0.2	27.6 ± 4.8
Cr, µg/mL	0.72 ± 0.02	0.74 ± 0.02	0.75 ± 0.02
Fe, µg/mL	0.60 ± 0.09	0.72 ± 0.02	3.45 ± 0.23
Ni, µg/mL	ND[a]	1.63 ± 0.22	0.62 ± 0.08
Zn, µg/mL	0.58 ± 0.05	3.39 ± 0.15	0.52 ± 0.04

[a] ND – not detected

Conclusions

SEM observations showed that there is need to improve the quality control of the gold coating process of ear piercing studs. Defects were found in the gold coating of two different types of commercial ear piercing studs. Ni, an allergenic element, was leached out into the culture medium (MEM) due to corrosion of the substrate in the defects. Therefore, SEM is a technique that could be useful for quality control of the coating process of ear piercing studs. An improved coating process would help to avoid the formation of defects which expose the substrate to body fluids, and consequently, the corrosive attack on the substrate and liberation of toxic/allergenic elements.

Acknowledgements

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