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Preliminary research on the use of SVET in non-aqueous media

A.C. Bastos*, M.C. Quevedo, M.G.S. Ferreira

DEMaC – Department of Materials and Ceramic Engineering and CICECO – Aveiro Institute of Materials, University of Aveiro, 3810-193 Aveiro, Portugal

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ABSTRACT

An investigation is presented on the use of the scanning vibrating electrode technique (SVET) in non-aqueous media, namely pure ethanol and ethanol saturated with NaCl. The SVET was able to measure the ionic currents flowing in the liquid phase between anodes and cathodes in electrochemical systems such as platinum disk electrodes connected to a battery, a zinc–iron galvanic couple, painted galvanised steel with artificial defects and alumina coated cast aluminium alloy. The results show the applicability of the technique in non-aqueous highly resistive medium.

1. Introduction

The Scanning Vibrating Electrode Technique (SVET) is used in corrosion research since the early 1980s after the work of Hugh Isaacs [1–4]. It has been applied to characterise many corrosion systems of localized nature as, for example, galvanic corrosion [5–8], pitting corrosion [9–12], crevice corrosion [13], stress corrosion cracking [14], microbiologically influenced corrosion [15], inorganic coatings [6,16,17], organic coatings [18–21], corrosion inhibitors [22–24], and conducting polymers [25,26]. Another field where the SVET is used, and in fact where it was developed, is biology and the life sciences, where it is known as vibrating probe and is applied in areas like electrophysiology [27–31], morphogenesis [32–34], cellular differentiation [35], tissue regeneration and would healing [29,36–38].

In all cases, the medium, either corrosion environment or biological fluid, is of aqueous nature but this is not a requisite. Since SVET measures the electrical field in solution associated to the electrical current flowing therein, it should work in any liquid crossed by a current. Notwithstanding, no references can be found with SVET measurements in non-aqueous medium. This paper describes a series of experiments performed in organic medium to analyse the SVET operation in such conditions.

2. Experimental

2.1. Non-aqueous media

The testing media were either pure ethanol (99.99%, Fisher Chemical) with a theoretical conductivity of 1.4×10^{-9} S cm^{-1} [39] or pure ethanol saturated with NaCl (p.a. grade reagent, >99,8%, Sigma–Aldrich) with a conductivity of 2.4×10^{-4} S cm^{-1} (23.5 °C) measured with Inlab 731 conductivity probe connected to SevenMulti Meter from Mettler Toledo. The reported solubility of NaCl in pure ethanol is 0.55 g/Kg$_{solvent}$ [40]. Ethanol was the chosen solvent because it is easily available, relatively safe and has a moderate evaporation rate. It is polar and protic, like water, which seems advisable for first trials.

2.2. Materials and samples

Four different samples were analysed in this work. The first comprised two platinum wires of 1 mm diameter embedded in epoxy resin (EpoKwick, Buehler, USA) and electrically connected to a battery, as shown in Fig. 1a). The second sample was similar to the first except that 1 mm pure iron and 1 mm pure zinc wires (99.99+%, Goodfellow, UK) were used in place of the platinum wires. The surfaces of the embedded metallic wires were abraded to 1200 grit finish with SiC paper, washed in distilled water followed by pure ethanol. A third sample consisted of 1×1 cm^2 piece of coil-coated steel. The steel sheet was 800 μm thick with 7.5 μm layer of electrodeposited zinc and 20 μm thick epoxy paint pigmented with TiO_2. Nine small defects were manually produced with a needle. The sample was glued to an epoxy holder with an

* Corresponding author. Tel.: +351 234378146.
E-mail address: acbastos@ua.pt (A.C. Bastos).

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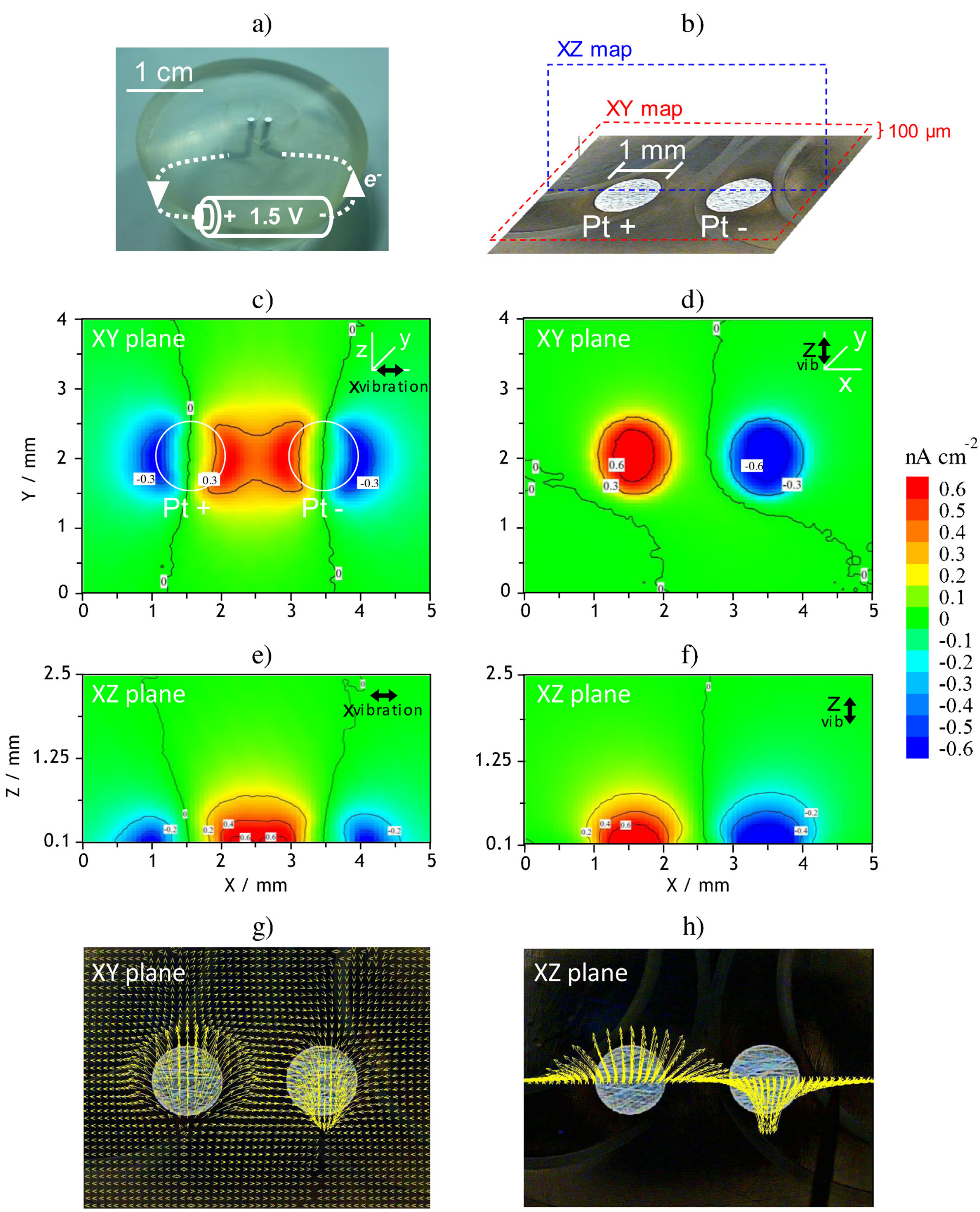

Fig. 1. SVET measurements over Pt electrodes connected to a battery in pure ethanol ($\kappa = 1.4 \times 10^{-9}$ S cm^{-1},[39]); a) test cell consisting of two platinum disks of 1 mm diameter embedded in epoxy resin and connected to 1.5 V battery; b) position of SVET maps measured above the 2 platinum disks in the plane parallel to the surface (XY) and a plane normal to the surface (XZ); c)-f) current density maps measured in the two planes depicting the x and z current density components measured by each SVET vibration; g)-h) 2D vectors of the same current density shown in c)-f).

embedded wire which allowed electrical connection from the back. The edges were protected with epoxy cement and further isolated with varnish (Lacomit, Agar Scientific, UK). The forth sample was a piece of LM24 cast aluminium alloy (AlSi8Cu3Fe) coated with 100 μm thick layer of alumina (Al_2O_3) deposited by plasma spraying. The sample was glued to an epoxy holder with electrical connection and the edges were isolated with a mixture of beeswax and colophony in a proportion 3:1 by weight. Adhesive