Study on Manganin High Pressure Array Sensor

DUAN Jianhua    DU Xiaosong    YANG Bangchao    ZHOU Hongren
(School of Microelectronics and Solid-State Electronics, UESTC Chengdu 610054 China)

Abstract   A new kind of thin film manganin array gauge is fabricated by adopting a new sensor fabrication technique. The sensitive materials (manganin thin films) are first deposited by magnetron sputtering on fused silica substrates, and then covered by a layer of SiO\textsubscript{2} thin films by electron beam evaporation. Based on impedance match method of “back configuration”, the highest pressure measured in Al target is 51.68 Gpa, the highest pressure in SiO\textsubscript{2} package is 35.396 Gpa and the piezoresistance coefficient $k$ is 0.026 Gpa\textsuperscript{-1}. The upper limit and measure precision of sensor is improved.

Key words  manganin film sensor;  fused silica;  back configuration

In the war industry and armament experiment, very high pressure is needed. This kind of high pressure is gained by the way of high speed impaction and nuclear explosion, which brings instantly high temperature. Therefore, it is necessary to design a special type of pressure sensor which is fit for high temperature and high pressure.

According to the data all over the world, only manganin high pressure sensor can meet the need of shock wave measure and GPa measure range at present\textsuperscript{[1]}. Several-year research shows that manganin alloy has the characteristics of low temperature coefficient of resistance (TCR), fast response and good linearity though its low coefficient of pressure-resistance. The current kinds of manganin sensor can only measure the pressure by only one sensor. The measure precision is still low. This paper illustrates the process of how the four manganin sensors are made on the same substrate as array structure and the measured pressure results are good.

1  Experiment

In order to get high frequency response, the design rules of manganin film sensor are as follows:

1) The structure of the sensor should be designed as plane structure and the section of the sensitive material be rectangle.

2) The original resistance of sensitive material should be low, which can release bypass effect.

3) The size of sensitive material should be small.

The thin film gauges are designed as array structure as shown in Fig.1. Fused silica is used as substrates. Manganin film and cooper leads are deposited by planar magnetron sputtering through molybdenum shadow masks. The active parts are array-like, having dimensions of 3.6 × 1.2 mm. The resistance of the four-terminal array-shaped is measured to be $0.34 \pm 0.3 \ \Omega$. The thickness of the manganin films and copper leads measured by the interferometer method are approximately 2 μm and 3 μm respectively.

Fig. 1  Construction of thin films manganin gauge package

Preparation of a low TCR film could be a key
point to ensure a gauge to be insensitive to temperature change (>1000ºC). A DC (direct current) sputtering apparatus equipped with a turbo molecule pump is used to deposit the films. The as-deposited films are silver white in color and have TCR in the order of 80 × 10⁻⁶/ºC. All the resistance measurements are made on a Wheatstone bridge together with a thermostatic bath heated from 25~45ºC. The ac-deposited films are comprised of 84.8% Cu, 12.8% Mn and 2.4% Ni by weight based on analysis of electronic probe. Our films consist of similar compositions. This finding is opposite to Ref.[2].

To complete the gauge package, a layer of SiO₂ films is deposited on the sensing element by electronic beam evaporation. The evaporated material is similar in composition to the fused silica substrates. The SiO₂ films should be thick enough to be a good insulator. The film thickness of 5 μm is examined in this work.

The plate impact experiment is performed using a 35-mm two-stage light gas gun. As Fig.2 illustrates, very thin layers of adhesive are painted on both sides. The gauges are inserted into the gap between a Al plate and a thick block of fused silica (back-surface configuration). With back-surface configuration, the stress in the specimen, especially for materials with high shock impedances, is much higher than that in the packaged device. This is the one of the basic approaches to measure high pressure [3]. Tektronix TDS 684B oscilloscopes with a constant current supply are used for recording the stress history.

![Fig.2](image.png)

2 Results and Discussion

As shown in Fig.3, we can find that the four signals are caught by Tektronix TDS 684B oscilloscopes at the same time. But the four signal are not consistent, which are caused by the tilt of the flyer in the course of impact. The rise time of the signals are very sharp, usually in the order of 30 ns, due to the absence of stress reverberations of the back-configuration structure. The stresses in the Al targets and SiO₂ packaged devices are calculated by the impedance-match method with the use of the Hugoniot parameters and initial density of fused silica. The Hugoniot parameters of the fused silica are taken as $C_0=1.73$ km/s and $\lambda=1.450$ 87. The initial density of fused silica is 2.20 g/cm³ measured by the Archmedean method. Tab.1 shows the impact calculation results.

![Fig.3](image.png)

3 Conclusions

A new type of thin film manganin gauge is fabricated in which four sensors are made at the same time. The gauge shows shock stress history up to 51 GPa with a flat-topped profile and had no indicating of shunt. The piezoresistance coefficient $k$ is 0.026 Gpa⁻¹, which is similar to that of ordinary foil gauges, e.g., 0.027 6 Gpa⁻¹ given in Ref.[4].
Tab. 1  Summary of impact experiments and results

<table>
<thead>
<tr>
<th>Shot</th>
<th>Flyer v/ km·s⁻¹</th>
<th>Stress/GPa Target package (Al)</th>
<th>Stress/GPa Target package (SiO₂)</th>
<th>Rise t/ns</th>
<th>△R/R₀</th>
<th>Piezoresistance coefficient/Gpa⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.464</td>
<td>51.68</td>
<td>35.396</td>
<td>37</td>
<td>0.934 16</td>
<td>0.026 4</td>
</tr>
<tr>
<td>2</td>
<td>4.464</td>
<td>51.68</td>
<td>35.396</td>
<td>35</td>
<td>0.922 20</td>
<td>0.026 1</td>
</tr>
<tr>
<td>3</td>
<td>4.464</td>
<td>51.68</td>
<td>35.396</td>
<td>33</td>
<td>1.092 20</td>
<td>0.030 9</td>
</tr>
<tr>
<td>4</td>
<td>4.464</td>
<td>51.68</td>
<td>35.396</td>
<td>32</td>
<td>0.817 57</td>
<td>0.023 1</td>
</tr>
</tbody>
</table>

Acknowledgments

The author would like to thank tutor Yang Bangchao, Zhou Hongren and Du Xiaosong for their experimentation help and Shi Shangchun for his impact test support.

References


Brief Introduction to Author(s)

DUAN Jianhua (段建华) was born in Hebei province, China, in 1978. She received the B.S. degree in Electronic Materials Science from UESTC in 2000, and the M.S. degrees in Microelectronics and Solid Electronics Science from UESTC in 2003. She is currently working on the design of Analog Integrated Circuits and devices. E-mail: cdyya@163.com

DU Xiaosong (杜晓松) was born in Sichuan province, China, in 1967. He received the B.S. degree in materials science from University of Tsinghua in 1992, M.S. degree in material science from University of Sichuan in 1995. In 2002, he received his Ph.D. degree in Microelectronics and Solid Electronics from UESTC, Where he is now an Associate Professor. His research interest include: focused on thin film materials and devices. E-mail: xsdu@uestc.edu.cn

YANG Bangchao (杨邦朝) was born in Sichuan province, China, in 1938. He is currently a Professor of the School of Microelectronics and Solid electronics, UESTC. He was the Project Leader for Development of the high pressure Manganin film sensor. His research interests include: the thin film materials and devices. E-mail: byang@uestc.edu.cn

ZHOU Hongren (周鸿仁) was born in Jiangsu province, China, in 1937. He received the B.S. degree in Wireless electronic measurement from UESTC in 1965. His research interests include: Pt and Ni Film sensor, film amplifier, and high pressure film sensor. Email: zhr-301@163.com

QIN Zhiguang (秦志光) was born in 1957. He is now a Professor, Doctoral Advisor student in UESTC. His research interests include: information security, ITS and middleware. E-mail: qinzg@uestc.edu.cn

LIU Jinde (刘锦德) was born in 1930. He is now a Professor and Doctoral Advisor in UESTC. His research interests include: opening distributed computing and middleware technology, mobile agent technology. E-mail: jdlju@uestc.edu.cn