別紙４（課程博士）

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Abstract

論文内容の要旨　(博士)

Title of Thesis 博士学位論文名	PHYSICO-CHEMICAL STUDY OF COPPER-CARBON SYSTEM FOR PREPARATION OF GRAPHITE DISPERSED COPPER ALLOY COMPOSITE (黒鉛分散銅基複合材料の開発に関する基礎研究)

(Approx. 800 words)

Graphite-dispersed copper composites is known to have good thermal and electrical conductivities, self-lubrication and low thermal expansion coefficient. These characteristic of it are derived from both characteristic of copper and graphite. Therefore, this composite is expected to be used for a sliding contact which an electric current flows in and friction acts on.

First, a Cu-Ni alloy in which the nickel was included up to approximately 5 mass% was melted in a graphite crucible with a high frequency induction furnace to prepare the Cu-Ni-C_{sat} (saturated carbon) alloy. Solubility of carbon into Cu-Ni alloy increased with the nickel content and with the melting temperature. The particles precipitated from the melt were graphite. The relation between the activity coefficient of carbon for Cu-Ni-C_{sat} and the temperature could be expressed by numerical formulas. This work proposed that the interaction parameter, ω_{C}^{Ni}, for Cu-Ni-C_{sat} was -17.1. Vickers hardness of Cu-Ni-C_{sat} system increased with C content. The Cu-Ni-C_{sat} alloy prepared in this study was hardened by precipitation hardening of the graphite particles and solution hardening of Ni.

Second, solubility of nitrogen gas into pure copper at temperature range of 1993 K to 2443 K was studied with using a levitation melting apparatus. The solubility of nitrogen which was equilibrated with nitrogen gas with a pressure of 101.3 kPa increased with the temperature of molten copper. However, the solubility was approximately 1.5 massppm even at 2443 K. The solubility obeyed the Sieverts' law. The relation between the change of Gibbs energy for this reaction, $\Delta_r G^0 = 61573 + 48.75T$ and thermodynamic temperature of the molten copper, T [K], was expressed as : $\ln[\text{mass\%N}] = -\frac{7406}{T} - 5.863$

Third, it was attempted that graphite dispersed copper composite was prepared only on the surface of a copper plate using a spot welding machine which could heat a material beyond 2073 K for short time. Experiments were carried out with changing the compressive load, the repetition number of the compression and the electrical

current in order to study their effects on carbon content and Vickers hardness of the composite. Generally, the carbon content of the composite prepared without an electrical current flow was smaller than that prepared with an electrical current flow. The former composite was prepared with that relatively small angular graphite particles were pushed into the copper plate. In the case of flowing electrical current, graphite particles was heated, and partially or wholly dissolved into molten copper. Therefore, this composite was prepared with undissolved graphite and precipitated graphite from the copper melt. The Vickers hardness of the copper matrix in the composite prepared without an electrical current flow was larger than that prepared with an electrical current flow, because the electrical heating annealed the composite. The relation between the Vickers hardness of the copper matrix in the composite and the volume fraction of graphite were expressed by the rule of mixtures.

Fourth, laser irradiation was used to prepare the graphite dispersed copper composite on a copper plate. The carbon dioxide laser was irradiated on the copper plate on which the graphite particles were plunged by rolling. Most plunged particles except the small angular graphite particles which were stuck in the copper plate were eliminated, when the rolled plate was dipped in the ultrasonic bath. When the laser was irradiated to the rolled plate, the number of graphite particles in the laser spot decreased with the laser irradiation time, because the particles was eliminated by the laser trapping. However, the fixing of the particles resulted from improvement of the wettability between the graphite particle and the molten copper. When the copper around the graphite particles further melted, the particles on the plate disappeared by the laser trapping. The number of the graphite particles on the outside of the laser spot increased with time. The laser trapping hardly acted on the graphite particles at this place. The copper at the outside of the laser spot were heated by the conduction from the laser spot, and melted. The particles were fixed by the wetting. The Vickers hardness decreased with an increase with the laser irradiation time due to annealing by the laser heat. The Vickers hardness at the outside of the laser spot was higher than that at the center of the laser spot.

Finally, it was tried to prepare the bulk of the graphite dispersed copper composite. The influence of the temperature, the way of addition of the graphite particles and the alloying elements (nickel, iron) were studied. The graphite particles were formed by the precipitation from the melt. When the temperature was above approximately 2073 K, copper could wet to the graphite, and this enhanced the dissolution of graphite into the molten copper. Therefore, the composite prepared at 2073 K included more graphite particles than that at 1673 K. In addition, the composite prepared by the addition of graphite particles on the melt hold at 2073 K contained more graphite than the composite prepared by the addition of them before heating. This resulted from the quantity of scattering graphite under heating and the wettability. The graphite particles in the composite contained nickel larger than that in pure copper because the solubility of carbon in copper-nickel system was larger than that in copper. The graphite particles in the composite contained iron were smaller than that in pure copper, and mainly existed in iron rich phase. The Vickers hardness of the composite after annealing was smaller than that before annealing because of the relaxation of solid-solution strengthening of carbon. The hardness of the graphite dispersed copper alloy was largest due to the solid-solution hardening of the alloying elements.