Eddy-Current Testing Probe With Spin-Valve Type GMR Sensor for Printed Circuit Board Inspection

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Eddy-Current Testing Probe With Spin-Valve Type GMR Sensor for Printed Circuit Board Inspection

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***Abstract*—This paper proposes an eddy-current testing (ECT) probe composed of a spin-valve giant magnetoresistance (SV-GMR) sensor and a meander coil for the inspection of bare printed circuit board. The SV-GMR sensor serves as a magnetic sensor for the ECT probe to sense the variation of the magnetic field distribution occurred on the printed circuit board. The SV-GMR sensor is used specifically to detect the changing magnetic field distribution occurred at the defect point. The characteristics of the proposed probe are discussed in this paper. The comparisons of signal-to-noise ratios obtained from ECT probe with SV-GMR sensor and with solenoid coil verify that the applying of SV-GMR sensor to the ECT probe can improve the PCB inspection results.**

***Index Terms*—Eddy-current testing (ECT), printed circuit board inspection, signal-to-noise ratio, spin-valve giant magnetoresistance (SV-GMR).**

I. Introduction

PRINTED circuit board (PCB) inspection by an eddy-current testing (ECT) probe is a novel application of ECT techniques. This inspection approach was verified that ECT probe is useful for the bare PCB inspection [1]. Consequently, the ECT probe can examine conductor disconnections or short circuits similar to the electrical testing method. Both the image processing technique and probe construction have been developed to improve the efficiency of the PCB inspection system [1]–[3]. Although these can improve efficiency of the inspection, the output signal achieved from the inductive sensor is not good enough because of limitations of the inductive sensor characteristics.

Giant magnetoresistance (GMR) sensor which was recently applied to the material inspection based on the ECT technique provided good inspection results [4]. In this paper, the ECT probe with the spin-valve GMR (SV-GMR) sensor for the PCB inspection is proposed. The signal-to-noise ratios achieved from both inductive sensor (solenoid coil) and SV-GMR sensor are discussed, and the results verified that the ECT probe with the SV-GMR sensor is able to improve the PCB defect inspection.

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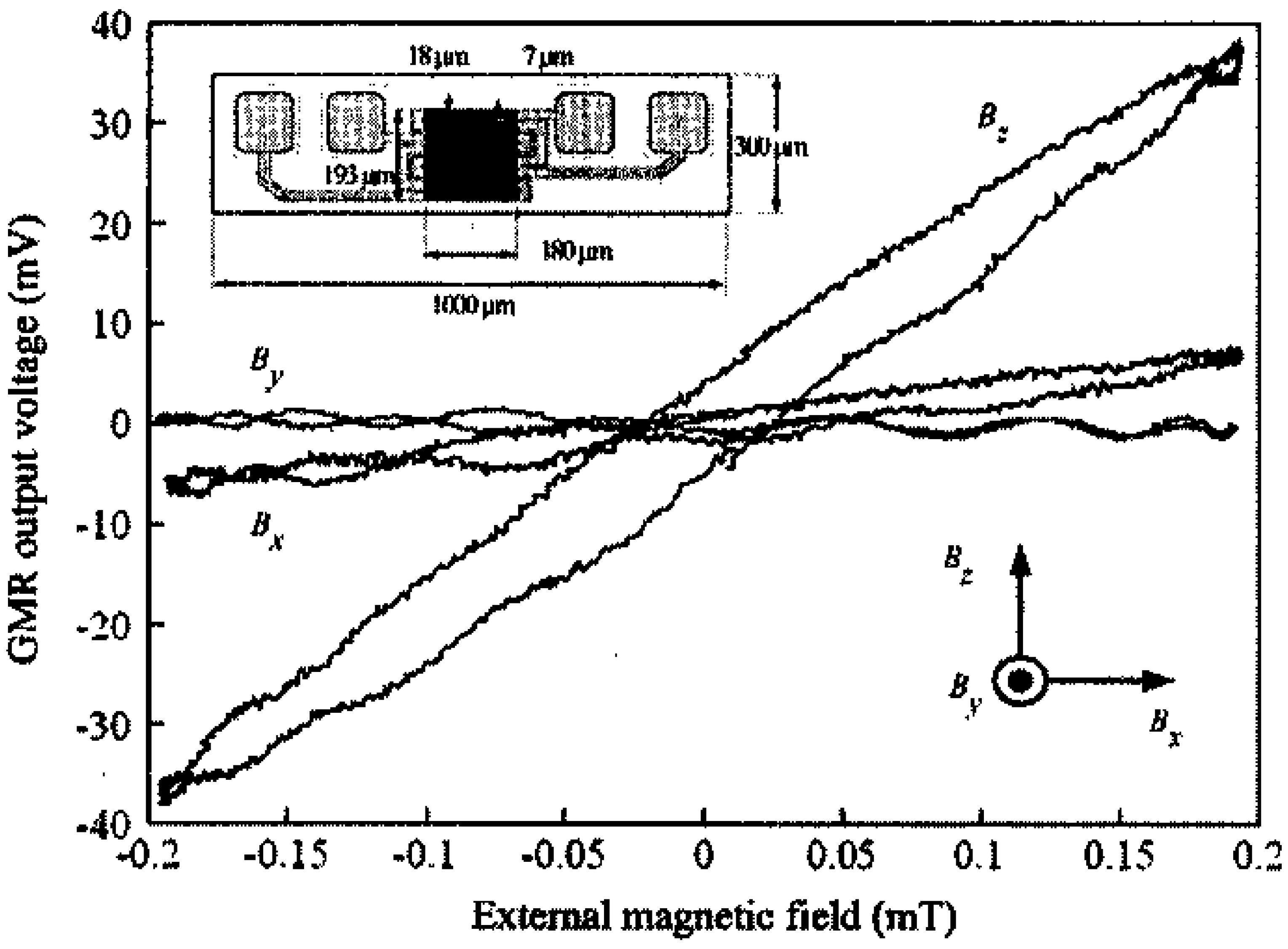

Fig. 1. AC characteristic of SV-GMR sensor for this purposed at each of SV-GMR sensor axis.

In addition, the inspection results of the PCB model are presented in the experiment.

II. Configuration of the Proposed ECT Probe

A. SV-GMR Sensor Construction and Characteristics

Fig. 1 shows the SV-GMR sensor and its ac characteristics used for the PCB inspection based on the ECT technique. The resistance of the SV-GMR sensor was 627 Ω with no external magnetic field applied. The dc constant current of 5 mA was fed to SV-GMR sensor and the lock-in amplifier was used to measure the voltage between the SV-GMR sensor. The ac characteristics at each of the SV-GMR sensor axis were tested by using the Helmholtz coil. From the characteristics, the SV-GMR sensor has sensitivity (20 mV/100 μT) only to the magnetic flux density in the z direction, B_z.

B. Proposed ECT Probe Construction

The proposed ECT probe construction consists of two parts, as shown in Fig. 2. The first part is the meander coil which is used as an exciting coil. The frequency of sinusoidal current which was fed to the meander coil was 5 MHz. The second part is the SV-GMR sensor which is used to detect the variations of magnetic flux occurred on the PCB.

Normally, the exciting current is flowing in the z axis and also generates the magnetic field along the x and y axis, these two normal components generate the eddy-current flowing in the PCB conductor. Whenever there is a defect or soldering

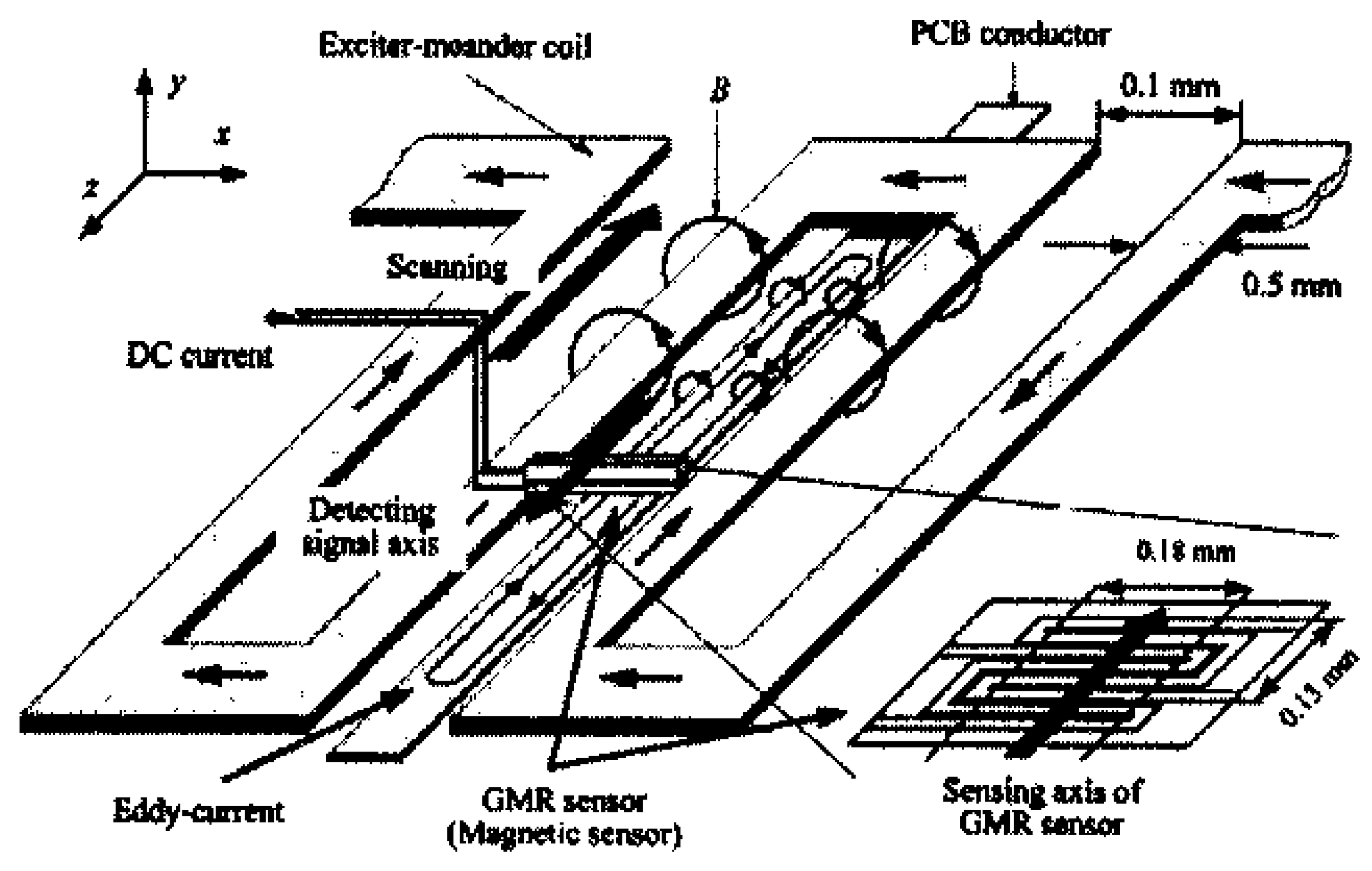

Fig. 2. Construction of the proposed ECT probe for PCB inspection.

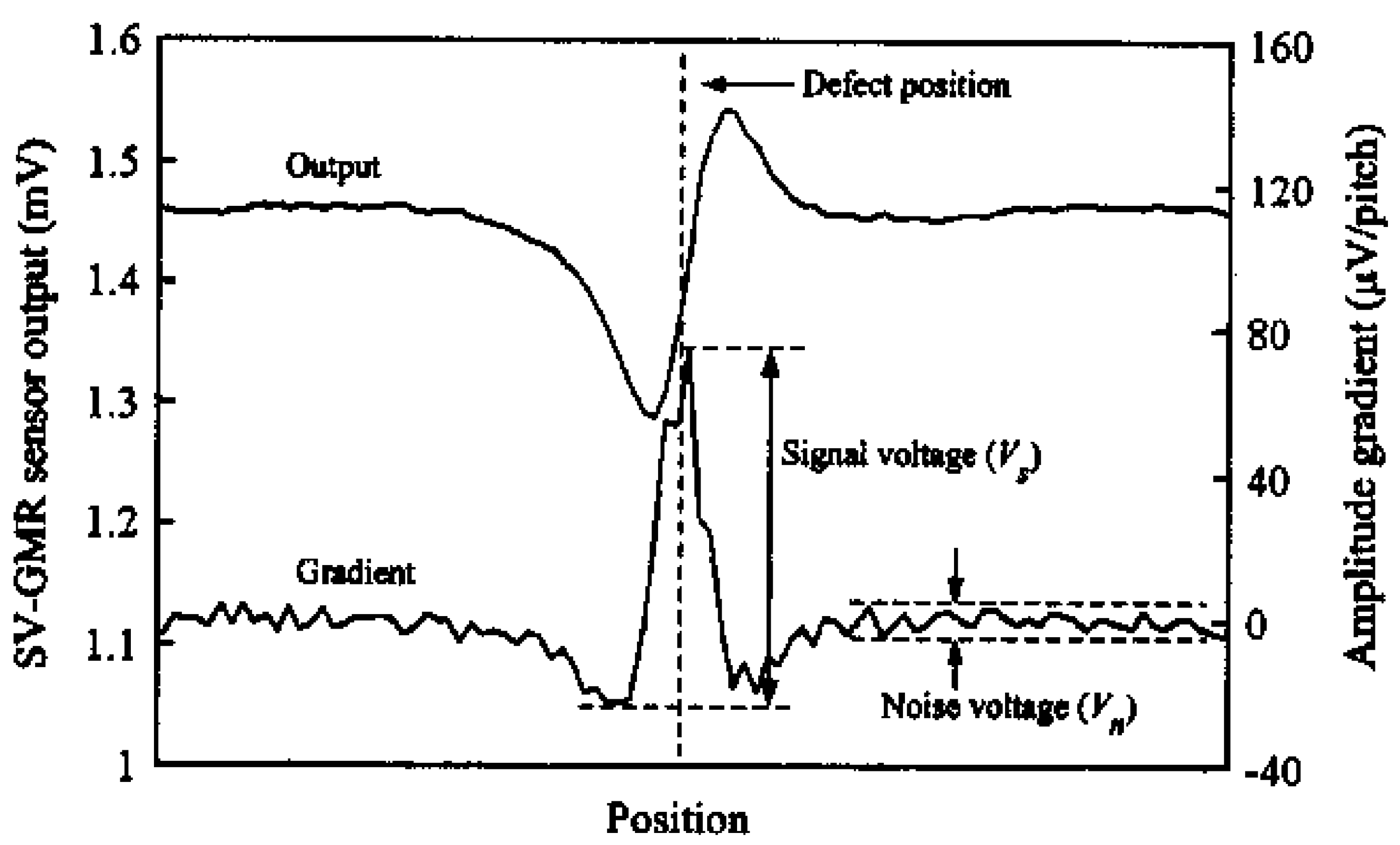

Fig. 3. Output and gradient signals of SV-GMR sensor output.

point occurred on the PCB conductor, the eddy-current path is changed and the magnetic flux the in the z axis, tangential component, occurs.

Considering the characteristics mentioned, the SV-GMR sensor was attached to the meander coil, as shown in Fig. 2, to detect only the tangential component. Therefore, the output voltage across the SV-GMR sensor will be varied only when a defect or a soldering point is detected.

III. Inspection Results

A. Inspection Signal

Fig. 3 shows the output and amplitude gradient signals of the SV-GMR sensor obtained from scanning the PCB conductor with a width and thickness of 100 and 35 μm, respectively. This PCB conductor had a disconnection width of 100 μm and the scan pitch was 0.05 mm. The numerical gradient technique was used to remove the offset of the output signals and also to enhance the output signals at the defect points. From amplitude gradient signals shown in Fig. 3, the signal-to-noise ratios, $R_{\rm sn}$, was defined by (1)

$$R_{\rm sn} = 20\log(V_s/V_n). \quad (1)$$

Fig. 4 shows the signal-to-noise ratios $R_{\rm sn}$ versus different PCB track width. The PCB conductors with track widths of 300, 200, and 100 μm with a defect width of 100 μm were used as a model. The signal-to-noise ratios obtained from the solenoid coil probe are smaller than 5 dB when the PCB conductor is less than 100 μm in width. In comparison with the solenoid coil

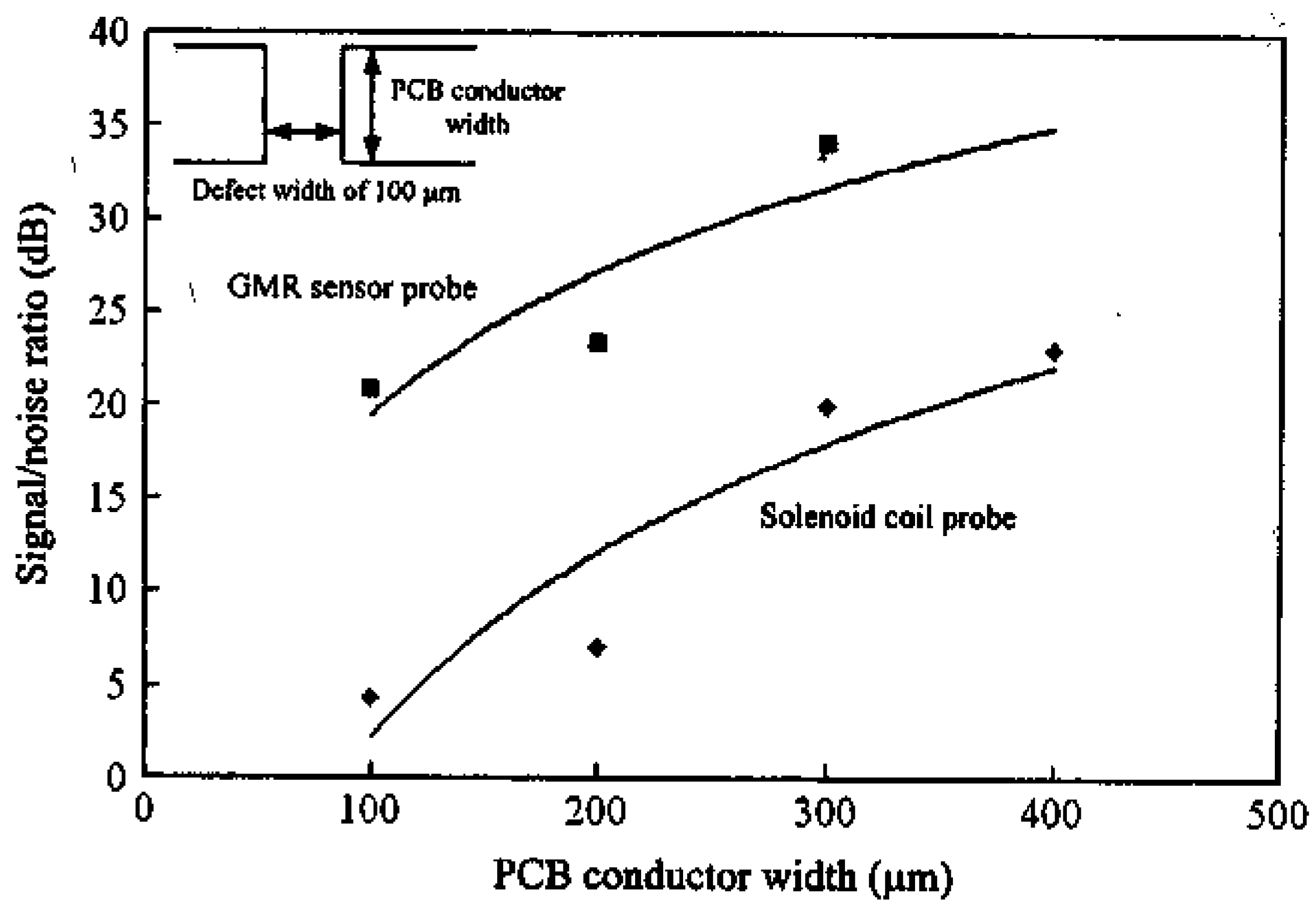

Fig. 4. Signal-to-noise ratios with different PCB conductor width.

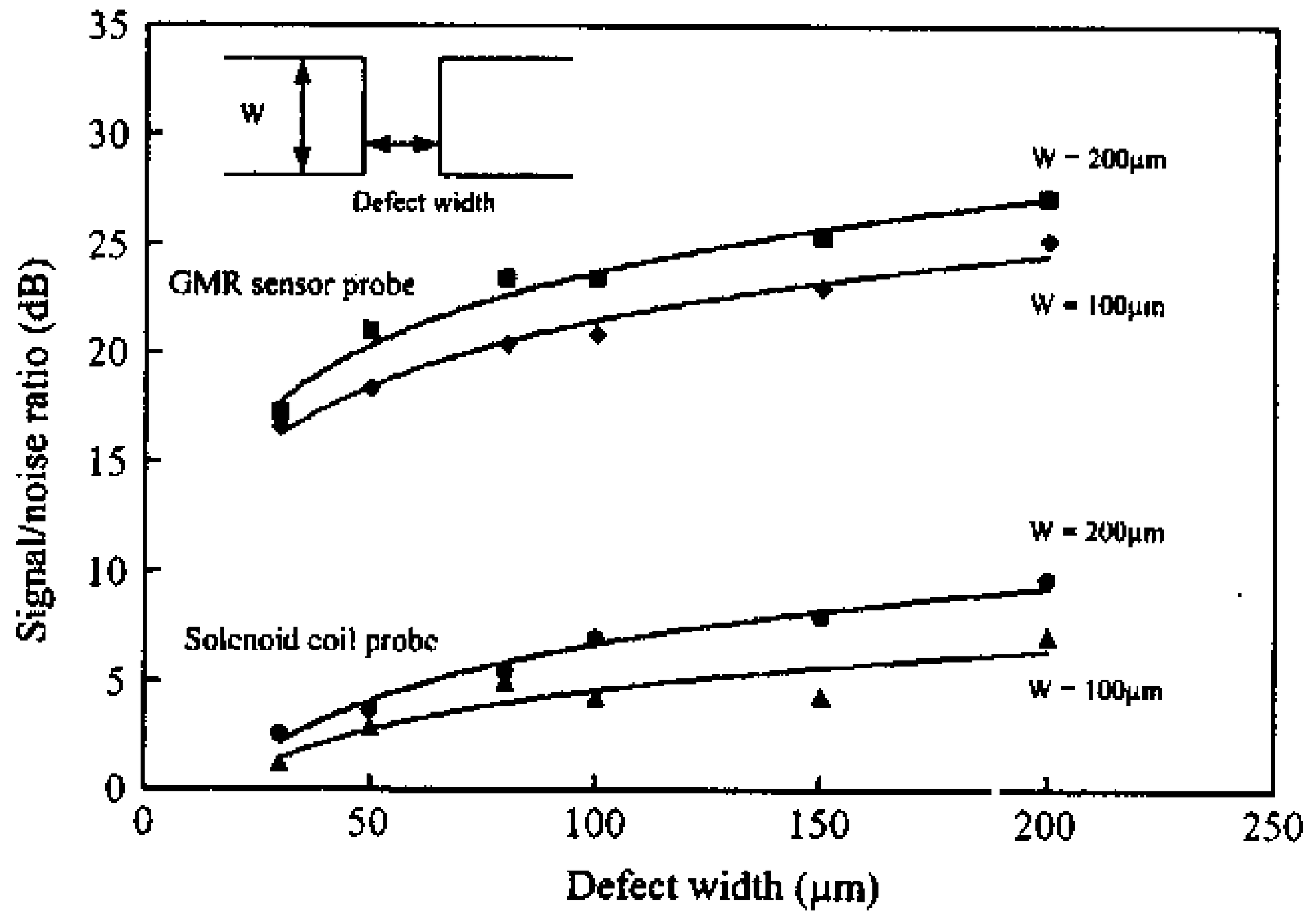

Fig. 5. Signal-to-noise ratios with different defect width.

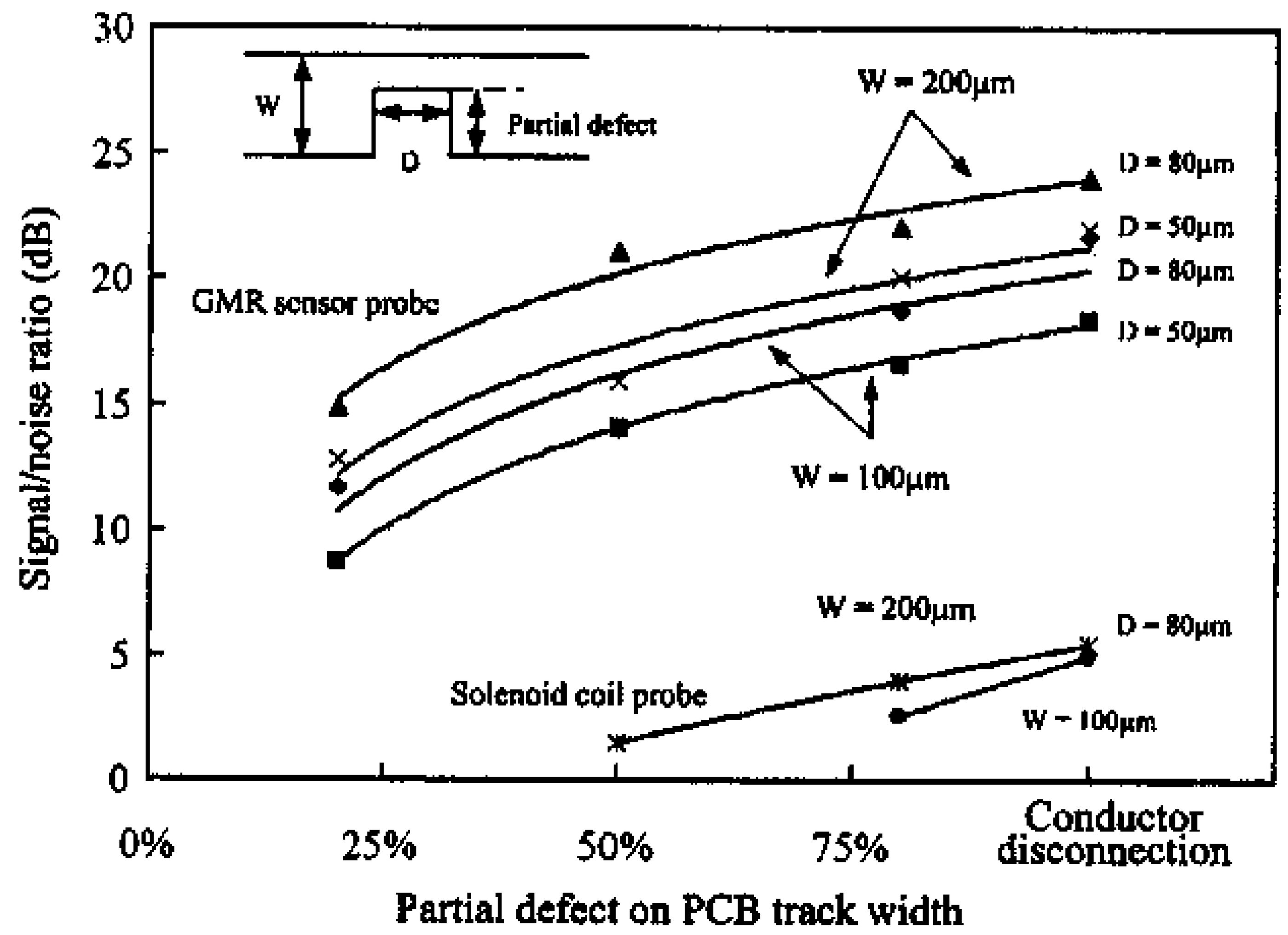

Fig. 6. Signal-to-noise ratios with different partial defect size.

probe, application of the SV-GMR sensor to the PCB inspection based on ECT technique improves the signal-to-noise ratios up to about 15 dB. Therefore, the ECT probe with the SV-GMR sensor is capable of applying to the high-density PCB which has the track width with less than 100 μm.

The relations of the signal-to-noise ratios and the width of defect points are shown in Fig. 5. The PCB conductor widths of 200 and 100 μm, with the conductor disconnection width range from 30 to 200 μm were inspected. Although the solenoid coil probe can detect the small conductor disconnections smaller

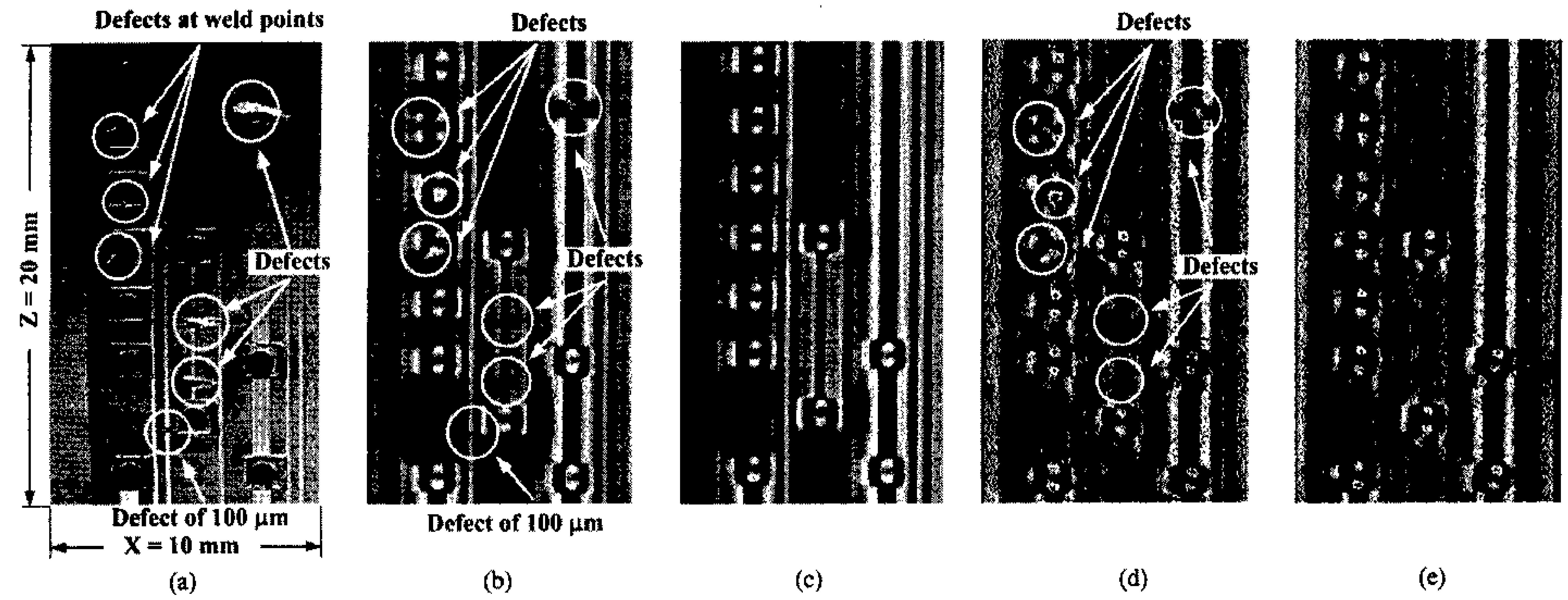

Fig. 7. (a) Photograph of defect PCB model. (b) Two-dimensional (2-D) images of defect PCB model and (c) nondefect PCB model achieved from SV-GMR sensor, respectively. (d) The 2-D images of defect PCB model and (e) nondefect PCB model achieved from solenoid coil, respectively.

than 100 μm, the signal-to-noise ratios are lower than about 6 dB. For SV-GMR sensor, the signal-to-noise ratios achieved from the inspection of the defect width of 30 μm are still more than 15 dB. Therefore, the inspection using the proposed ECT probe with SV-GMR sensor provides an effective examination for conductor disconnection with less than 100 μm.

In addition, the partial defect on PCB conductor can be also inspected by this proposed ECT probe. The PCB conductor widths of 200 and 100 μm, with the defect widths of 80 and 50 μm were used to demonstrate the partial defect inspections on the PCB conductor. Fig. 6 shows the signal-to-noise ratios achieved from the partial defect inspections of both the SV-GMR sensor and solenoid coil. The signal-to-noise ratios will decrease when the partial defects become smaller. The signal-to-noise ratios are lower than 6 dB when measure with the solenoid coil. On the contrary, they are higher than 8 dB when measures with the SV-GMR sensor.

B. Bare PCB Inspection

In Fig. 7(a), the bare PCB model with defect points was used for experiments. The smallest PCB conductor width had a width of 100 and thickness of 35 μm. The defect points occurred at the soldering points and conductor disconnections on the PCB conductor were demonstrated. The smallest conductor disconnection width was 100 μm. The 2-D images of the defect and nondefect PCB models obtained from the SV-GMR sensor are shown in Fig. 7(b) and (c), respectively, and the images from solenoid coil sensor are shown in Fig. 7(d) and (e). The defect points are shown in white-edged circles. The defect points in the 2-D image obtained from the PCB model scanning can be located by comparison with the 2-D image obtained from the nondefect PCB model. The inspection results by the solenoid coil can not inspect the defect of 100 μm whereas the inspection results by the SV-GMR sensor can specify all of the defect points. Moreover, the 2-D image by the SV-GMR sensor provides clearer details than by the solenoid coil.

IV. Conclusion

The SV-GMR sensor was applied to the PCB inspection based on the ECT technique to improve the inspection efficiency. The application of the SV-GMR sensor as a magnetic sensor of the ECT probe improves the signal-to-noise ratio of the primary signal obtained from magnetic sensor. Moreover, the signal changing at precise defect position can be achieved from the SV-GMR sensor because the SV-GMR sensor provided high-resolution inspection. The proposed ECT probe with the SV-GMR sensor gives the possibility of inspecting disconnection on the high-density PCB with less than 100 μm.

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