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Tohoku University

Alps Electric Co., Ltd.

**Alps Electric and Tohoku University Aim to Contribute to the Realization of a Sustainable Society from the Tohoku Region**

Dust core prototype successfully developed using new high-performance soft magnetic powder, for size reductions and energy savings in a wide range of power electronics, including automotive and electrical equipment applications

**Outline**

Alps Electric and Tohoku University have been advancing a hetero-amorphous material development and commercialization project through the Tohoku University Business Incubation Program (BIP) and have successfully developed an innovative soft magnetic powder with high saturation flux density and low core loss. The new powder is expected to greatly improve performance and lead to major size reductions of devices in the power electronics field, where energy savings and low loss are important requirements.

Following the Great East Japan Earthquake of March 2011, it has been anticipated that application of superior soft magnetic materials to fields from electricity transport to appliances will help to reduce the world's energy consumption. Through this project, Tohoku University and Alps Electric, both with strong links to the Tohoku region, are looking to contribute to the region's recovery and to resolve energy and environmental issues through collaborative efforts to commercialize the university's research under the Tohoku University BIP.

The new material has 20 to 25% higher saturation magnetic flux density and 20 to 25% lower core loss than existing amorphous powders. Saturation magnetic flux density is 1.6 tesla; core loss is less than 500 $kW/m^3$ (@100kHz, 100mT). Another unique feature of the material is that it can be produced using gas atomization, an environmentally friendly method without waste liquid.

The material is expected to improve power electronics applications for automotive systems and electrical components by supporting larger currents, lower energy loss, and size and weight reductions. The project will now proceed with development targeting application to magnetic components that make use of the conversion of electrical energy into magnetic energy, including power module parts, actuators and motors.

Alps Electric also plans to participate in a joint venture centered around Tohoku University that is to be established in fiscal 2015. Alps Electric and the joint venture will carry out joint development with an eye to commercialization of new products.

**Tohoku University Business Incubation Program (BIP)**

The Tohoku University BIP is a program for carrying out collaboration to advance commercialization of university research. It is funded by a special operating grant provided for under the fiscal 2012 supplementary budget in accordance with the public-private innovation program of Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT). Under the program, the university and companies will jointly fund and advance collaborative research, aiming for the realization of business plans creating targets for future investment, with an eye to social implementation.

**Background**

Devices and equipment in the information, communication, consumer electronics, industrial, automotive and energy industries are performing better than ever before and are becoming lighter and smaller. Even further advancements will necessitate improving the performance of the materials. Improvements to material performance are also being looked to as a way to achieve energy savings for electrical devices, which are essential for reducing environmental impact and improving energy efficiency.

In this respect, soft magnetic materials are one of the most important materials. For relatively small electronic parts, in particular, magnetic powders such as metallic glass and iron-based amorphous alloy are used to form dust cores of various shapes.

These materials conventionally have low saturation magnetic flux density of around 1.3 to 1.4 tesla, limiting potential size reductions and compatibility with large currents. Tohoku University and Alps Electric have now successfully developed an innovative soft magnetic material with both high saturation magnetic flux density and low core loss. The prototype core was also confirmed to have low core loss.

**Detail**

This material can be produced using the gas atomization method (cooling rate: $10^3$ – $10^4$ K/s), for which the cooling rate is slower than for water atomization ($10^4$ – $10^5$ K/s). The method also allows simpler equipment and enables a production process without waste liquid for a low environmental impact. Photos of the developed core are shown on the right. The core using this material powder achieves high performance with both high saturation magnetic flux density (approx. 1.6T) and low core loss (less than 500 kW/$m^3$ (@100kHz, 100mT)).

**Future Plans**

Industrialization of the material will be advanced as a joint venture to be established around Tohoku University.

**Reference**

(1) FeSiBP Bulk Metallic Glasses with Unusual Combination of High Magnetization and High

Glass-Forming Ability. [Materials Transactions, Vol. 48, No11 (2007) pp. 3024 to 3027] Makino A, Kubota T.

(2) Soft magnetic FeSiBPCu heteroamorphous alloys with high Fe content. [JOURNAL OF APPLIED PHYSICS,105(1),(2009),13922-] Makino A, Men H, Yubuta K, Kubota T.

**Glossary**

1. Saturation magnetic flux density: When an external magnetic field is applied to a magnetic material, the material is magnetized, meaning it becomes like a permanent magnet. The stronger the external magnetic field, the stronger the magnetization of the material. However, the material gradually reaches a point when magnetization increases no further even if a strong magnetic field is applied. The magnetic flux density generated in the magnetic material at this point is called the saturation magnetic flux density.
2. Water atomization method: Water atomization is a process for manufacturing metal powders. Molten metal dropped through a nozzle collides with jets of high pressure water. The particle shape is non-spherical.
3. Gas atomization method: Gas atomization is a process for manufacturing metal powders. Molten metal dropped through a nozzle collides with jets of gas (e.g. air, nitrogen, argon). The particle shape is almost spherical. The cooling rate with this method is slower than for water atomization because the heat capacity of gas is some magnitudes lower than water. This method was therefore difficult to apply to existing amorphous metals.
4. Hetero-amorphous: Non-homogeneous amorphous. A state where an amorphous matrix with a random atomic structure contains a high density of iron particles similar to crystals smaller than 2nm.
5. Soft magnetic powder: A powder with soft magnetic properties. Permanent magnet-like magnetic properties appear when an external magnetic field is applied and disappear when the magnetic field is removed. The size is generally smaller than 100μm.
6. Core loss: When the core is subjected to a changing magnetic field, as it is in devices that use AC current such as transformers and electric motors, some of the power that would ideally be transferred through the device is lost in the core, dissipated as heat and sometimes noise.