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Characterization of the Thermoelectric Behavior of Plastically Deformed Steels

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Different studies on the thermoelectric behavior of metals and metal alloys expose an influence of plastic deformation on the Seebeck coefficient. At present a detailed, quantitative analysis and descriptions of the effects of plastic deformation are not available, even though the thermoelectric properties are of fundamental importance for both theory and application. Therefore, the impact of plastic deformations on the temperature-dependent thermoelectric behavior of steel alloys is introduced in this paper. To achieve this, a device based on the integral measuring method was built to measure the relative Seebeck coefficient of steel alloys to platinum at different temperature gradients and for several degrees of plastic deformation. Well-defined values of plastic deformation were realized by cold rolling. With this compressive forming technology, logarithmic deformation up to 2.2 was set for all steel samples. Increasing plastic deformation results in a significant change in the relative Seebeck coefficient for all tested steel alloys. A relation between the thermoelectric behavior and plastic deformation of steels can be clearly illustrated based on the combination of metallurgical examinations and measurements of microhardness. These results provide new insights into the thermoelectric mechanism in steels in diverse plastic deformation states.

Key words: Thermoelectric, steel, plastic deformation, Seebeck coefficient, integral method

INTRODUCTION

The thermoelectric phenomenon can be applied across a promising spectrum of applications. Power generation from waste heat and the cooling of devices are very popular research and application examples. Therefore, typical thermoelectric materials are semiconductors with high charge carrier concentration because of their high figure of merit, which characterizes the efficiency of the material.[1,2]

In contrast, metals are not suitable due to their low figure of merit, and on this account, little attention has been paid to their behavior recently.[3] Metal alloys are usually used in practical temperature measurements with thermocouples due to their thermoelectric behavior, especially the Seebeck effect.

Another important field of application is nondestructive testing, such as sorting or quality testing of metals and metal alloys.[4,5] In many fields of mechanical engineering, particularly in metal forming, detection of plastically deformed materials by nondestructive characterization is of great interest; For instance, the correlation between the degree of deformation and the thermoelectric behavior can help to check formed metal parts or crushed automotive parts regarding their serviceability. In this context it is a great advantage that the thermoelectric voltage does not depend on the geometric form of the test sample.

Detailed knowledge of thermoelectric behavior is required for all of these applications, but the approach and requirements are quite different from investigations on semiconductors. Besides the dif-

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