DESIGN AND CONSTRUCTION OF RESONANCE VIBRATING SAMPLE MAGNETOMETER

Ratipat Yamyim, Pongsakorn Jantaratana*
Department of Physics, Kasetsart University, Bangkok 10900, Thailand
*e-mail: fscipsj@ku.ac.th

Abstract: The resonance vibrating sample magnetometer (R-VSM) was constructed for magnetic hysteresis loop measurements of thin films and nanostructures magnetic materials. The performance of the R-VSM was tested and compared with that of the vibrating sample magnetometer (VSM). The measurement of hysteresis loops of $Fe_{40}Ni_{38}Mo_4B_{18}$ ribbon and magnetic tape show that the R-VSM is a valuable tool for investigation magnetic properties of nanostructures magnetic materials.

Introduction: Vibrating sample magnetometer (VSM) was developed for the first time by Foner in 1959.[1] For magnetic properties measurement, the sample is vibrated perpendicular to the external magnetic field generated by an electromagnet. A set of sensing coils is used to measure magnetic properties of the material. The voltage induced (V) in the VSM sensing coils is given by:

$$V = mAfS,$$

where m is magnetic moment of the sample, A is the amplitude of vibration, f is the frequency of vibration and S is the sensitivity function of the sensing coils. The cgs unit of m, A, f and S are emu, cm, s^{-1} and $Vscm^{-1}emu^{-1}$ respectively. It is clear from the expression that the moment sensitivity can be improved by increasing A, f and S. The moment sensitivity of VSM, is known as the calibration constant, can be found by measuring magnetic moment of small high purity nickel sphere.

In recent years there has been extensive experimental in the thin magnetic films and nanostructures.[2-4] The magnetic properties of these structures are becoming difficult to measure owing to the decreasing of the magnetic moment signal. In this paper, R-VSM system was designed and constructed in order to use for magnetic hysteresis loop measurements of thin film magnetic materials.

Methodology: The R-VSM, shown schematically in figure 1, consists of an electromagnet providing the dc magnetic field, a vibration unit and detection coils generating the signal voltage due to the vibrating sample.

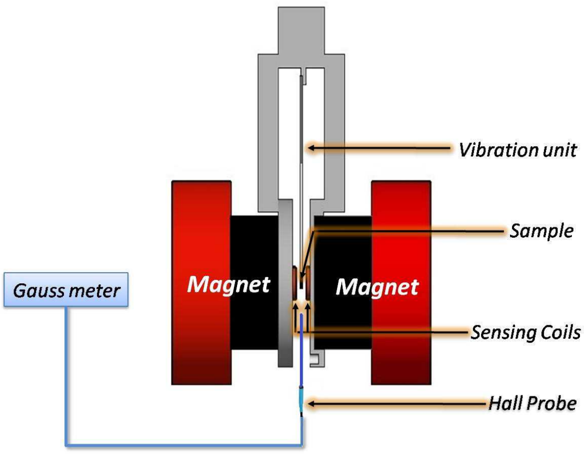
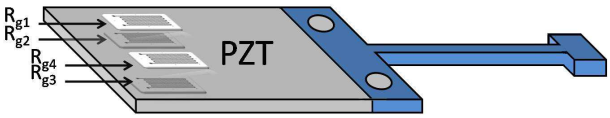
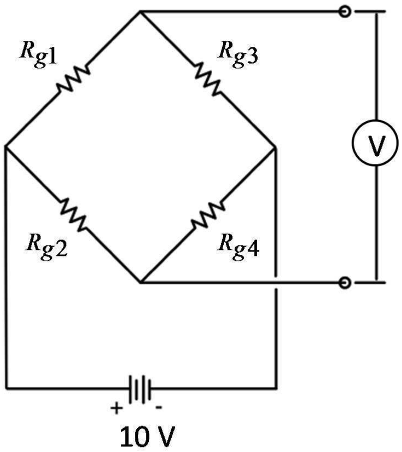


Figure 1. Schematic diagram of the R-VSM.

An electromagnet (Walker Scientific Inc. model HV-4H with a power supply) was used to generate the applied field H. A gaussmeter (LakeShore model 455) equipped with a Hall probe (LakeShore model HMMT-6J04-VR) was used for measuring the magnetic field. The field was controlled by adjusting the current of the power supply. The piezoelectric bending actuator (Piezo Systems Inc. model D220-A4-503YB) with four strain gages (figure 2) was used as the vibration unit. A power amplifier (TOA Corporation model A-2120H) was used to amplify the sinusoidal signal from the lock-in amplifier (Stanford Research Systems model SR850) and then supplied to a piezoelectric bending actuator to vibrate the sample.





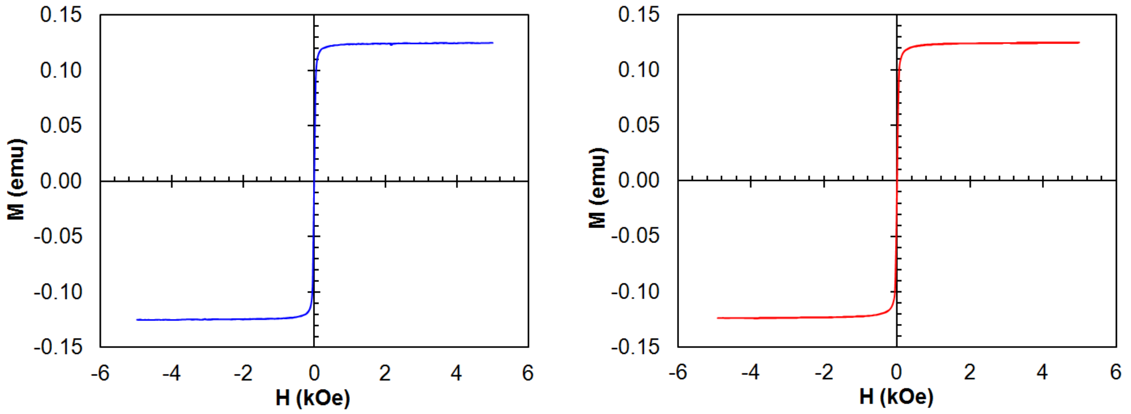
(A) (B)

Figure 2. Schematic diagram of the vibration unit: (A) bending actuator with four strain gages; and (B) gage position in the Wheatstone bridge.

In order to detect amplitude of the vibration, the strain gages were wired into a Wheatstone bridge and supplied by a constant voltage 10 V as shown in figure 2. The sample under test was attached to the end of an epoxy strip which oscillates in parallel to the direction of applied field. Two similar sensing coils connected in series and opposite direction were used as the sensing coils. The induced voltage at the sensing coils was measured by the lock-in amplifier. The performance of the R-VSM system was tested and compared with that of VSM.

Results, Discussion and Conclusion: The VSM used in this study was calibrated by using a nickel sphere (LakeShore model 730908). The magnetic moment of $Fe_{40}Ni_{38}Mo_4B_{18}$ (Metglas^{TM} 2826MB) ribbon under magnetic field of 5 kOe was measured by the VSM and used as reference for the R-VSM. The reference $Fe_{40}Ni_{38}Mo_4B_{18}$ ribbon was attached to the end of the epoxy strip of the R-VSM which oscillated at the resonance frequency of 35.9 Hz with the constant amplitude. The calibration constant of 246.4×10^{-3} Am^2/V (equivalent to 246.4 emu/V in the cgs unit system) was obtained by measuring induced voltage of the sensing coils under applied magnetic field of 5 kOe. The obtained calibration constant can then be used to convert the measuring voltage to the magnetic moment of the sample under test.

The in-plane magnetic hysteresis loops of $Fe_{40}Ni_{38}Mo_4B_{18}$ ribbon measured by VSM and R-VSM are shown in figure 3. Data were collected at room temperature under applied magnetic field of 5 kOe aligned in-plane and parallel to the easy axis of the sample. According to the results, it is confirmed that the R-VSM can be used to measure magnetic property of the soft ferromagnetic ribbon.



(A) (B)

Figure 3. Hysteresis loops of $Fe_{40}Ni_{38}Mo_4B_{18}$ ribbon (Metglas^{TM} 2826MB) measured by VSM (A) and R-VSM (B).

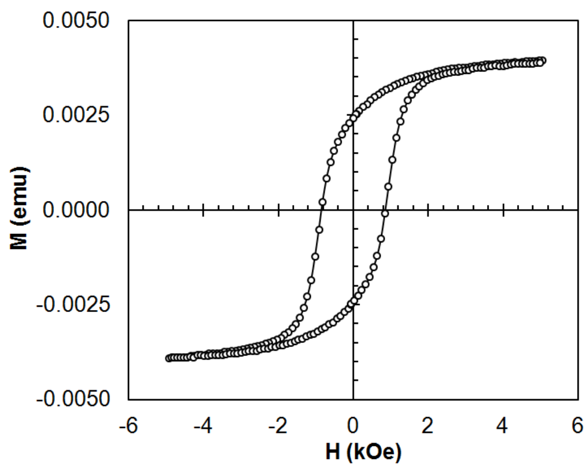


Figure 4. Hysteresis loop of magnetic tape measured by the R-VSM.

Figure 4 show the in-plane hysteresis loop for a magnetic tape sample (3 mm×3 mm) cutting from the commercial 3.25 inch floppy disk. The results show the quite good signal-to-noise ratio when the peak-to-peak of data fluctuation is only a few 10 μemu.

In conclusion, the designed R-VSM is sensitive enough for hysteresis loop measurements of magnetic thin films and ribbons. The cost of designed system is very lower than those of the commercial VSMs.

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Keywords: hysteresis loop, magnetic moment, magnetometer, nanostructure, thin film