【Grant-in-Aid for Scientific Research (S)】

Broad Section D

Title of Project : Development of a new upgrade recycling technology for titanium

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Research Project Number : 19H05623 Researcher Number : 00280884

Keyword : Titanium, Recycling, Deoxidation, Rare earth element, Pyrometallurgical process

【Purpose and Background of the Research】

Titanium is an attractive metal because of its abundance and excellent properties such as high specific strength and corrosion resistance. However, no process can produce Ti from its ore at a low cost. Furthermore, during the fabrication of Ti, a large amount of scrap is generated due to its poor workability (Fig. 1). Therefore, Ti products are expensive and not used widely.

The oxygen concentration in Ti scrap is high and the price of such scraps is between one-tenth and half of that of virgin metal (Ti sponge). In this study, we developed a novel method to directly remove oxygen from Ti scrap to use it for producing high-purity Ti ingots. With this new "upgrade recycling method," we aim to establish a new recycling scheme for Ti scrap to decrease the cost of Ti products.

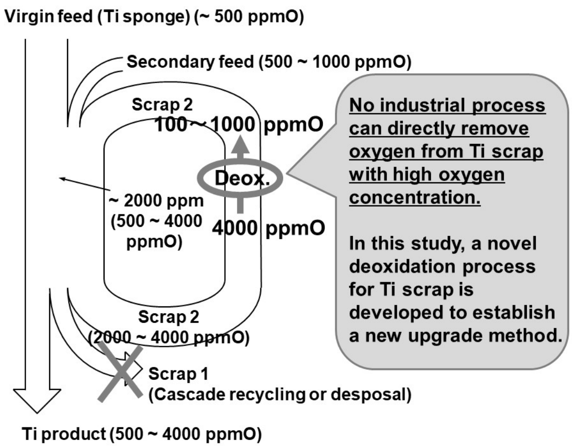

Fig. 1 Material flow of Ti scrap and oxygen concentration in Ti scraps.

【Research Methods】

If Mg can be used as a deoxidizing agent for Ti deoxidation in molten $MgCl_2$, vacuum separation of Mg and $MgCl_2$ and electrolysis of $MgCl_2$ for Mg regeneration—employed in the conventional Ti production process (the Kroll process)—can be utilized. However, as Ti has a high affinity for oxygen, it is considered impossible to remove the oxygen dissolved in Ti ($O_{\text{in Ti}}$) by forming MgO utilizing Mg deoxidation ($O_{\text{in Ti}}$ + Mg → MgO) due to the low deoxidation ability of Mg.

In our recent studies, a novel method for decreasing the activity of MgO in MgX_2 (X: F, Cl) by adding a rare earth halide (REX_3) was proposed, based on thermodynamic assessment. $O_{\text{in Ti}}$ reacts with Mg and the REX_3 to form a rare earth oxyhalide REOX ($O_{\text{in Ti}}$ + Mg + REX_3 → REOX + MgX_2). It was found that this novel method decreases the oxygen concentration in Ti to levels below 100 ppm O (relevant literatures has been cited below).

However, thermodynamic data available on rare earth compounds involve large errors and are unreliable. Therefore, in this study, we will experimentally investigate the reliability of the thermodynamic data available on rare earth compounds. During the course of the experiments, we will evaluate the errors in the thermodynamic data, investigate the effect of the formation of rare earth oxyhalides on the deoxidation of Ti, and develop a novel deoxidation method. Furthermore, a method for the recovery of rare earth oxyhalides will be developed to establish a process with no consumption of rare earth. Moreover, new removal techniques or mitigation techniques for contaminants in Ti ores, such as iron, will also be developed.

【Expected Research Achievements and Scientific Significance】

The material flow of Ti will change when the cost of Ti production process using upgraded Ti scrap becomes comparable to that of the conventional Ti production process from ores (the Kroll process). If it becomes possible to export highly valuable Ti products produced from imported low-cost Ti scrap, global business concerning Ti metal production will face a paradigm shift.

【Publications Relevant to the Project】

・T. H. Okabe, C. Zheng, and Y. Taninouchi: 'Thermodynamic Considerations of Direct Oxygen Removal from Titanium by Utilizing the Deoxidation Capability of Rare-Earth Metals', Metall. Mater. Trans. B, vol. 49, no. 3, (2018) pp.1056–1066. (DOI: 10.1007/s11663-018-1172-4)
・T. H. Okabe, Y. Taninouchi, and C. Zheng: 'Thermodynamic Analysis of Deoxidation of Titanium Through the Formation of Rare-Earth Oxyfluorides', Metall. Mater. Trans. B, vol. 49, no. 6, (2018) pp. 3107–3117. (DOI: 10.1007/s11663-018-1386-5)

【Term of Project】 FY2019-2023

【Budget Allocation】 155,300 Thousand Yen

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