Crystal alignment by imposing a magnetic field during solidification

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Alignment of crystals having an anisotropic unit cell structure can enhance anisotropy of physical, chemical and/or biological properties, and thus a lot of investigations on the crystal alignment have been done for many industrial applications. One of the crystal alignment methods is imposition of a magnetic field on the crystals under the condition that they can rotate to reduce magnetization energy. In this presentation, improvement of thermoelectric property of higher manganese silicide having a chemical formula of $MnSi_{1.73}$ synthesized by solidification under the imposition of the static magnetic field[1)] and a suitable condition for crystal alignment during solidification[2, 3)] are mentioned. .

Pure manganese and silicon were prepared as raw materials, and they were mixed with a molar ratio of 1:1.8. The mixture was heated under argon atmosphere using an induction heating system for its complete melting to over 1773K which is higher than melting points of silicon of 1700K and manganese of 1517K, for its complete melting and it was subsequently homogenized by holding the sample at 1523K which was higher than its liquidus temperature of 1435K. Then it was cooled for synthesis of $MnSi_{1.73}$ by the solidification under the controlled cooling rate of 2.5K/minute until 423K. The magnetic field parallel to gravitational direction was imposed on the sample from 1523K till 1273K in which the sample completely changed from liquid to solid because its liquidus and eutectic temperatures are 1435K and 1415K, respectively. After the sample reached room temperature, it was cut for evaluation of precipitated phase, degree of crystal alignment and thermoelectric properties. The primary composed phase in the samples with and without the magnetic field was $MnSi_{1.73}$ phase. The averaged angle between the (001) crystallographic plane of $MnSi_{1.73}$ crystals and the plane perpendicular to the magnetic field direction was 85.9 degrees in the case with the magnetic field while that was 48.1 degrees in the case without the magnetic field. This indicated that most of its c-axis was aligned perpendicular to the magnetic field direction in the sample solidified with the magnetic field. Therefore, the magnetic field imposition during the solidification introduced the crystal aligned structure. The electrical conductivity in the direction parallel to the magnetic field solidified with the magnetic field was three times larger than that solidified without the magnetic field while the Seebeck coefficient solidified with the magnetic field was 10% lower than that solidified without the magnetic field. As the result, the power factor solidified with the magnetic field was about two times larger than that solidified without the magnetic field.

For crystal alignment by imposing a magnetic field during solidification, an environment in which crystals can rotate to reduce magnetization energy is required. Solidification starts from a wall when the wall temperature is lower than the bulk temperature. This is popular in casting processes. However, dendrites grown from a wall can not rotate. Thus solids floating in a liquid is essential for crystal aligned structure formation by imposing the magnetic field. For this purpose, not only a magnetic field but also an electrical current were introduced and model experiments have been done using low temperature melting point alloys[2, 3)]. The simultaneous imposition of the static magnetic field and the electrical current in the initial stage of the solidification can break dendrites into pieces and the sequential static magnetic field imposition make them to reduce the magnetization energy.

References
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