Manufacturing process and material characteristics of Ag–Ni contacts consisting of nickel-compounded particles

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Using a high-speed, high-shear mill, particle surfaces of Ag–Ni alloy in which Ni is finely dispersed in the Ag matrix were coated and compounded with Ni powder. Particles thus compounded can be processed into a wire. Post-processing compounded Ni forms a fibrous texture on the wire longitudinal section and a network on the cross-section. This characteristic metallurgical structure improves the contact performance (fusion and wear resistances).

1. Introduction
Contacts are used in relays, magnetic switches, contact breakers and similar current-switching devices. From the standpoint of conductivity and corrosion resistance, Ag-base materials, particularly Ag–metal oxide and Ag–Ni, are most often in service [1, 2]. Ag–Ni contacts, well known as having high workability and low contact resistance, are used as medium to weak current contacts [2].

The size of particles dispersed in Ag affects the contact performance [3–5], and a number of reports have been publicized with regard to improved performance by the fining of CdO [4] and Ni [3]. In another report [2] it is reported that contact performance is improved by using as the contact surface a section of 5 μm or less of fibrous Ni dispersed in the longitudinal direction. Thus, although better contact performance is anticipated by fining fibrous Ni, such fining is difficult with the conventional manufacturing process, which is limited to an average of 3 to 5 μm. The reason is as follows. Ag–Ni contacts are obtained by forming and bringing to normal sintering the mixture of electrolytic Ag powder and carbonyl Ni powder. With 1 μm or finer particles, dispersion down to primary particles is difficult, because of agglomeration. Moreover, the particle surfaces adsorb gas, and this represents an additional difficulty for obtaining a sintered body of the theoretical density.

Recent reports [6–8] propose the so-called dry particle compounding process, a method of compounding two types of particle by coating mother particle surfaces with fine particles using a high-speed, high-shear mill.

In the present study this process was applied to contact manufacture. We propose a new manufacturing process to provide Ag–Ni contacts with fine fibrous Ni, revealing the advantages of the new method. This report describes the metallurgical structure, material characteristics and contact performance of a material prepared by forming, sintering, extruding and drawing using Ni-coated Ag–Ni alloy particles.

2. Experimental procedure
Ag–Ni alloy particles were obtained by melting 99.99% Ag and Ni, bringing the molten metal ejected from a nozzle to rapid cooling by the water-atomizing method, and finely dispersing Ni in Ag. The particle surfaces were coated with Ni fines and compounded to high concentration with a high-speed, high-shear mill. The mill used was a modification of a fine grinding mill. Fig. 1 shows the construction. In this mill the rounded piece was made of hard alumina so as to prevent the mixing of worn powder.

Compounded particles thus obtained were formed, sintered, hot-extruded, and drawn into wires. Fig. 2 provides the flow chart of this series of processing. In this chart swaging and drawing are steps for wire forming, and revet-forming is a step to prepare samples for the evaluation of contact performance. Wires consisting of uncompounded Ag–Ni alloy particles only were also produced by the same procedures to be used as a control.

With these two types of wire, high-temperature hardness up to 823 K was measured, tensile tests at normal temperature performed, and mechanical characteristics studied. Further, with revet-shape contacts, contact performance, i.e. fusion and wear resistances, was studied.

3. Results and discussion
Fig. 3 shows scanning electron micrographs of a section of Ag–Ni alloy particles prepared by the rapid
Figure 1 Construction of high-speed, high-shear mill (dimensions in mm).

Figure 2 Ag-Ni contact manufacturing process.

Figure 3 Section of Ag–Ni alloy particle: (a) external view, (b) magnified interior (SEM).

The compounding process using a system as shown in Fig. 1 is as follows. The drum rotates at high speed. The rounded piece fixed inside the drum with a given spacing in-between presses (against the drum wall) particles charged in the drum and pressed on to the drum wall due to the centrifugal force. Particles thus packed between the drum wall and the rounded piece undergo strong compression and shear. With this process repeated, the compounding proceeds [6–8].

Fig. 4 shows a scanning electron micrograph of the Ni particles used. Fig. 5 shows this Ni, 1 μm in mean diameter, added to a total of 10 wt % and treated for 4500 s in an argon atmosphere at a rotational speed of 17.2 rps, with the drum–piece clearance set at 3.9 mm. In this process 1 mm zirconium beads were used as a medium to prevent fine particles from sticking to the drum wall and the rounded piece, so as to improve the dispersion effects of Ni particles and shear and compression effects. Fig. 5a shows a secondary electron micrograph of a section of the compounded material, and Fig. 5b the X-ray micrograph (NiKα). The particle surfaces are coated with Ni to a thickness of 5 to 15 μm, and the Ni layer is tightly packed. This is attributed to strong compression and shear and high frictional heat. The Ni proportion after compounding particles in which Ni is dispersed in advance is to achieve improved contact performance by virtue of the strength of dispersed Ni in the Ag matrix, and to prevent plastic deformation of particles due to compression and shear during Ni compounding with a high-speed, high-shear mill, thus obtaining uniform and tight Ni coating.