Corrosion Behavior of Alloy U2.5Zr7.5Nb in Relation to Phase Stability

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Introduction

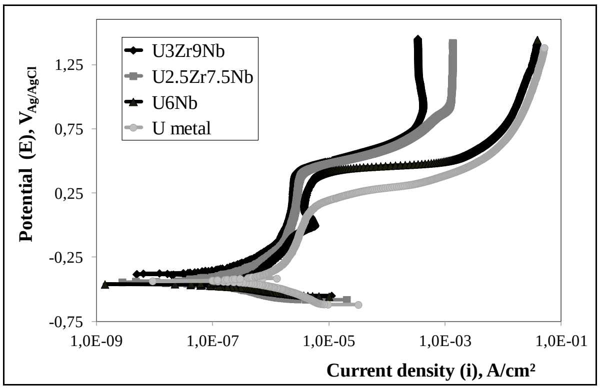
Metallic nuclear fuel can be constituted by uranium alloys with density up to 17.5 g/cm^3 which is much higher than the usual uranium oxide fuel density, 10.5 g/cm^3. Higher uranium density provides greater neutron flux and therefore better performance in the reactor, even keeping the fuel enrichment limit of 20% U-235 as established by international agreements [1,2]. Uranium corrodes in room-temperature air at a rate slightly less than that of cast iron, but with the addition of alloying elements the corrosion behavior greatly improves. Uranium is commonly alloyed with γ-phase stabilizer elements such as zirconium, niobium, molybdenum and titanium. UZrNb alloys combine high mechanical strength due to niobium with the stability under irradiation achieved by zirconium. In this paper the corrosion behavior of U2.5Zr7.5Nb submitted to different heat treatments (HTs) was evaluated.

Experimental

The material investigated in this work was cast in an induction furnace at 1500 °C. Ingots were obtained in a raw state of fusion and submitted to HTs at 300 ºC during 100, 1000 and 10000 min and at 600 ºC during 100 min. After that, samples for the electrochemical tests were cut from the ingot, embedded in resin, ground with emery paper and polished with diamond paste up to 1 μm. The tests were performed in a three-electrode electrochemical cell, at 25 ºC, with Ag/AgCl (3M KCl) as the reference electrode and a platinum plate as the auxiliary electrode. Three tests were performed for each condition. The test solution contained 1000 ppm B, 2 ppm Li and Na_2SO_4 as support electrolyte to increase the solution conductivity. The solution was deaerated with N_2 gas for 50 min before the tests. The potentiodynamic polarization tests were performed with a scan rate of 0.000167 $V.s^{-1}$. The potential was scanned from -0.2 V to 1.5 V with relation to the open circuit potential. The impedance measurements were performed with 10 mV RMS amplitude and 12 kHz to 5 mHz frequency range. The tests were performed using an Autolab potentiostat PGSTAT20 with softwares GPES (General Purpose Electrochemical System 4.9) and FRA (Frequency Response Analysis 4.9).

Results and Discussion

The corrosion behavior of uranium and U2.5Zr7.5Nb casting alloy is presented in Figure 1 and corrosion results of alloys U3Zr9Nb and U6Nb are also shown for comparison. From these curves it is evident the benefit of adding alloy elements to increase the corrosion resistance of uranium alloys as observed for the U3Zr9Nb alloy due to presence of the higher alloy elements concentration. This behavior can be easily evaluated from the impedance data in Fig. 1b and Fig. 1c. The results for alloy U2.5Zr7.5Nb submitted to HTs at 300 ºC for different periods of time can be seen in Figure 2. In this figure, we can observe that the HTs caused an increase in the corrosion resistance of the alloy. The HT at 300 ºC for 1000 min resulted in a higher corrosion resistance, clearly seen by the impedance data (Fig.2b and Fig. 2c). As known, the predominant phase for 1000 min and 10000 min is the monoclinic α” phase which presents good chemical stability and mechanical strength [3-5]. For 1000 min a small amount of γ phase is still present, but for 10000 min the alloy microstructure is completely constituted of α” phase [3]. Considering a time period of 100 min, Figure 3 shows the effect of temperature on the corrosion resistance of the U2.5Zr7.5Nb alloy, for two conditions, 300 ºC and 600 ºC. As can be seen, the results at 300 ºC showed higher corrosion resistance. The corrosion behavior at 300 ºC can be associated to phase stability when transition elements are added to uranium [5].



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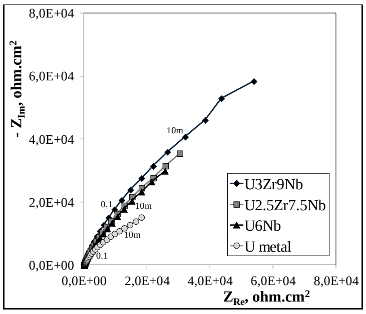
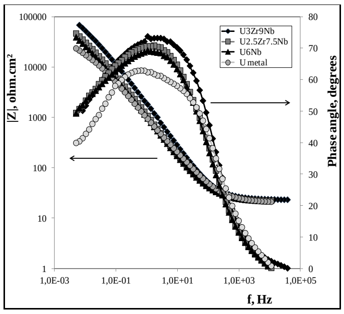
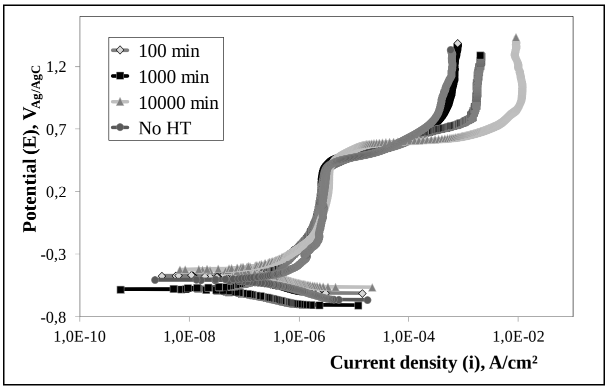




(b) (c)

Figure 1. Corrosion behavior of uranium and casting alloys; a) polarization curves; b) Nyquist plots; c) Bode plots.



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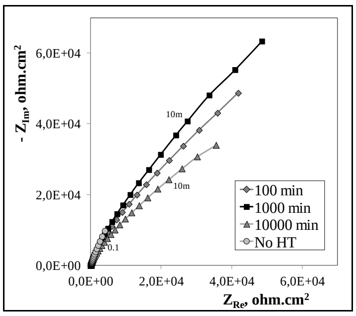
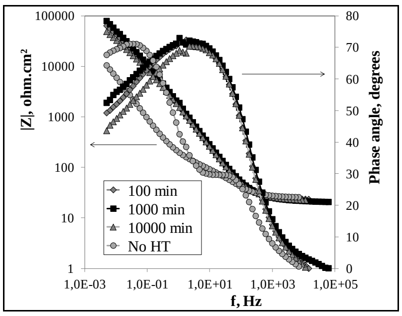
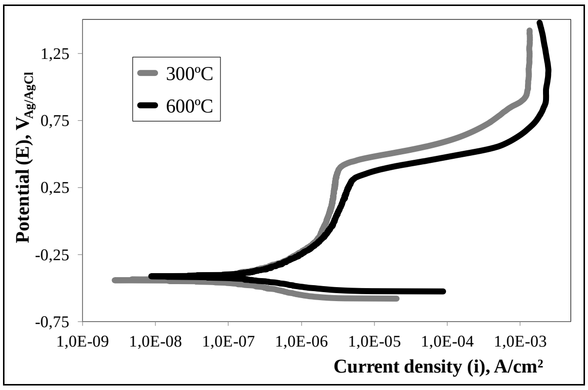




(b) (c)

Figure 2. Effect of HT time on the corrosion behavior of uranium alloy U2.5Zr7.5Nb submitted to different times of heat treatment at 300ºC; a) polarization curves; b) Nyquist plots; c) Bode plots.



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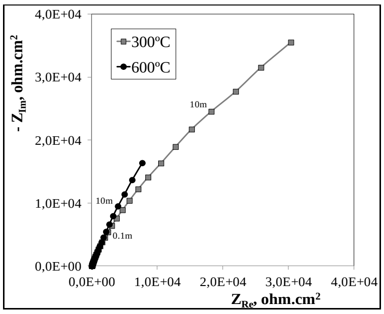
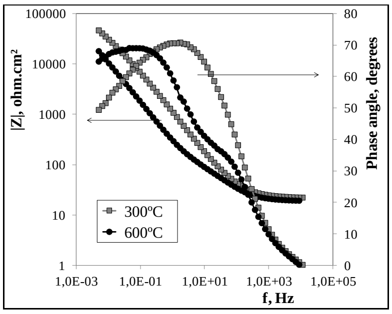


(b)



(c)

Figure 3. Effect of temperature on the corrosion behavior of U2.5Zr7.5Nb alloy for 100 min HT; a) polarization curves; b) Nyquist plots; c) Bode plots.

Conclusions

The corrosion behavior of uranium and its alloys was studied using electrochemical tests. The corrosion resistance is directly associated with phases transformation that can occur in different conditions of heat treatments. The uranium alloys heat treated at 300 ^{o}C for times superior to 100 min showed good corrosion resistance. The effect of temperature for heat treatments during 100 min for alloy U2.5Zr7.5Nb showed lower resistance for the heat treatment at 600 ºC. This behavior can be associated to phase stability when transition elements are added to uranium.

Acknowledgements

The authors thank CNPq and FAPEMIG for the financial support to develop and present this work.

References

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