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MEASUREMENTS ABOUT THE EFFECT OF GRAIN BOUNDARIES ON THE ELECTRICAL RESISTIVITY OF URANIUM DIOXIDE

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One of the reasons for the scattering in electrical resistivity data of UO₂ (up to 4 orders of magnitude at room temperature!) may be the difference in grain size. To find out to what extent grain boundaries can affect the UO₂ electrical resistivity the following measurements have been made. Two types of UO₂ specimens having different grain sizes have been used, the chemical analysis and stoichiometry of which were very similar (UO ratios: 1.96 for coarser grain; 1.98 for finer grain). Starting with the same powder, the compacts have been prepared by extrusion (\( \rho = 10.69 \, \text{g/cm}^3 \approx 97.6\% \, \text{TD} \)). Different heat treatments led to the different microstructures shown in fig. 1. A rough stereometric analysis using Tomkeiff’s

Fig. 1. Microstructure of coextruded UO₂ with different grain size; etchant: HCL + HNO₃ (1:1). \( \times 450 \)
equation 2)

\[ S_Y = \frac{2}{L} \]

(\(L\)—measured mean intercept length) shows that the total internal surface (grain boundary area) per unit test volume of UO\(_2\) (\(S_Y\)) is approximately twice as large in the fine grained UO\(_2\) as in the coarser one (fig. 1). Three specimens of each type of microstructure have been used for measuring the temperature dependence of the electrical resistivity. The resulting curves are shown in fig. 2 demonstrating that the electrical resistivity of the coarser grained UO\(_2\) is approximately one order of magnitude higher than that of the finer grained UO\(_2\) at all temperatures in the measured range.

Due to the different heat treatments of the specimens they should also have different amounts of lattice defects. This— as well as the different microstructure—could be the reason for the difference in the electrical resistivity. Lattice defects, however, would create an effect opposite to that shown in fig. 2: the finer grained material should have the higher resistivity because of the higher concentration of lattice defects. Consequently, one can assume that the difference in the electrical resistivity shown here comes from the different grain size. Because of the high electrical resistivity of the UO\(_2\) crystallites the conductivity of the bulk material is improved by the grain boundaries. These results were observed for polycrystalline NaCl [ref. 3)] as well as for Al\(_2\)O\(_3\) [ref. 4)], although in the latter case of Al\(_2\)O\(_3\) other workers 5) have reported low grain boundary conductivity. Both results, higher as well as lower grain boundary conductivity, can be explained in terms of “binder material” in the grain boundaries of Al\(_2\)O\(_3\) changing the electron affinity between the grain boundary and the crystal 6,7).

No conclusion can be drawn from the present results as to whether this effect occurs in UO\(_2\). In spite of the clear results here, it cannot be
stated generally, that the grain boundary conductivity of UO₂ at lower temperatures is always higher than that of the crystals.

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