Chemical Stability Of Sr(Ti,Fe)$O_{3-\delta}$ Exhaust Gas Sensors

Thomas Schneider[1], Ellen Ivers-Tiffée[1],
Harumi Yokokawa[2]

[1]Institut für Werkstoffe der Elektrotechnik IWE, Universität Karlsruhe (TH), Adenauerring 20b, 76131 Karlsruhe, Germany

[2]Fuel Cell Group, Energy Electronics Institute
National Institute of Advanced Industrial Science and Technology (AIST), AIST Tsukuba Central 5, Tsukuba 305-8565, Japan

Oxygen sensors for automotive applications control the air-fuel ratio in order to reduce fuel consumption. New control strategies for direct injection engines or lean burn engines operating with air excess (lambda > 1) require more advanced sensor concepts [1].

As a future option, research groups evaluate the features of a temperature independent resistive-type oxygen sensor based on semiconducting metal oxides.

Acceptor doped Sr(Ti,Fe)$O_{3-\delta}$ has been qualified as a resistive type oxygen sensor material [2], its electrical conductivity reflects the equilibrium between the oxygen partial pressure pO_2 in the atmosphere and the bulk stoichiometry at temperatures typically above 700 °C. In contrary to donor doped compounds, Sr(Ti,Fe)$O_{3-\delta}$ shows a long term stable and temperature independent characteristic [3].

The dependence of electrical conductivity on the oxygen partial pressure is well understood on a defect chemistry basis [4].
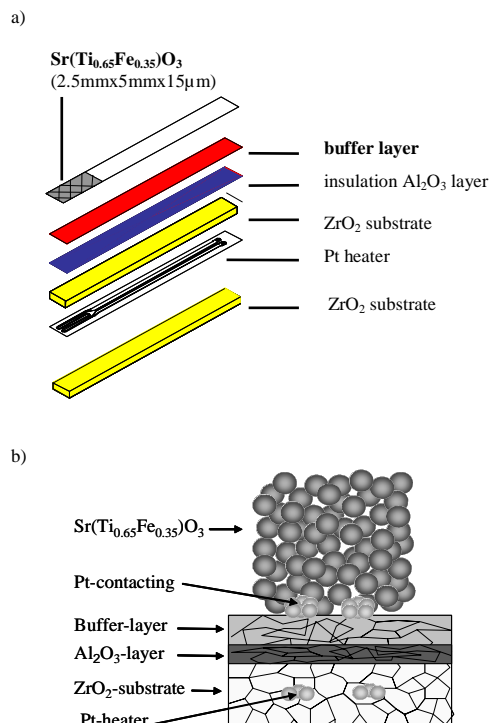

Fig. 1: Design concept of a planar exhaust gas sensor. Sr(Ti,Fe)$O_{3-\delta}$: resistive type oxygen sensor material

For the development of a planar type sensing element, Sr(Ti,Fe)$O_{3-\delta}$ has to be applied as a thick film on a zirconia substrate, which has integrated Pt heating elements as well as Pt contacts. Fig. 1 shows the design concept and the multi-layer structure of a planar exhaust gas sensor [5].

Temperature independence (at T=750...900°C, pO_2=10^{-6}...1 bar) and fast response times (t_{90}= 6.5 ms at 900 °C), both key issues of Sr(Ti,Fe)$O_{3-\delta}$, have to be maintained over the entire lifetime of the sensing element. In this work, financially supported by the BMBF (PTJ-NMT 03N3102), the stability of the interface Sr(Ti,Fe)$O_{3-\delta}$/Al_2O_3 was investigated by interdiffusion experiments and by the calculation of chemical potential diagrams (CPD) using the software MALT [6,7,8,9].

CPDs have been calculated for the solid solution end members $SrTiO_3$ and $Sr_2Fe_2O_5$, both in contact with the insulating Al_2O_3 layer, for T=750...900°C and pO_2, as shown in figures 2 and 3.

The results support the development of a buffer layer, which inhibits the interdiffusion and the formation of secondary layers at the interface Sr(Ti,Fe)$O_{3-\delta}$/Al_2O_3
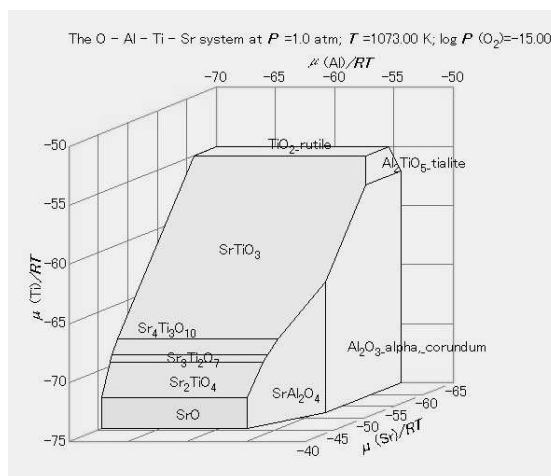

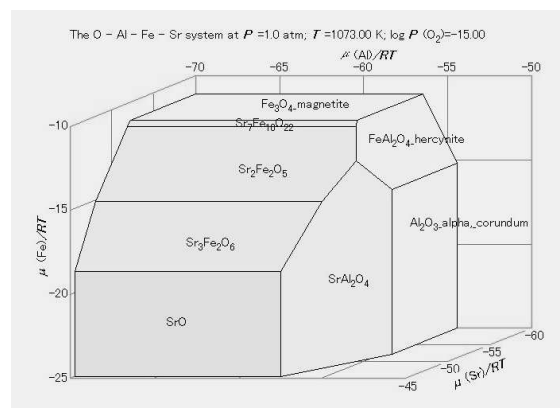Fig. 2: Chemical potential diagram of Sr-Ti-O-Al system at T=800 °C and pO_2=10^{-15} bar

Fig. 3: Chemical potential diagram of Sr-Fe-O-Al system at T=800 °C and pO_2=10^{-15} bar

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