Study of the behaviour of different dental alloys in case of exposure to high and very high potentials

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Most of the dental alloys used in prosthetic dentistry are composed of noble elements as gold, platinum, palladium, ... Other ones are also generally very resistant against corrosion in the buccal milieu although they are based on nickel and chromium, thanks to their easiness to become passive. However, exposed to high potentials in a three-electrodes cell, they can know significant anodic currents, as it can be seen near the end of the anodic parts of polarization runs in artificial saliva. Since high potentials can be sometimes achieved in reality (e.g. intensive aeration of saliva), it can be interesting to extrapolate such situations in order to see how these alloys can be significantly deteriorated in some extreme situations.

Chemical compositions of the studied alloys: eight parent alloys and four post-solder alloys

HIGH NOBLE ALLOYS	Au	Pt	Pd	Ga	In	Other elements
dSIGN98	86	12	/	/	/	2.0 Zn
Aquarius Hard	86	8.5	2.6	/	1.4	
dSIGN91	60	/	31	1.0	8.4	
Lodestar	52	/	39	1.5	8.5	
W	54	/	26	/	1.5	16 Ag - 2.5 Sn
NOBLE ALLOY	Au	Pt	Pd	Ga	In	Other elements
dSIGN59	/	/	59	/	2.7	28 Ag 8.2 Sn– 1.3 Zn
PREDOMINANTLY BASE ALLOYS	Ni	Cr	Mo	W	Si	Other elements
4ALL	61	26	11	/	1.5	/
Pisces Plus	62	22	/	11	2.6	2.3 Al

(alloys used for the metallic frameworks reinforcing fixed partial dentures)

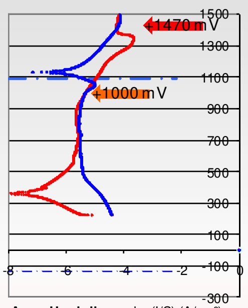
POST-SOLDER ALLOYS	Au	Ag	Cu	Ga	Other elem[nts]	for
.650	65	13	20	2		dSIGN98
.615	61	13	17	/	7.6 In	d91, d59, Lodestar
.585	59	16	18	7	/	Aquarius Hard
LFWG	56	27	/	/	16 Zn	W, Pisces Plus, 4ALL

Preparation of the Fusayama saliva

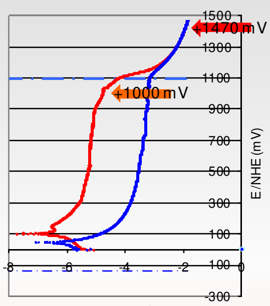
(acidified to pH=2.3 with lactic acid and heated to 37°C)

Chemical products	Concentrations
KCl	0.4 g/L
NaCl	0.4 g/L
$CaCl_2, 2H_2O$	0.906 g/L
$NaH_2PO_4, 2H_2O$	0.690 g/L
$Na_2S, 9H_2O$	0.005 g/L
urea	1 g/L

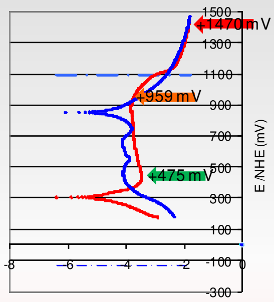
Examples of initial polarization curves and of the constant potentials applied



Aqua.Hard alloy: log(I/S) (A/cm²)

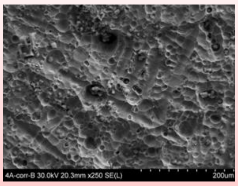


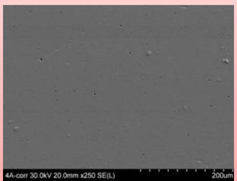
Pisces+alloy: log(I/S) (A/cm²)

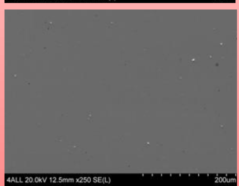


.585 alloy: log(I/S) (A/cm²)

4ALL parent alloy


after 72h of polarization at +1470mV/NHE


after 72h of polarization at +1000mV/NHE


initial microstructure

Surface deterioration and ICP analyses of the artificial saliva

ICP results for the electrolyte after the 72 hours-tests at imposed anodic potential; typically the "*nothing*", "*traces*", "low", "MEDIUM", "**HIGH**" and "**VERY HIGH**" notations correspond respectively to the following ranges: < 1ppb, between 1 and 10 ppb, between 10 and 100 ppb, between 100 and 1000 ppb, between 1000 and 10 000, and more than 10 000ppb.

Correspondence with the Pourbaix's domains and semi-quantitative ICP results

dSIGN98	86% Au	12% Pt	2%Zn
crit. **1 Mol/L** or 10^{-6}Mol/L if +1470mV	**$Au(OH)_3$** $Au(OH)_3$ MEDIUM	**PtO_2** PtO_2 **HIGH**	**Zn^{++}** Zn^{++} **HIGH**
crit. **1 Mol/L** or 10^{-6}Mol/L if +1000mV	**Au^0** Au^0 *nothing*	**PtO_2** PtO_2 *nothing*	**Zn^{++}** Zn^{++} MEDIUM

Aqu. Hard	86% Au	8.5% Pt	2.6% Pd	1.4% In
crit. **1 Mol/L** or 10^{-6}Mol/L if +1470mV	**$Au(OH)_3$** $Au(OH)_3$ MEDIUM	**PtO_2** PtO_2 MEDIUM	**$Pd(OH)_4$** $Pd(OH)_4$ MEDIUM	**In^{+++}** In^{+++} MEDIUM
crit. **1 Mol/L** or 10^{-6}Mol/L if +1000mV	**Au^0** Au^0 *nothing*	**PtO_2** PtO_2 *nothing*	**$Pd(OH)_2$** $Pd(OH)_2$ *nothing*	**In^{+++}** In^{+++} *nothing*

dSIGN91	60% Au	31% Pd	1.0% Ga	8.4% In
crit. **1 Mol/L** or 10^{-6}Mol/L if +1470mV	**$Au(OH)_3$** $Au(OH)_3$ *traces*	**$Pd(OH)_4$** $Pd(OH)_4$ *traces*	**Ga_2O_3** Ga^{+++} *traces*	**In^{+++}** In^{+++} low
crit. **1 Mol/L** or 10^{-6}Mol/L if +1000mV	**Au^0** Au^0 *nothing*	**$Pd(OH)_2$** $Pd(OH)_2$ *nothing*	**Ga_2O_3** Ga^{+++} *nothing*	**In^{+++}** In^{+++} *traces*

Lodestar	52% Au	39% Pd	1.5% Ga	8.5% In
crit. **1 Mol/L** or 10^{-6}Mol/L if +1470mV	**$Au(OH)_3$** $Au(OH)_3$ *traces*	**$Pd(OH)_4$** $Pd(OH)_4$ low	**Ga_2O_3** Ga^{+++} *traces*	**In^{+++}** In^{+++} low
crit. **1 Mol/L** or 10^{-6}Mol/L if +1000mV	**Au^0** Au^0 *traces*	**$Pd(OH)_2$** $Pd(OH)_2$ *traces*	**Ga_2O_3** Ga^{+++} *traces*	**In^{+++}** In^{+++} *traces*

W	54% Au	26% Pd	16%Ag	1.5% In	2.5% Sn
crit. **1 Mol/L** or 10^{-6}Mol/L if +1470mV	**$Au(OH)_3$** $Au(OH)_3$ *traces*	**$Pd(OH)_4$** $Pd(OH)_4$ *traces*	**Ag^+ / Ag_2O_3** Ag^+ *traces*	**In^{+++}** In^{+++} *traces*	**$Sn(OH)_4$** $Sn(OH)_4$ **HIGH**
crit. **1 Mol/L** or 10^{-6}Mol/L if +1000mV	**Au^0** Au^0 *nothing*	**$Pd(OH)_2$** $Pd(OH)_2$ *nothing*	**Ag^+** Ag^+ *nothing*	**In^{+++}** In^{+++} *nothing*	**$Sn(OH)_4$** $Sn(OH)_4$ MEDIUM
crit. **1 Mol/L** or 10^{-6}Mol/L if +500mV	**Au^0** Au^0 *traces*	**Pd^0** Pd^0 *nothing*	**Ag^0** Ag^+ *traces*	**In^{+++}** In^{+++} *traces*	**$Sn(OH)_4$** $Sn(OH)_4$ **HIGH**

dSIGN59	59% Pd	28%Ag	2.7% In	8.2% Sn	1.3% Zn
crit. **1 Mol/L** or 10^{-6}Mol/L if +1000mV	**$Pd(OH)_2$** $Pd(OH)_2$ *nothing*	**Ag^+** Ag^+ *traces*	**In^{+++}** In^{+++} *traces*	**$Sn(OH)_4$** $Sn(OH)_4$ **HIGH**	**Zn^{++}** Zn^{++} **HIGH**
crit. **1 Mol/L** or 10^{-6}Mol/L if +400mV	**Pd^0** Pd^0 *nothing*	**Ag^0** Ag^0/Ag^+ *nothing*	**In^{+++}** In^{+++} *nothing*	**$Sn(OH)_4$** $Sn(OH)_4$ low	**Zn^{++}** Zn^{++} MEDIUM

4ALL	61% Ni	26% Cr	11% Mo
crit. **1 Mol/L** or 10^{-6}Mol/L if +1470mV	**NiO_2** Ni^{++} **VERY HIGH**	**$HCrO_4^-$** $HCrO_4^-$ **VERY HIGH**	**MoO_3** $HMoO_4^-$ **VERY HIGH**
crit. **1 Mol/L** or 10^{-6}Mol/L if +1000mV	**Ni^{++}** Ni^{++} MEDIUM	**$Cr(OH)_3$** Cr^{+++} low	**MoO_3** $HMoO_4^-$ low

Pisces Plus	62% Ni	22% Cr	11% W
crit. **1 Mol/L** or 10^{-6}Mol/L if +1470mV	**NiO_2** Ni^{++} **VERY HIGH**	**$HCrO_4^-$** $HCrO_4^-$ **VERY HIGH**	**WO_3** WO_3 **VERY HIGH**
crit. **1 Mol/L** or 10^{-6}Mol/L if +1000mV	**Ni^{++}** Ni^{++} **VERY HIGH**	**$Cr(OH)_3$** Cr^{+++} **HIGH**	**WO_3** WO_3 **HIGH**

.585	59% Au	16% Ag	18% Cu	7.2% Ga
crit. **1 Mol/L** or 10^{-6}Mol/L if +1470mV	**$Au(OH)_3$** $Au(OH)_3$ **HIGH**	**Ag^+** Ag^+ low	**Cu^{++}** Cu^{++} **VERY HIGH**	**Ga_2O_3** Ga^{+++} **VERY HIGH**
crit. **1 Mol/L** or 10^{-6}Mol/L if +959mV	**Au^0** Au^0 *traces*	**Ag^+** Ag^+ *traces*	**Cu^{++}** Cu^{++} MEDIUM	**Ga_2O_3** Ga^{+++} MEDIUM
crit. **1 Mol/L** or 10^{-6}Mol/L if +475mV	**Au^0** Au^0 *nothing*	**Ag^0** Ag^+ *traces*	**Cu^{++}** Cu^{++} low	**Ga_2O_3** Ga^{+++} low

.615	61% Au	13% Ag	17% Cu	7.6% In
crit. **1 Mol/L** or 10^{-6}Mol/L if +430mV	**Au^0** Au^0 *nothing*	**Ag^0** Ag^0/Ag^+ *nothing*	**Cu^0/Cu^{++}** Cu^{++} low	**In^{+++}** In^{+++} *traces*

.650	65% Au	20% Cu	13% Ag	2% Ga
crit. **1 Mol/L** or 10^{-6}Mol/L if +430mV	**Au^0** Au^0 *nothing*	**Cu^0/Cu^{++}** Cu^{++} low	**Ag^0** Ag^0/Ag^+ *nothing*	**Ga_2O_3** Ga^{+++} *nothing*

LFWG	56% Au	27% Ag	16% Zn
crit. **1 Mol/L** or 10^{-6}Mol/L if +1470mV	**$Au^0/Au(OH)_3$** $Au(OH)_3$ low	**Ag_2O_3/Ag^+** Ag^+ *traces*	**Zn^{++}** Zn^{++} **HIGH**
crit. **1 Mol/L** or 10^{-6}Mol/L if +1000mV	**Au^0** Au^0 *traces*	**Ag^+** Ag^+ *traces*	**Zn^{++}** Zn^{++} **HIGH**
crit. **1 Mol/L** or 10^{-6}Mol/L if +490mV	**Au^0** Au^0 *nothing*	**Ag^0** Ag^+ /Ag^0 *nothing*	**Zn^{++}** Zn^{++} MEDIUM

The dental alloys studied here are very corrosion-resistant, thanks to their high contents in noble elements (Au, Pt, Pd), or to the fact that their main elements can get easily passivated (e.g. Cr). However, their long-time exposure to a very high potential may lead to detectable corrosion for some of these alloys. Fortunately, such high potentials (+1000mV/NHE) are not probable in real situation, since this should suppose, for example, a saliva extremely aerated on long times. Furthermore potentials 500mV higher are of course strictly not possible to achieve in natural conditions. But it was interesting to see that the alloys, even of the High Noble category, did not behave all similarly.