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Guest Editorial

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In a general sense composite materials are materials consisting of several phases which are strategically combined to achieve overall materials properties being, at least with respect to a certain application, superior to those of the individual constituents. This means that beyond chemical synthesis the formation of composites allow for a tailoring of the materials parameters by varying the composititon of the phases or the microstructure. This flexibility is the basis of the great technological success of composites. (In some cases, materials prepared by combining constituents on a scale on which the term ''phase'' loses its validity, are called composites. Then the term ''composite'' and its demarcation with respect to a chemical compound becomes vague, too.) Particularly in the area of structural ceramics composites are very common and used to optimize mechanical or thermal properties. Fiber- and whisker-reinforced ceramics for the purpose of increasing fracture toughness might serve as an example of such structural ceramic composite [1].

On the other hand, composites are also predestined to optimize so-called functional qualities as electrical, optical, or magnetic properties. They are, for example, used (i) to combine good mechanical/ thermal properties of one phase with superior electrical or magnetic properties of another, (ii) to improve the overall property in a systematic way or (iii) to create new functional properties. In the latter case the whole system is definitely more than the sum of its parts. Such synergistically improved functional properties might be related to a particular microstructure (e.g., in thick film resistors) or to chemical/physical interaction of the phases. In particular the unique features of interface regions between different phases allow for a tailoring of materials qualities. It can especially be expected that nanocomposites will play an important role in future. This is not only due to the fact that they exhibit an increased interface-to-volume ratio, they also allow for mesoscalic phenomena emerging from the fact that typical phenomenological length scales become comparable with the sample size [2].

Many ''functional composites'' consist of electroceramic materials, and in view of the flood of information in this area it is definitely worth to review the status and recent progress of electroceramic composites. However, owing to the limited space only some aspects can be treated in this special issue. We decided to restrict the content (i) to an introduction into the theoretical concepts to calculate and predict electrical composite properties and (ii) to an overview of the composite activities dealing with ionic conduction in at least one of the constituents and, related to that, to activities in the area of energy conversion systems such as fuel cells and batteries.

Hence several equally important topics of electroceramic composites are not addressed and the reader is referred to recent reviews e.g., on electronically conducting polymer composites [3], multilayer ceramic capacitors [4], piezoelectric ceramic-polymer composites [5,6].

Two important methods to theoretically describe composite properties are percolation theory and effective medium theory and each approach is reviewed in an article (A. Bunde and W. Dieterich, ''Percolation in Composites'' and D. S. McLachlan, ''Analytical Functions for the dc and ac Conductivity of Conductor-Insulator Composites''). Moreover, finite element and resistor network calculations become more and more important to determine the spatial field distribution in composites (e.g., electrical potential and current lines). This topic is not addressed in a separate paper but application examples are given in [7] and [8].

The ionic conductivity of several solid electrolytes can be enhanced by admixing comparably insulating phases. This so-called heterogeneous doping [2] turned out to be a general strategy to tailor the electrical properties of a given phase comparable with the classical doping. Several aspects of such ionically conducting composites are reviewed by P. Knauth

(''Ionic Conductor Composites: Theory and Materials''). One of the commercially most important electrochemical applications are Li-batteries and an intensive search for optimized electrolytes is running. This topic is addressed by B. Kumar and L. G. Scanlon (''Composite Electrolytes for Lithium Rechargable Batteries''). In fuel cells composite electrodes are of actual or potential interest and usually consist of both electrolyte and current collector particles yielding improved electrochemical performance as well as better thermomechanical properties. The status of such electrodes is summarized by M. Mogensen, S. Primdahl, M. J. Jorgensen, and C. Bagger (''Composite Electrodes in Solid Oxide Fuel Cells and Similar Solid State Devices''). The special issue is completed by an article dealing again with solid oxide fuel cell composite electrodes but now from a theoretical point of view (S. Sunde, ''Simulations of Composite Electrodes in Fuel Cells'').

Although we are aware of the fact that only a small part of composites in electroceramics could be dealt with we hope that the reader gets an impression on the potentials and recent progress but also on the complexity of this fascinating field.

References

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