Formation of soft magnetic thin films by means of electrochemical methods

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Electrochemical processing offers great potentialities as was already demonstrated by several successful applications of such processes in the fabrication of magnetic recording heads and ULSI interconnects known as Damascene process. A typical example of application of electrochemical technology is the formation of thin film magnetic recording head fabricated using a precision electroplating technique in combination with photolithography, which was originally proposed in 1970s by IBM Corporation. In the fabrication of magnetic recording head, an electrochemical paddle plating system with a frame plating method invented by Romankiw, IBM, led to the realization of a three-dimensional shape complexity in micro-size patterning [1]. Such a nano-scale fabrication capability has never been achieved by conventional dry processes, and it can be stated that electrochemical processing is quite different in significance from the conventional technologies of electroplating and etching. It is a new innovation contributing to the creation of new technologies.

In 1970s, we found the basic idea on how to control the interface between electrode and electrolyte on the basis of atomic level mono- or sub-adsorbed layer (ad-atom layer). This led to the success of applying electroless deposition method for the preparation of high density magnetic recording medium. The combination of this basic idea with electrochemical nano-fabrication method, has become the start of our research work on electrochemical nano-technology. We have developed this research, and nowadays, electrochemical wet processes are commonly performed in a clean room system with an air filtering apparatus for fabricating fine patterned devices.

Here, I will introduce our recent studies about formation of soft magnetic thin films by means of electrochemical methods.

Electrolytic deposition of soft magnetic thin films for magnetic recording head core

A head of magnetic recording system is a key device for achieving high-density magnetic recording, where soft magnetic thin films are being used for its core materials. As the coercivity (Hc) of magnetic recording media has greatly increased, soft magnetic thin films with high saturation magnetic flux density, Bs, have been sought for writing magnetic signal on the recording media with high Hc. The electrochemical deposition is the most appropriate process for fabricating recording head core because of its ability to deposit a high-aspect-ratio film with a thickness more than 1 μm on a substrate with complex configuration.

CoNiFe alloys in the regions of Co-rich and/or Fe-rich compositions show relatively high Bs values. We attempted to develop CoNiFe soft magnetic thin films with Bs higher than 20 kG by focusing on the additives containing sulfur element in the plating bath. The additives containing sulfur element, e.g. saccharin and thiourea, had been reported to effectively decrease the grain size of CoNiFe deposits, leading to the reduction of coercivity.

On the other hand, with an increase in sulfur content, we found that the phase boundary was shifted from the high Bs to the low Bs regions in the CoNiFe ternary alloy phase diagram. We have already reported that near an fcc-bcc phase boundary, an electrodeposited CoNiFe film is composed of fine crystallites, and exhibited low coercivities. On the basis of these results, we tried to use the bath without these additives, and succeeded in developing $Co_{65}Ni_{12}Fe_{23}$ with Bs as high as 20 kG, and Hc as small as 1.2 Oe [2]. In addition, by using and optimizing the plating bath composition, CoNiFe film was applied to practically-used recording head, where the film as thick as 1.5 μm was uniformly deposited without any voids and cracks even at bending parts.

Moreover, thin films with much higher Bs are desired for write core materials to achieve the ultra high-density magnetic recording. The $Co_{30\text{-}40}Fe_{60\text{-}70}$ film has attracted much attentions since it exhibits Bs value of 24 kG, the highest value among the Co-Ni-Fe alloys. We succeeded in electrodepositing the CoNiFe films with Bs value of 24 kG by using a separated compartment dual cell system and a novel bath containing trimethylamineborane to prevent the oxidation of ferrous [3].

Electroless deposition of soft magnetic underlayer for a double-layered perpendicular recording

A double-layered perpendicular magnetic recording medium consists of a recording layer with high magnetic anisotropy in a direction perpendicular to the film surface and a soft magnetic underlayer (SUL). Usually, sputter-deposited Co- and/or Fe- based soft magnetic thin films with more than 100 nm in thickness are used as SUL. The critical issue in fabricating SUL for practical use is to develop the preparation method with sufficiently high mass productivity for the thick SUL. We have proposed a novel preparation methods of CoNiFe-based SULs by electroless deposition, which has a great advantage in view of mass productivity compared with the sputtering deposition. The uniform formation of the CoNiFe-based SUL on a 2.5 inch-diameter disk was achieved by electroless deposition with rotating the disk and chemical mechanical polishing.

Equally important, the two-dimensional image of Kerr effect for the CoNiFeP SUL electroless deposited under the external magnetic field exhibited no marked domain boundary. In contrast, when the SUL was deposited under zero magnetic field, clear and complicated magnetic domain patterns was observed. The double-layered perpendicular magnetic recording media with the SUL deposited under the external magnetic field showed a good over-write performance and high signal-to-noise ratio, such a high recording performance as the media with conventional sputter-deposited SUL [4]. These results strengthen the validity of electroless deposition as a preparation method of SUL.

References

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