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Time-efficient nondestructive characterization of customized magneto-optical thin layers for industrial use

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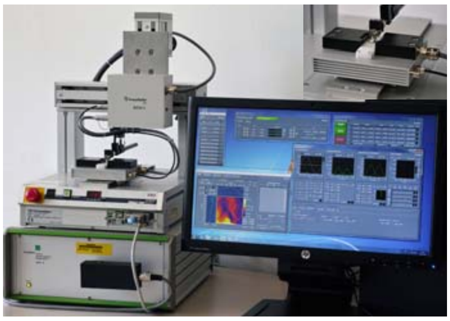

Fig. 1: Barkhausen Noise and Eddy current Microscope (BEMI II) and detail of BEMI probe (upper right)

In the production of coating systems for magnetic and magneto-optical sensors the homogeneity of the layer thicknesses is of significant importance for the metrological characteristics. Materials optimization and quality assurance can benefit from inspection procedures that reflect such critical parameters quickly and easily. For fast micromagnetic layer thickness characterization of ferromagnetic layers the "Barkhausen Noise and Eddy current Microscopy" (BEMI) technique and the "BEMI II" device were developed and tested extensively.

BEMI II

- Based on "Micromagnetic Multiparameter Microstructure and stress Analysis" (3MA)
- Improved miniature Barkhausen noise and eddy current probes
- Acquisition of micromagnetic parameters with a spatial resolution of about 20 µm by stepwise scanning of sample surfaces in defined x and y positions
- Control of the scanner, data acquisition, visualization and evaluation of the results by a PC
- Primary information on material homogeneity by illustration of the distribution of the micromagnetic parameters
- Qualitative and quantitative estimation of the material or layer properties by calibration on several samples and comparison of the characteristics

Aim: Qualitative characterization of thin layers before and after ion implantation and laser irradiation → quick illustration of the effects caused by ion implantation or laser-thermal treatment on the local modification of the magnetic properties.

Results

- Detectability of NiFe layers (in untreated condition) from a thickness of as few as 5 nm (Fig. 2).
- Detection of microstructure changes caused by the ion implantation can already be detected in 5 nm thin layers (Fig. 2).
- Suitability of BEMI to qualitatively characterize changes of residual stress in CoFe and CoFeB thin layers due to laser irradiation (Fig. 3) → surface scans of the maximum Barkhausen noise amplitude M_{MAX} in the untreated and laser-treated condition, respectively
- 20nm CoFe layers (Fig. 3 left-hand side): increase of M_{MAX} after laser irradiation → a reduction of compressive stresses and formation of tensile stresses
- For CoFeB layers (Fig. 3 right-hand side), M_{MAX} decreases after the laser irradiation, because in addition to the modification of the residual stress, a transformation of the crystalline structure into a semi-crystalline one takes place.
- BEMI is an alternative to X-ray measurements for residual stress analysis of amorphous layers, for example, CoFeB.

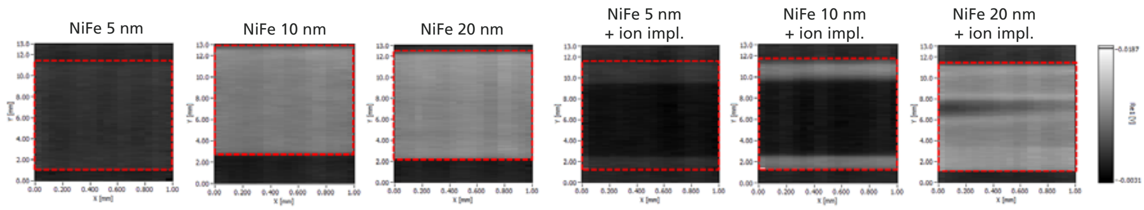

Fig. 2. Detection of modification due to ion implantation in $Ni_{80}Fe_{20}$ thin layers by means of eddy current measurements

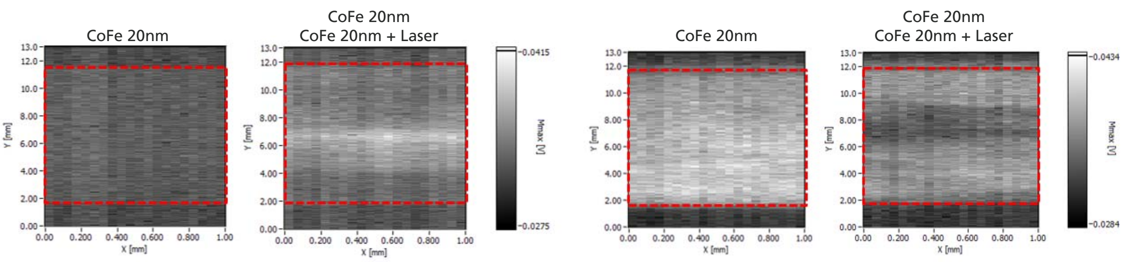

Fig. 3. Detection of residual stress changes due to laser irradiation in CoFe (20 nm) and CoFeB (20 nm) thin layers by means of Barkhausen noise measurements

Conclusion: Barkhausen noise and eddy current microscopy (BEMI) is a powerful tool for development and quality assurance of materials and coating systems which contain magnetic and / or electrically conductive components. With the ability to quickly map residual stress and layer thickness distributions and magnetic material properties and a spatial resolution of about 10-20 µm, it provides information needed to optimize the process parameters. BEMI can demonstrate the effect of ion implantation and laser irradiation on NiFe and CoFe or CoFeB layers, respectively, with thicknesses in the range of 5 to 20 nm, and thus makes it possible to evaluate the modification of microstructure and residual stress.

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