Applications of Electromagnetic Phenomena in Electrical and Mechanical Systems
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DETECTION OF METALLIC BEAD BY EDDY-CURRENT PROBE WITH GMR SENSOR

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Abstract

Eddy-current testing (ECT) technique as one of non-destructive testing is the importance and common tool to inspect defect and property on metallic industrial goods. In addition, the progress of the ECT probe with micro magnetic sensor becomes possible to apply to various applications. The detection of metallic bead used for electric packaging has been reported in this paper. We proposed micro ECT probes with meander coil as exciter and Spin-Valve Giant Magneto-Resistance (SV-GMR) as receiver. Micro metallic bead(solder ball) with the diameter of 0.25 to 0.76 mm is used as a measuring object. We discuss the detection of metallic bead and the recognition of its position by using ECT technique.

1. INTRODUCTION

It is indispensable to inspect products during manufacturing process in a factory. Recently, the development of non-destructive testing (NDT) techniques yields to promote the inspection for many kinds of industrial products. Eddy-current techniques(ECT) as one of non-destructive testing techniques is the importance and common tool to inspect defect and property on metallic production things. Actually, ECT technique is applied to the evaluation of nuclear equipment, aircraft, engine and others. In addition, the progress of the ECT probe with micro magnetic sensor becomes possible to apply to various applications. For example, the inspection of high-density printed circuit board by the ECT technique gives a near-future attractive tool in the PCB production industry[1].

We propose the detection of metallic bead with the diameter of 0.25 to 0.76 mm as a new application of ECT techniques in this paper. A metal detector to use for finding metallic particles on the ground is useful. However, both detection of micro metallic bead and identification of its size and position are difficult. It is well-known that micro ECT technique is applied to inspect the defect as nonconductive fragment on the uniform metallic parts and products. On the contrary, we try to detect a conductive micro bead in which eddy currents flow.

This paper describes the structure of micro ECT probe and the principle of the detection. The examination of the experimental results discusses the feasibility of the detection of metallic bead.

2. DETECTION OF METALLIC BEAD AND ECT PROBE

2.1 Detection of micro metallic bead as a new application of ECT

The high-density mount technology produces the Ball Grid Array (BGA) package. One of the advantages of BGA is that it is placed onto printed circuit boards and assembled by using existing surface mount elements. The BGA surface mount needs the small solder ball(bead) to connect LSI elements onto the solder pad as shown in Fig.1. The size of the solder bead is less than 1.0 mm and decreases with increasing the density of packaging[2].

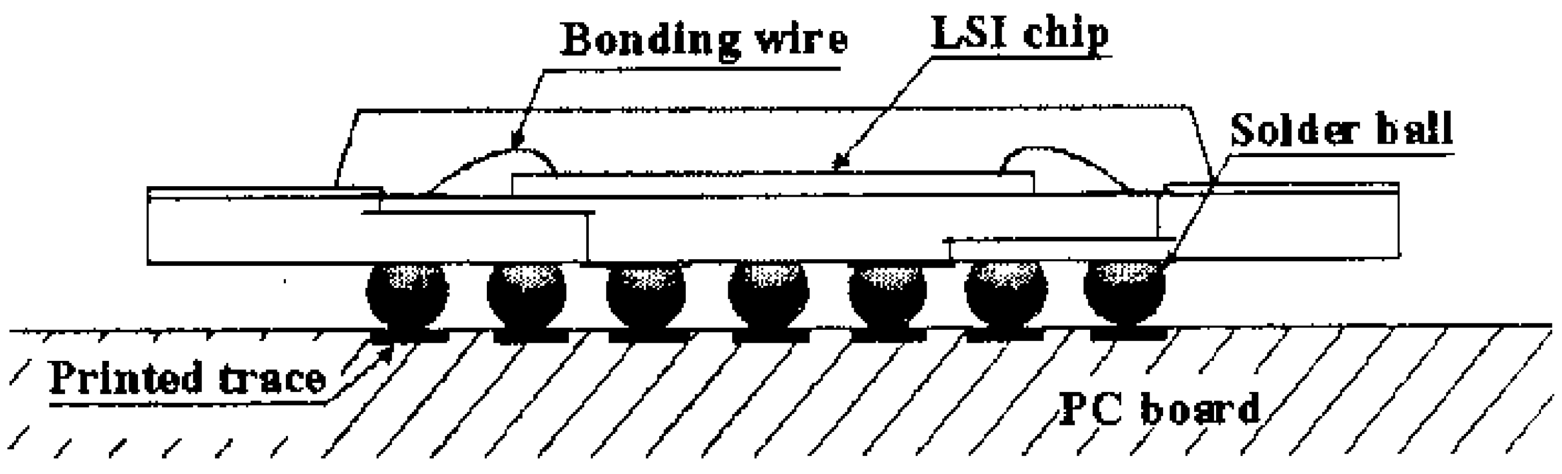


Fig. 1 Ball grid array and solder bead

The mount system needs the recognition of both size and position of solder balls on the BGA package. It is known that an optics system is used at this inspection apparatus generally. But the system is easily disturbed by the influence such as a noise of optics or dust. On the contrary, the inspection technique by eddy-current testing as the electromagnetic technique resists disturbances under the factory environment. We discuss the possibility of detecting the position of solder bead by eddy-current technique.

2.2 Structure of ECT probe

2.2.1 Meander coil and GMR sensor

The ECT probe for the detection of metallic bead consists of two parts, meander coil as exciter and Spin-Valve Giant Magnetic Resistance (SV-GMR) as receiver. The GMR is a well-known magnetic sensor as head element at the hard disk device. Fig. 2 shows the configuration of the ECT probe and the pattern of GMR sensor. The size of GMR is 180 μm in length and 132 μm in width. The size of one element is 18×180 μm in width and length. The width and length of meander conductor is 0.5 and 20 mm, and the width of slit is 100 μm. The GMR sensor is placed on the top of the meander coil between two conductors as shown in Fig. 2.

Fig. 3 shows that the arrangement of ECT probe and metallic bead (cross-section). The thickness of meander coil is 35 μm. The ECT probe is the thickness of 135 μm. The meander coil is installed over the metallic bead as shown in Fig. 3. The lift-off height between the solder ball and the probe is kept at 100 μm. The distance between GMR sensor and bead is 185 μm.

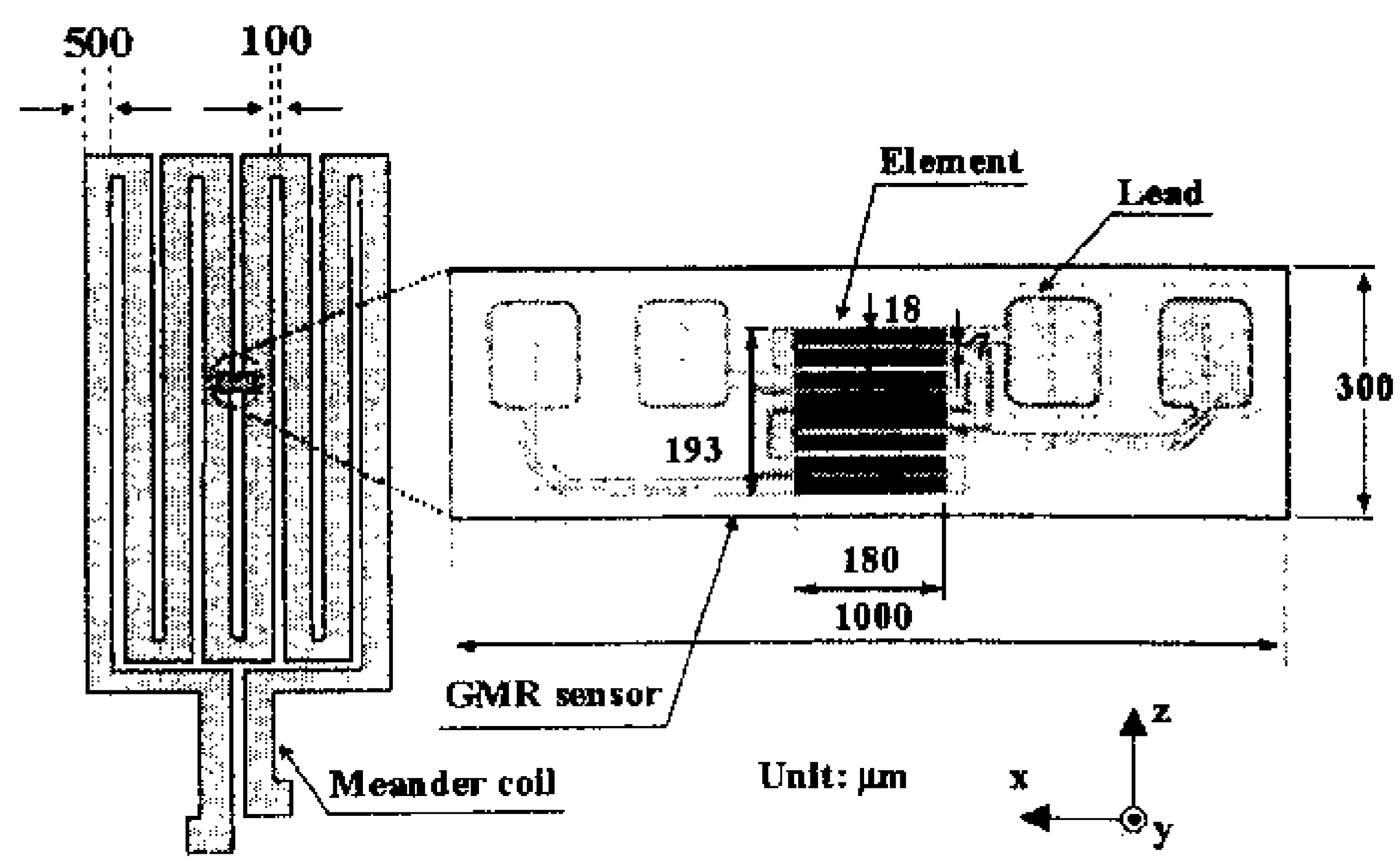


Fig. 2 Configuration of ECT probe and GMR sensor

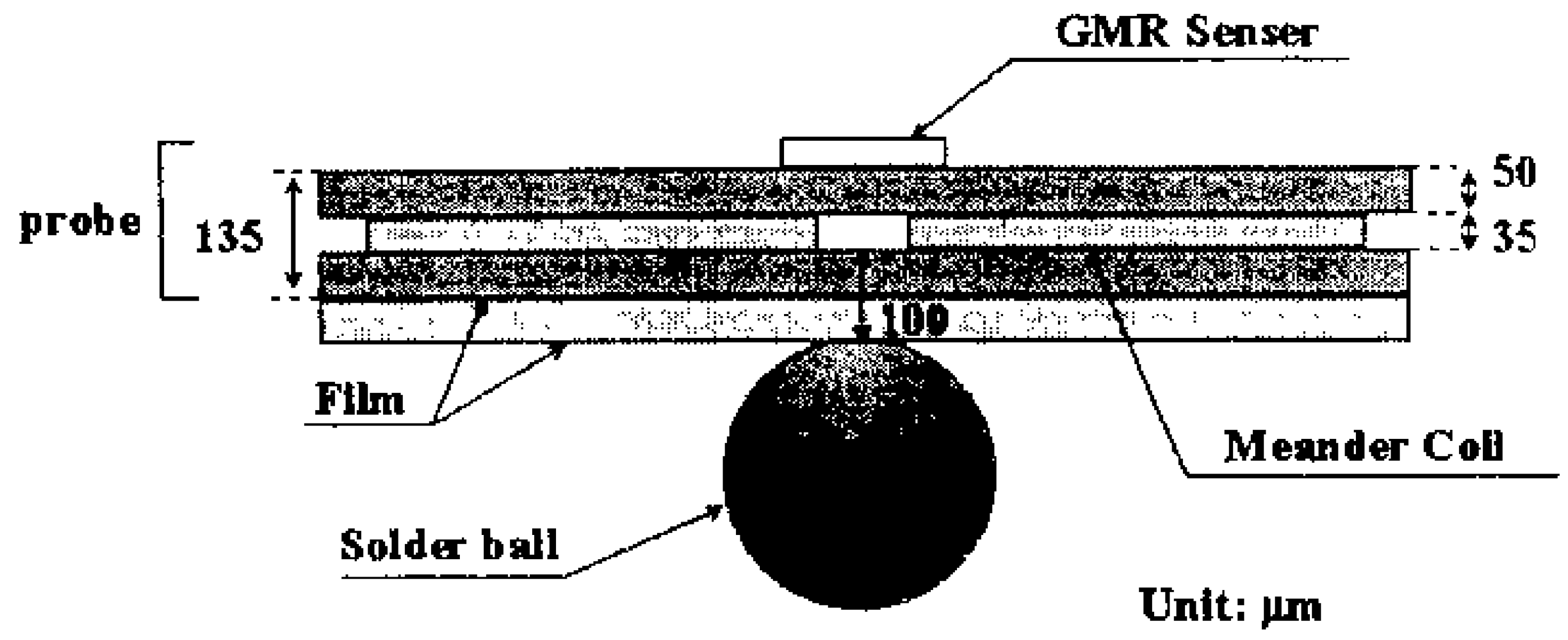


Fig. 3 Arrangement of ECT probe (cross-section)

2.2.2 Characteristics of GMR sensor

The resistance of GMR sensor changes by external magnetic field and this sensor has the high sensitivity and good frequency characteristics for magnetic-field component of one direction[3,4]. Fig.4 shows the characteristic of the resistance change of the GMR sensor when a small external ac magnetic field is 200 μT and the frequency is 100 kHz. The resistance value of GMR sensor is about 627 Ω when there is not any external magnetic field. The dc constant current of 5mA is fed to SV-GMR sensor and the lock-in amplifier is used to measure voltage changing across the SV-GMR sensor. The GMR sensor has high sensitivity only to magnetic flux density in z-direction *Bz*. The change of resistance is 0.61 % under the signal of 100 μT. The x-axis and y-axis sensitivity is very lower than the z-axis one.

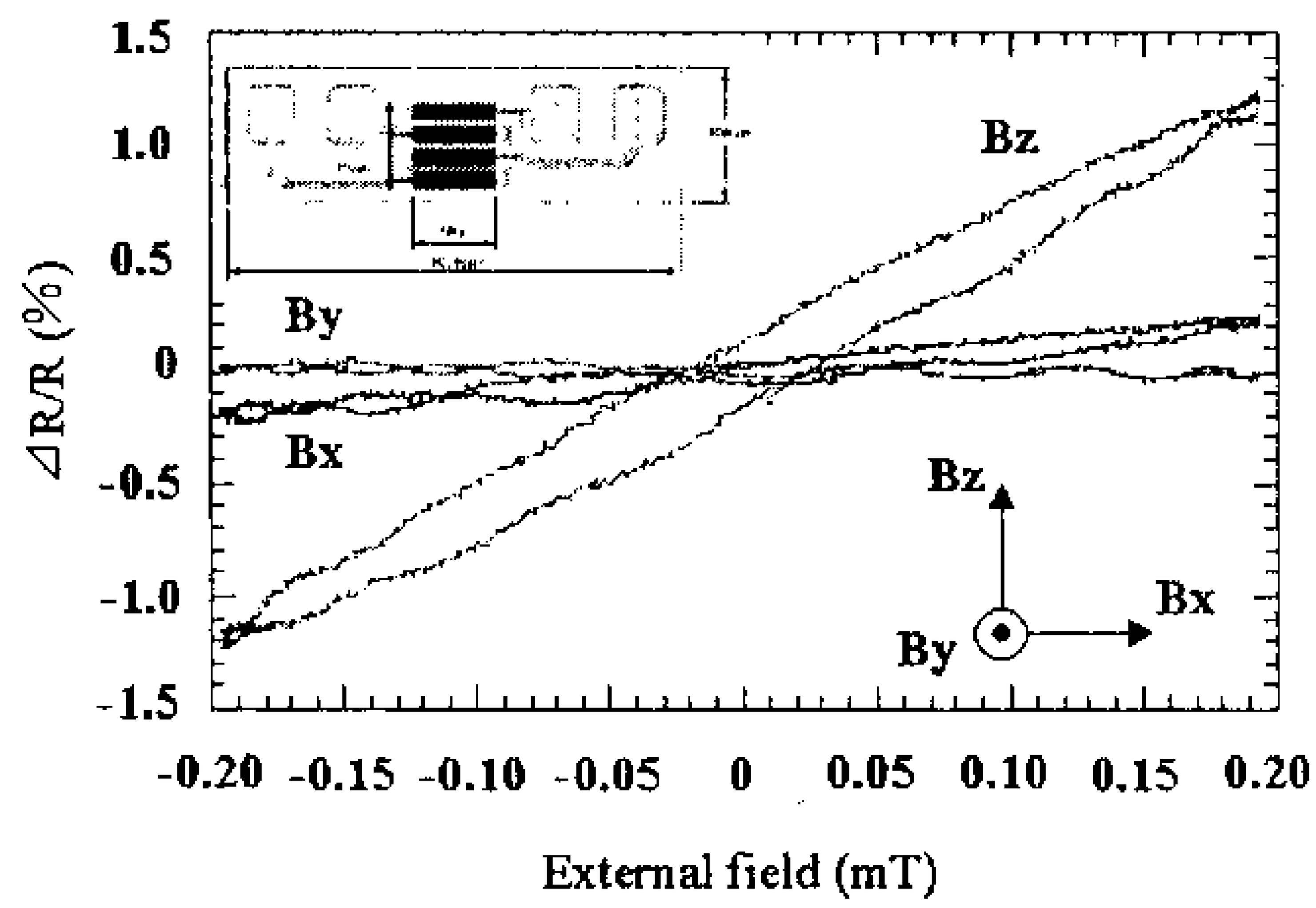


Fig. 4 Characteristics of magnetic-field vs. ⊿*R*/*R* curves of GMR sensor (at 100 kHz)

2.3 Fundamental principle of detection

Fig. 5 shows the arrangement between the ECT probe and solder beads. Eddy currents are induced on the surface of solder ball by a high frequency excitation. We explain the fundamental principle of detection of metallic bead according to Fig. 6 from the viewpoint of the top. The sinusoidal current with the frequency of 5 MHz in the meander coil is applied along the z-direction. The magnetic flux by exciting current is induced along x and y-axis. Eddy currents flow on the surface of solder bead. The z-component of the magnetic flux by eddy currents gives the important signal for detection. The detection of metallic bead can be recognized by picking up the z-direction component. The high sensitive direction of GMR as shown in Fig. 4 is fitted to the z-position.

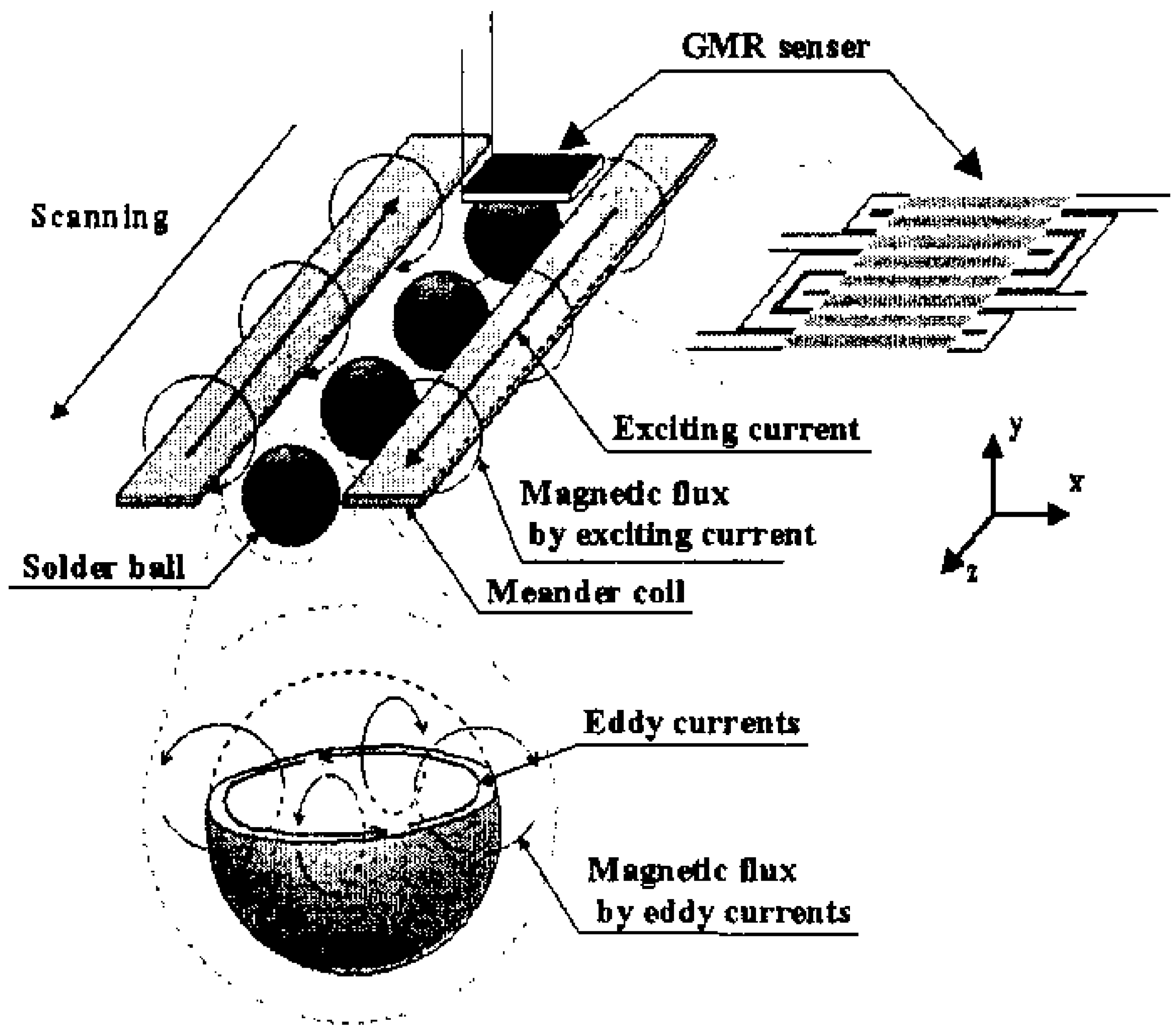


Fig. 5 ECT probe for detection metallic bead

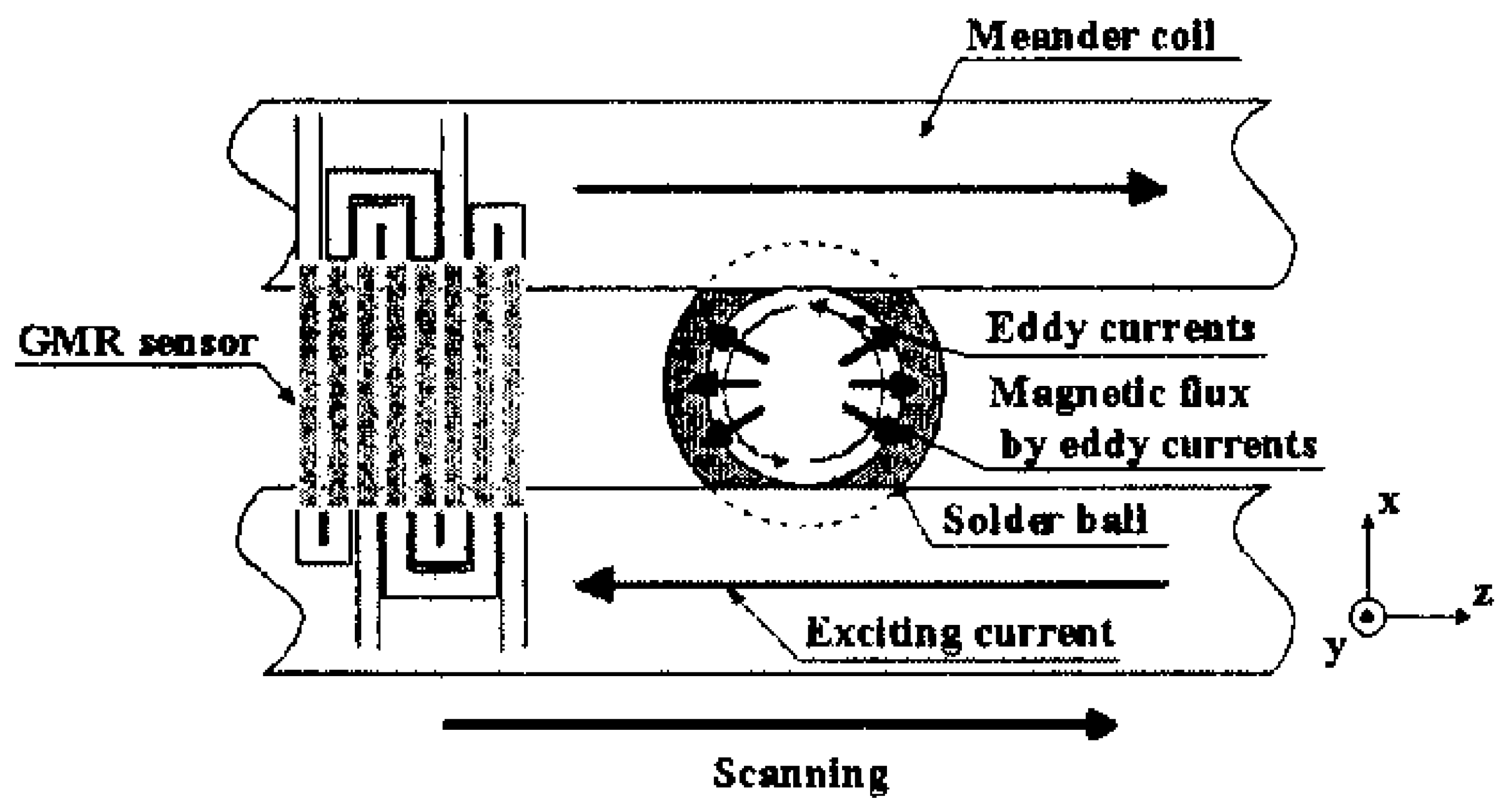


Fig. 6 Fundamental principle of detection for solder ball

3. DETECTION METALLIC BEAD AND CHARACTERISTICS

3.1 Numerical analysis

Using the electromagnetic field analysis software, the simulation of the distributions of magnetic fields and eddy currents was carried out. We discussed the detection of micro metallic bead based on the electromagnetic field.

3.1.1 Analysis of magnetic field distribution

Fig. 7 shows the result of the analysis of the magnetic field distribution by meander coil. The meander coil and solder ball are made of Cu and SnPb, and these conductivities are 5.76×10^{7} and 6.8×10^{6} S/m respectively. The sinusoidal current is 0.1 A and the frequency is 5 MHz. The exciting current is flowing near the surface of the meander coil by the effect of the skin effect. The magnitude of magnetic field becomes high and the solder ball gives the disturbance of magnetic field.

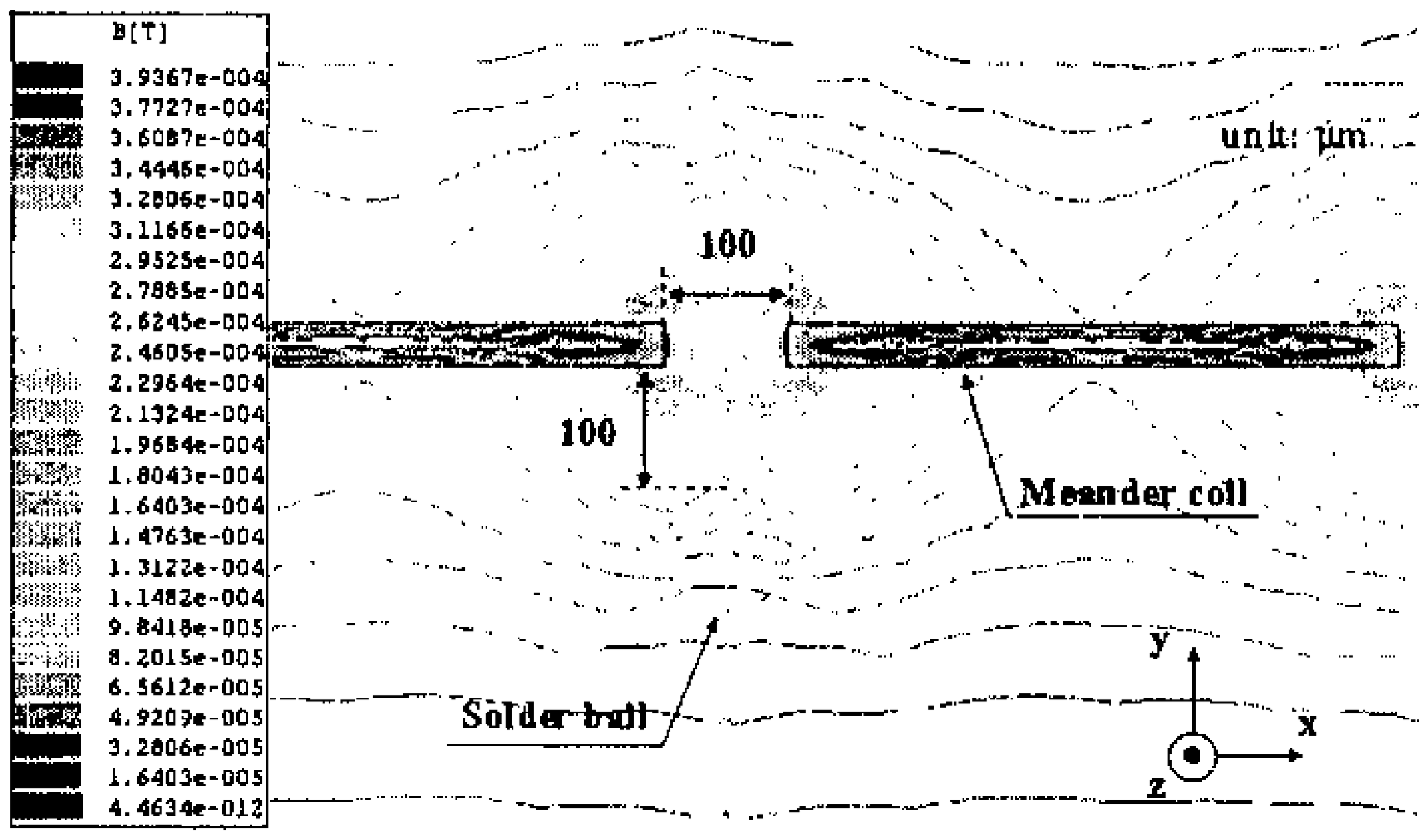


Fig. 7 Magnitude of magnetic field by meander coil

3.1.2 Analysis of eddy-current distribution of solder ball

Fig. 8 shows the computed distribution of eddy-current inside solder ball. The diameter of the solder bead is 300 μm. The micro solder ball as metallic bead is used mostly in BGA package. Eddy currents inside solder bead are flowing in the counter clockwise.

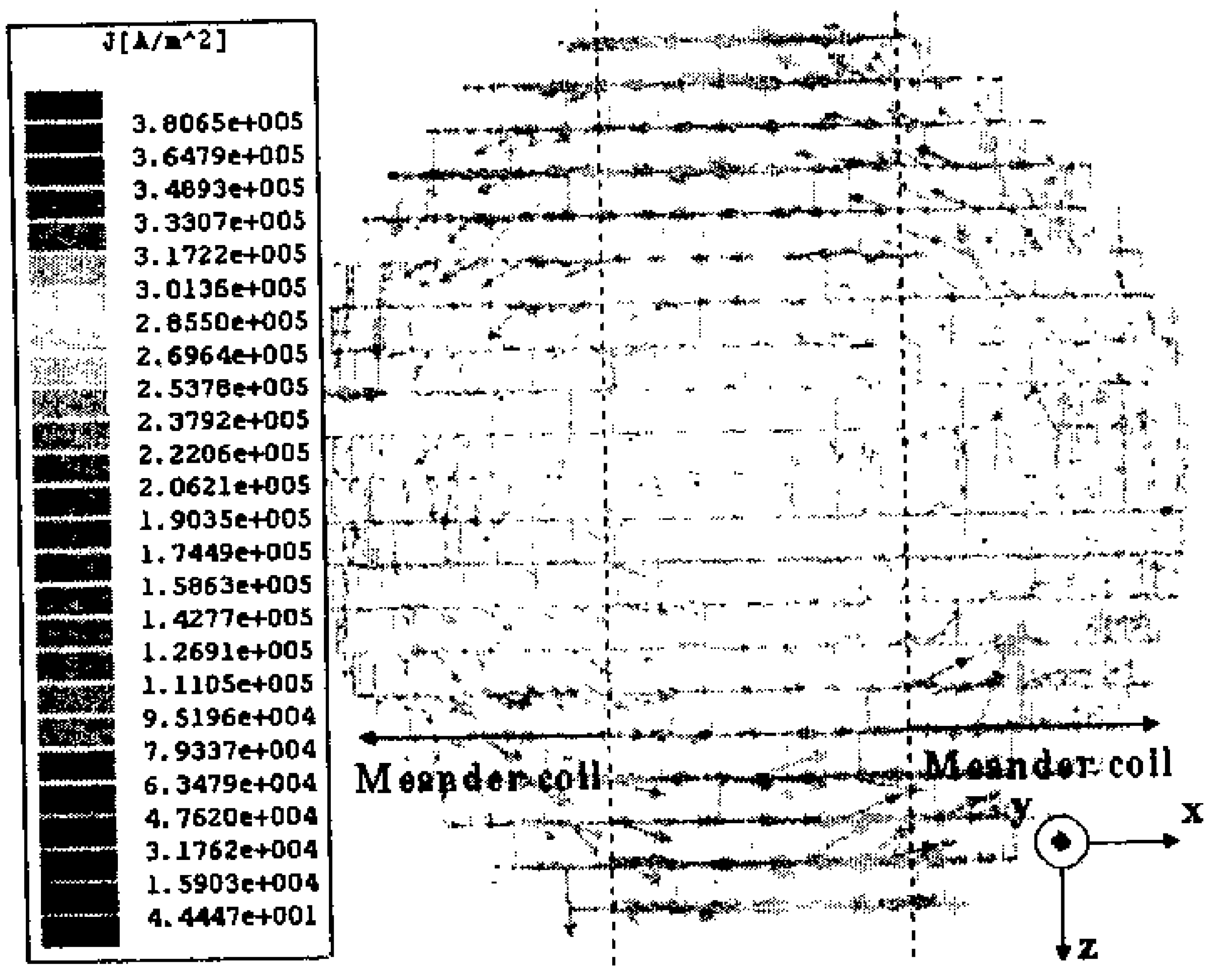


Fig. 8 Eddy-current distribution of metallic bead

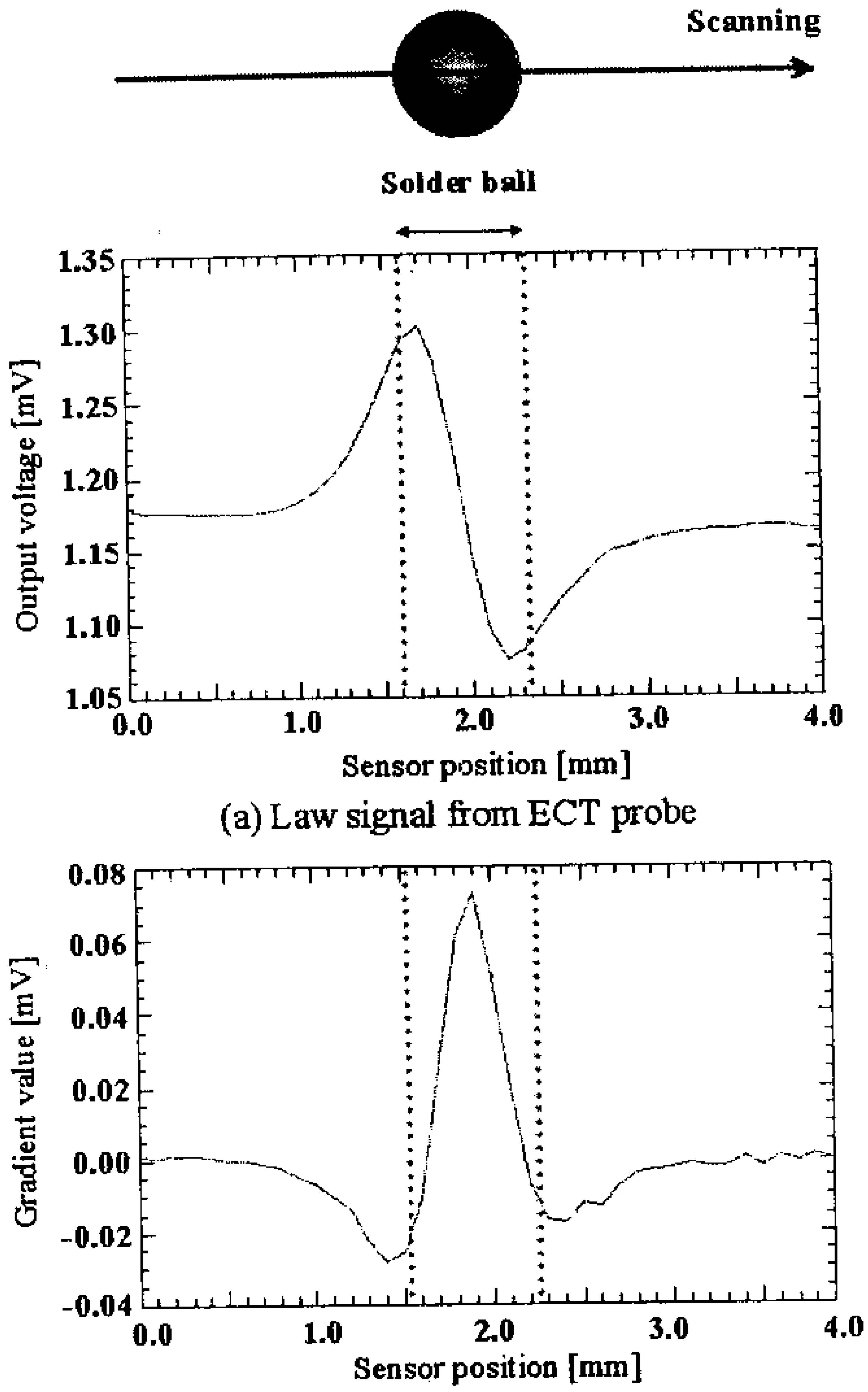
3.2 Experimental results

3.2.1 Characteristics of detection

Fig. 9 shows the characteristics of detection of solder ball with the diameter of 760 μm. The scanning step of the ECT probe is 0.1 mm. Fig. 9(a) shows the raw data of the signal of solder ball. Fig. 9(b) shows the numerical gradient values of the signal to remove offset and also to enhance the output signal[3,4]. The point at that the maximum value of the signal is taken seems to be the middle of metallic bead. The results show that the solder ball can be detected clearly by using ECT technique and the position of metallic bead can be detected.

3.2.2 Relationship between size and signal

From gradient signals as shown in Fig. 10, the signals of solder ball, *Vs*, and the noise, *Vn*, are defined by the peak to peak amplitude of the gradient values. Fig. 11 shows relationship between size of bead and signal. Solder balls with the diameter of 0.25 to 0.76mm are tested. The signal of solder ball will decrease when the diameter of the ball decreases. On the contrary, the noise amplitude are kept at the same value. It is possible to distinguish the size of the bead from the size of signal. The results show that these solder balls with the diameter of 0.25 to 0.76 mm can be detected clearly.



(a) Law signal from ECT probe

(b) Gradient signal

Fig. 9 Output and gradient signals of SV-GMR sensor

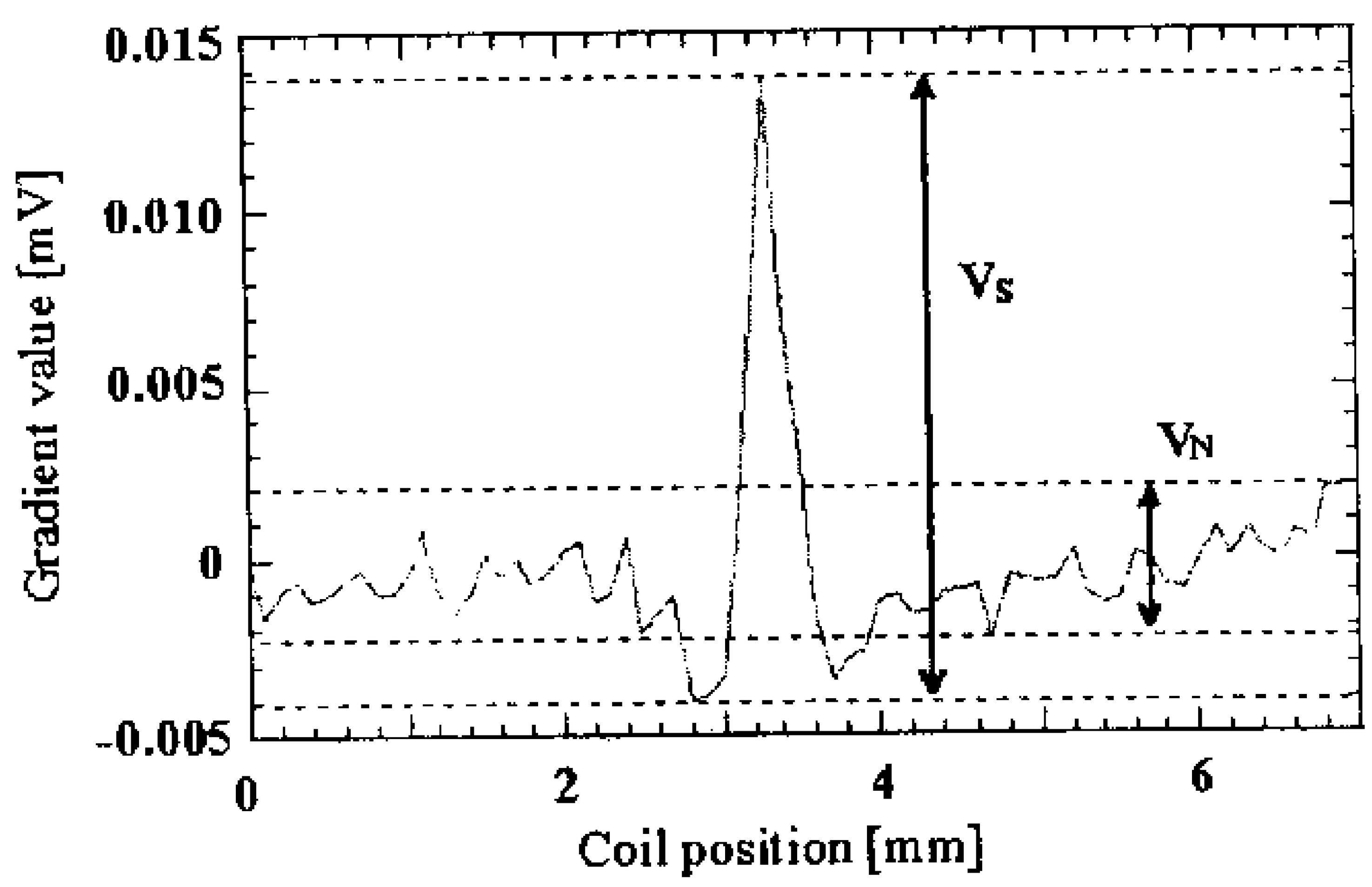


Fig. 10 Definition of signal level

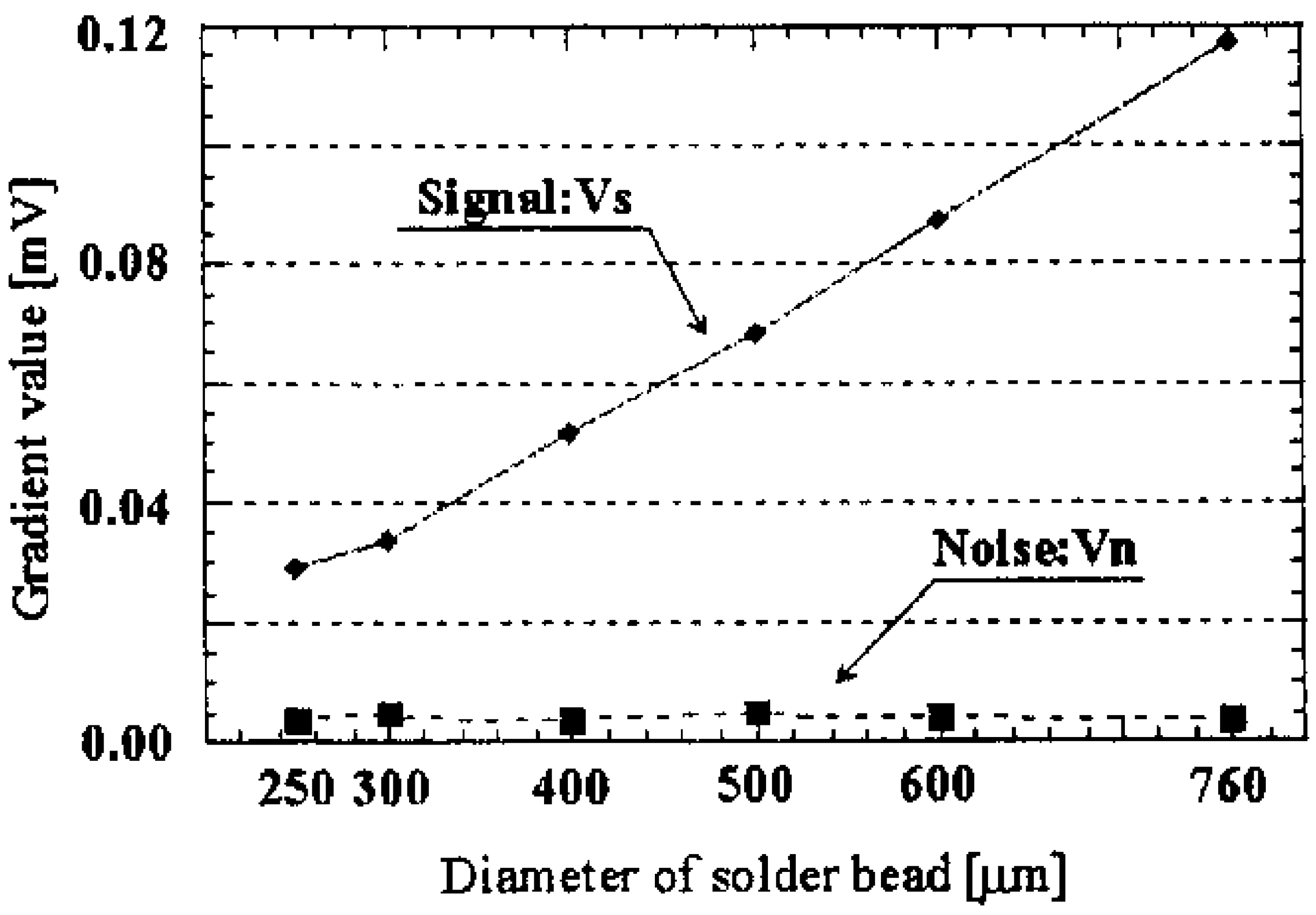


Fig. 11 Characteristics of signal vs. diameter of solder ball

3.2.3 Relationship between lift-off height and signal

Fig. 12 shows relationship between lift-off height and signal. According to Fig. 3, the minimum lift-off height is 100 μm (distance between meander coil and metallic bead). Two kinds of solder balls with the diameter of 0.30 and 0.76 mm are measured. The signal should be more than 3 times higher than noise signal to keep the realization of detection. These results show that the lift-off height is kept less than 200 μm for 0.76 mm solder ball and less than 150 μm for 0.30 mm ball.

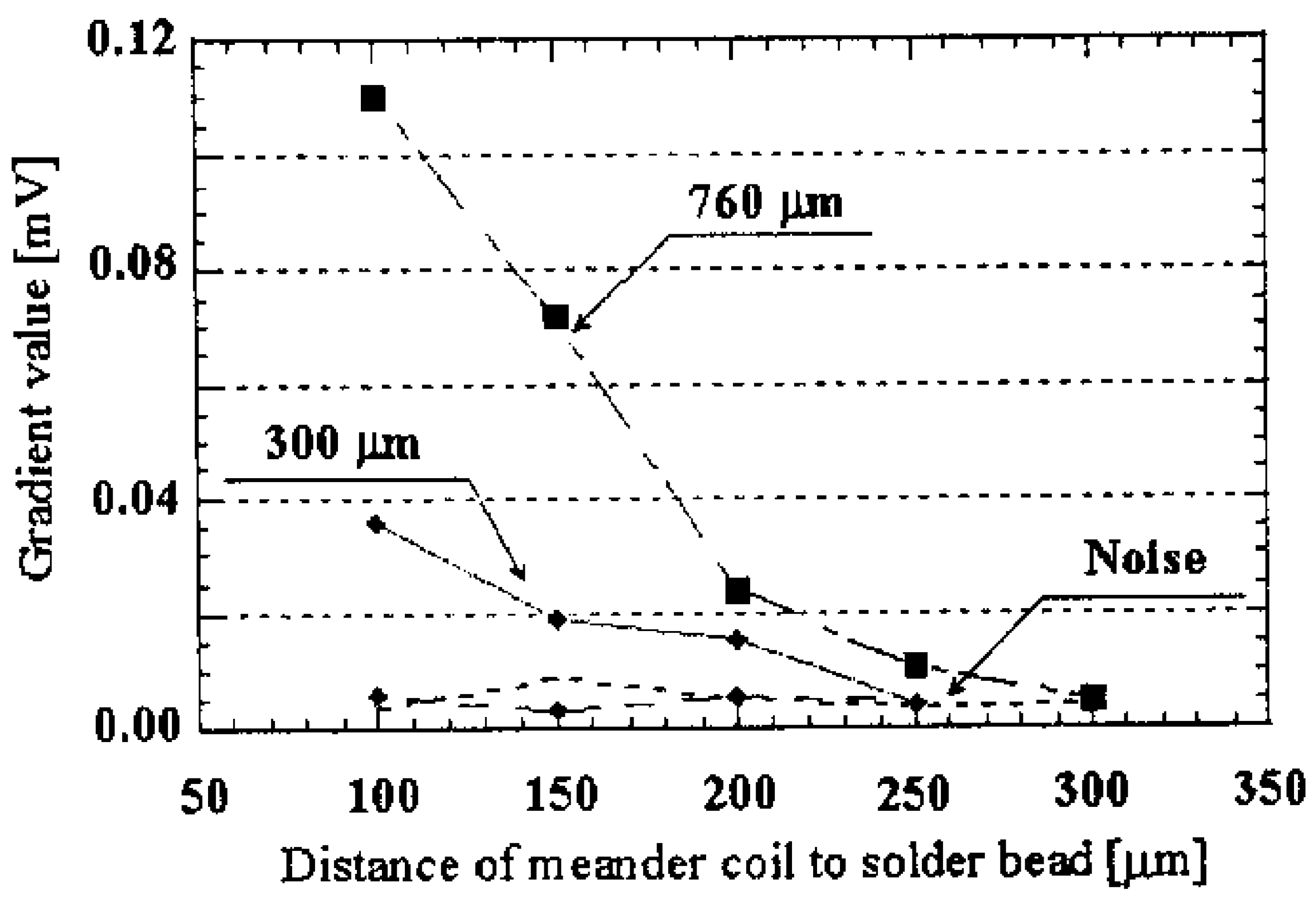
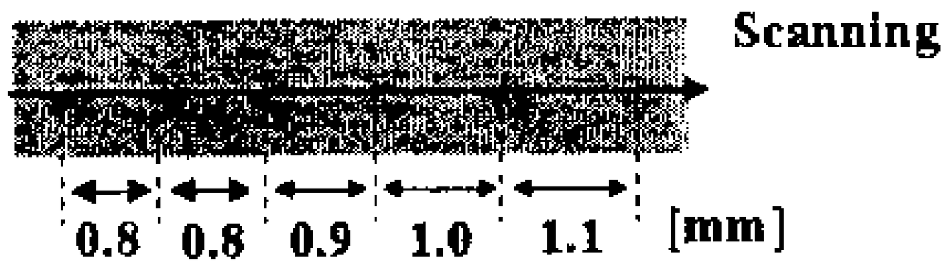


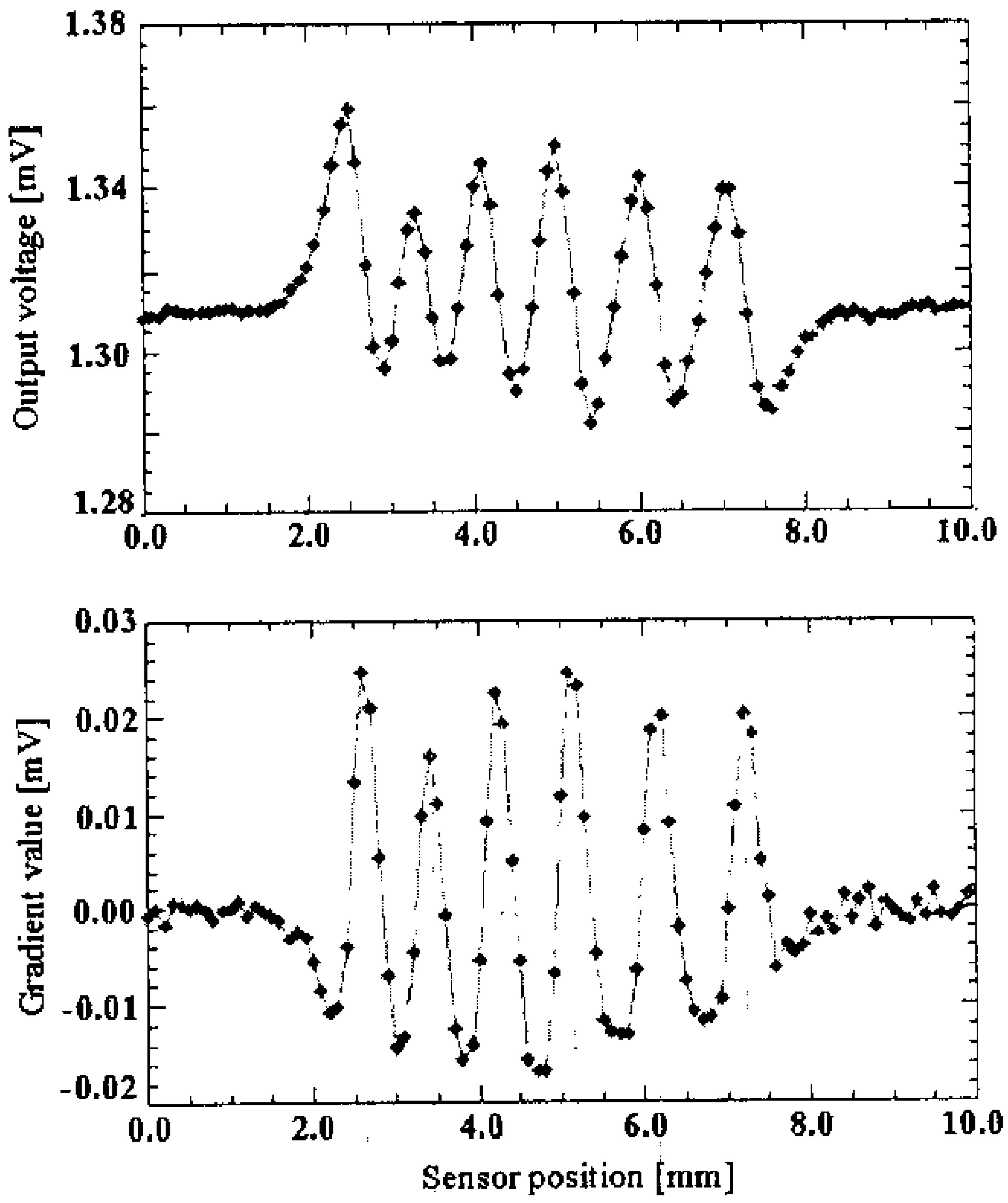
Fig. 12 Characteristics of signal vs. lift-off height

3.3 Detection of the position of solder ball

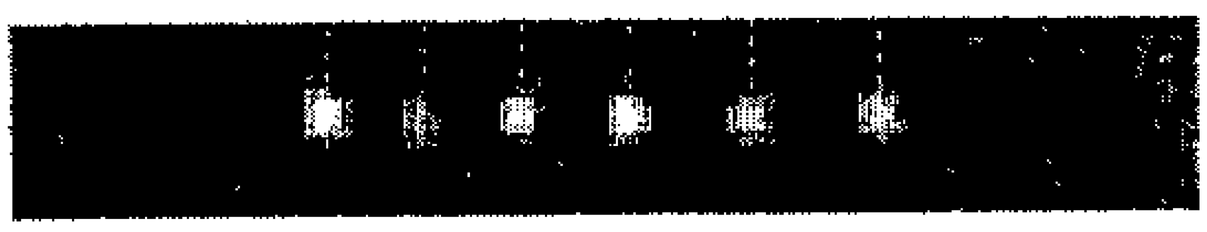
We can recognize the position of solder ball from output signal. By detecting ball arrange in the side, the position of solder ball is detected. Fig. 13(a) shows the photo of the model. The distances of each bead are changed a little. The diameter of these solder balls is 0.30 mm. Fig.13 (b) shows the raw data and gradient signal. The point at that the maximum values are taken seems to be the midpoint of solder ball. The result shows that the position of metallic bead can be measured with 20% error. Fig. 13(c) shows the 2-D image around the array of solder ball.



(a) Model of arrayed balls



(b) Strip chart of law signal and gradient value



(c) 2-D image

Fig. 13 Detected signals for solder balls

4. CONCLUSION

We proposed the defection of metallic bead by ECT technique as a new application. We used the ECT probe consists of meander coil and GMR sensor. As the results, we can detect the existence, size and position of metallic bead from the signal by using ECT technique. The experimental verification of the model proves prospective possibilities for the development of biosensors, physical measurement systems and others.

5. ACKNOWLEDGMENT

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6. REFERENCES

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