# Differential Impedance Analysis – a New Tool for Conductivity Studies of Yttria Stabilized Zirconia

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## INTRODUCTION

Yttria stabilised zirconia (YZS) is an important solid electrolyte with applications for SOFC and oxygen separators, due to its good electrical and mechanical properties. Although well known and widely investigated, this material continues to be attractive for deeper conductivity studies, which are expected to improve the possibilities for its application. It has been firmly established (1,2) that the ionic conductivity of the material takes place by a vacancy mechanism. The high concentration of the dopant $Y_2O_3$ aids the formation of associates, which serve as vacancy trapping centers. What is less known and uncertain is the mobility and concentration of the free vacancies able to take part in the mass transport process and their temperature dependence. The existence of vacancy ordered phases (microdomains) with different temperature stability is also supposed. In addition, the conductivity of the material is strongly affected by its complicated microstructure.

The application of the Electrochemical Impedance Spectroscopy, which could separate the bulk from the grain boundary properties, provides for a better understanding of their contribution in the total conductivity process. The region of mixing, however, conceals part of the information concerning the bulk properties. The accuracy of the analysis is additionally hampered by the necessity of a preliminary working hypothesis, which gives very often a simplified description of the observed impedance picture.

This work presents an impedance study of both single crystal and polycrystalline YSZ, which provides for a better understanding of the material's properties. The impedance data analysis is performed by the new structural approach, known as Differential Impedance Analysis (DIA) (3, 4). It does not require a preliminary working hypothesis since it extracts the impedance model from the experimental data. In addition, DIA ensures recognition of distributed parameters' behavior.

## EXPERIMENTAL

YSZ single crystal and polycrystalline samples were measured on Solartron 1260 FRA over a wide frequency range (13 MHz - 0,1Hz) with density 9 points per decade within a temperature interval 20$^o$C – 950$^o$C.

The presentation includes more detailed information about the principle of the DIA and its application in this investigation. A catalogue with impedance models and their DIA images is applied to help the interpretation of the results.

## RESULTS AND DISCUSSION

One of the experimental problems concerning the impedance analysis of YSZ bulk conductivity is its sharp temperature dependence. In practice at temperatures above 300$^o$C the high frequency semicircle, corresponding to the bulk properties, disappears. The picture is additionally complicated by the appearance of an inductive "tail". These inaccuracies influence the correctness of the Arrhenius plot, obtained from the impedance analysis. In some works a kink is found at about 700$^o$ C (1), while in others a gradual transition in a wide temperature interval is reported (2). In this study a special algorithm for correction of the parasitic inductance is introduced. It ensures a more precise determination of the bulk conductivity and its temperature dependence. We suppose that the kink in the Arrhenius plot, presented in Fig.1, is due to the increased degradation of vacancy trapping associates.

Since the low frequency impedance of YSZ is usually attributed to the electrode response (2), it is very often eliminated from the impedance analysis. The application of DIA, however, recognizes a transport behavior, which changes its character with the temperature. This result introduces the idea for optimization of the conductivity in YSZ and other solid electrolyte materials by controlling the transport processes, which can be registered by DIA in the low frequency range.

## ACKNOWLEGEMENTS

The authors gratefully acknowledge the financial support of the Royal Society for this study.

## REFERENCES

1. S. P. S. Badwal, L. Mater. Sci., **19**, 1767 (1984)

2. P. S. Manning, J. D. Sirman, R. A. De Souza and J. A. Kilner, Solid State Ionics, **100**, 1 (1997)

3. Z. Stoynov, Polish J. Chem., **71**, 1204 (1997).

4. D. Vladikova, P. Zoltowski, E. Makowska and Z. Stoynov, Electrochemica Acta, **47**, 2943 (2002)

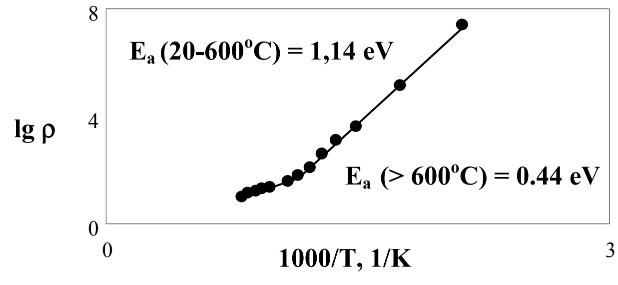


Fig. 1. Arrhenius plot for YSZ single crystal sample