Journal of ELECTRONIC MATERIALS, Vol. 42, No. 7, 2013
DOI: 10.1007/s11664-013-2579-y
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Simulations for the Development of Thermoelectric Measurements

KNUD ZABROCKI,[1,2] PAWEL ZIOLKOWSKI,[1] TITAS DASGUPTA,[1] JOHANNES DE BOOR,[1] and ECKHARD MÜLLER[1]

1.—German Aerospace Center (DLR), Institute of Materials Research, Thermoelectric Materials and Systems, Linder Höhe, 51147 Cologne, Germany. 2.—e-mail: knud.zabrocki@dlr.de

In thermoelectricity, continuum theoretical equations are usually used for the calculation of the characteristics and performance of thermoelectric elements, modules or devices as a function of external parameters (material, geometry, temperatures, current, flow, load, etc.). An increasing number of commercial software packages aimed at applications, such as COMSOL and ANSYS, contain vkernels using direct thermoelectric coupling. Application of these numerical tools also allows analysis of physical measurement conditions and can lead to specifically adapted methods for developing special test equipment required for the determination of TE material and module properties. System-theoretical and simulation-based considerations of favorable geometries are taken into account to create draft sketches in the development of such measurement systems. Particular consideration is given to the development of transient measurement methods, which have great advantages compared with the conventional static methods in terms of the measurement duration required. In this paper the benefits of using numerical tools in designing measurement facilities are shown using two examples. The first is the determination of geometric correction factors in four-point probe measurement of electrical conductivity, whereas the second example is focused on the so-called combined thermoelectric measurement (CTEM) system, where all thermoelectric material properties (Seebeck coefficient, electrical and thermal conductivity, and Harman measurement of zT) are measured in a combined way. Here, we want to highlight especially the measurement of thermal conductivity in a transient mode. Factors influencing the measurement results such as coupling to the environment due to radiation, heat losses via the mounting of the probe head, as well as contact resistance between the sample and sample holder are illustrated, analyzed, and discussed. By employing the results of the simulations, we have developed an improved sample head that allows for measurements over a larger temperature interval with enhanced accuracy.

Key words: Measurement of thermoelectric properties, electrical resistivity/conductivity measurement, error correction, finite-element modeling, ANSYS

INTRODUCTION

Thermoelectricity, as one form of direct energy conversion[1–3] where heat is directly converted into electricity or vice versa, is currently a field of active research which offers open issues and problems for chemists, materials scientists, mathematicians, physicists, and engineers.[4–13] The focus of such investigations lies on the development of new thermoelectric (TE) materials and their characterization. Materials research aims to increase the electrical conductivity σ and Seebeck coefficient α, while a low thermal conductivity κ must be adjusted

(Received July 22, 2012; accepted March 20, 2013; published online May 1, 2013)