Extended Abstracts of the 2007 International Conference on Solid State Devices and Materials, Tsukuba, 2007, pp. 286-287

F-3-1

Fabrication of 3-D Silicon Micro Probes for Neural Recording Using Multi-Step VLS Growth

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1. Introduction

Study of our nervous system by highly complex structures is a key problem in modern neuroscience. We have proposed silicon-probe arrays fabricated by vapor-liquid-solid (VLS) crystal growth for penetrating microelectrodes [1, 2]. This silicon-probe is about 3 μm in diameter and can be integrated with circuit. As the next stage, we aim 3-D silicon-probes, having various lengths in an array, for recording 3-D distribution of neural activities.

2. Experiment

To fabricate 3-D silicon-probes, we have proposed multi-step VLS Crystal Growth shown in Fig. 1.

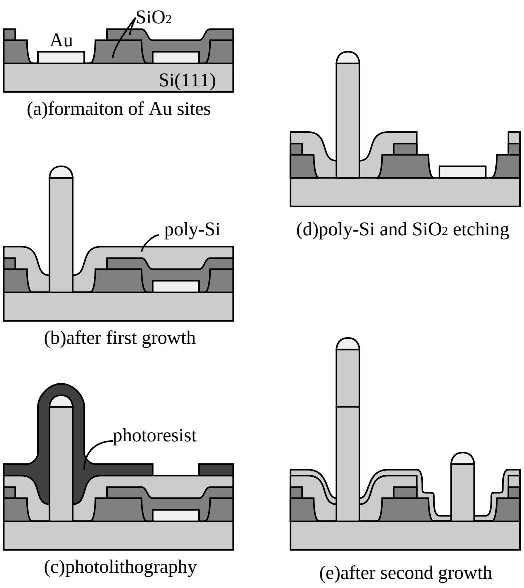


Fig. 1 Process sequence of multi-step VLS growth

Au sites were formed on Si(111) substrate, and some of Au sites were covered by SiO_2 film for second growth as shown in Fig. 1(a). After first VLS growth, the probes grew from the Au sites without SiO_2 and the probes did not grow from Au sites covered with SiO_2 shown in Fig. 1(b). To get Au surface as the sites for second growth, resist coating and photolithography were carried out shown in Fig. 1(c), and poly-silicon and SiO_2 film on Au sites were removed shown in Fig. 1(d). After second VLS growth, the probes were grown from sites where Au surface appears in the previous process and the probes grown by first growth became longer as shown in Fig. 1(e). In order to realize this process, photolithography for 3-D structures was required.

For photolithography, spin coating is generally used. However, if silicon probes were coated by spin coating, the tip of probe was not covered and the bottom of the probe has too much resist to pattern. Therefore, spray coating [3] was used. Spray coating is a technique that sprays diluted photoresist to the sample as shown in Fig. 2.

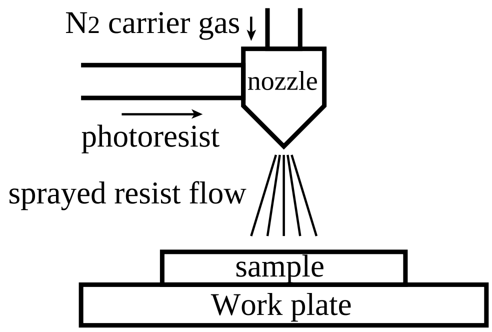
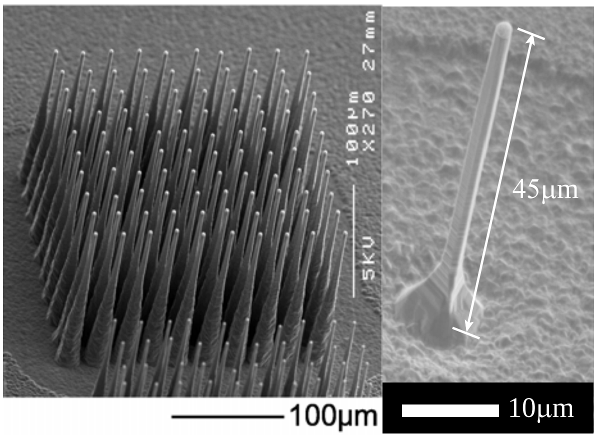


Figure 2. schematic of spray coating

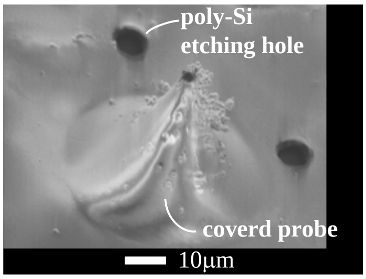
The sample is fixed on the work plate and kept about 100 °C. The photoresist is sprayed through the nozzle by force of N_2 carrier gas to the work plate which is transferred in a vertical plane to the sprayed resist flow. Sprayed photoresist particle is about 5-10 μm in diameter and deposited drying on the surface. The important parameters are a temperature of the work plate, flow of photoresist and transfer velocity of work plate. By this method, we can coat 3-D structures of probes with photoresist uniformly.

Result of the process using spray coating is shown below. Figure 3(a), (b) shows SEM of silicon-probe array after first growth (correspond to Fig. 1(b)). This sample was coated with photoresist by spray coating, exposed by projection and developed. Figure 4(a) shows that the probe was covered and holes for poly-silicon etching were patterned (correspond to Fig. 1(c)). By etching poly-silicon by XeF_2 and removing photoresist, silicon-probes were no damaged and SiO_2-covered Au sites for second growth appear from the bottom of poly-silicon hole as shown in Fig. 4(b).

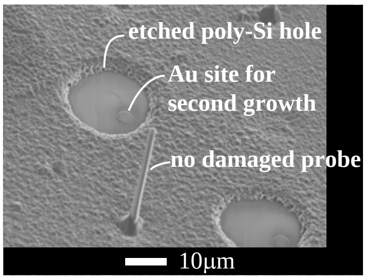


(a)Si-probe array (b) Si-probe

Figure 3. SEM of silicon-probe



(a) aftre photolithography



(b) after reisist removal

Figure 4. SEM of the sample during process

After etching SiO_2 film on Au sites, second VLS growth was carried out. Two-step silicon-probes were obtained as shown in Fig. 5 (correspond to Fig. 1(e)).

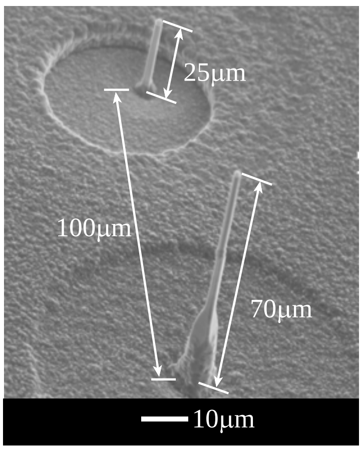
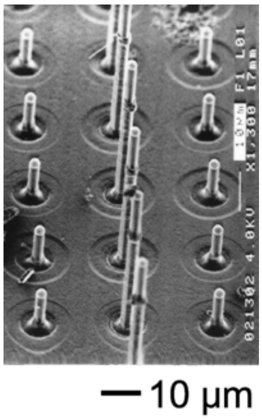


Figure 5. SEM of two-step silicon-probe

By repeating this process, we can fabricate multi-step silicon-probe array as shown in Fig. 6.



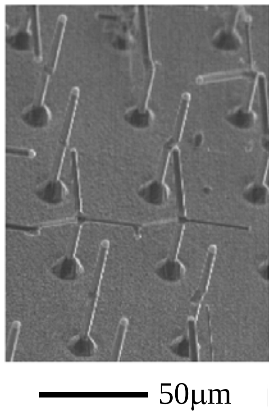


Fig. 6 Si-probe array with different probe length

Fig. 7 not vertical probes by second growth

To grow silicon-probes, the sample was heated by ~700^{o}C and supplied with Si_2H_6 gas. For multi-step growth, chamber pressure has to be step down during the end of growth. If this procedure was omitted, the probe did not grow vertically to the substrate from the next as growth shown in Fig. 7. The mechanism of the growth is explained by our proposed model.

3. Conclusions

In this study, it was realize to fabricate 3-D silicon-probes using novel spray coating techniques and VLS growth methods. According to these results, it is expected for application of recording 3-D distributed neural behavior. Also this coating technique can be used to form 3-D structures for MEMS fields.

Acknowledgements

This work was supported in part by the 21st Century COE Program “Intelligent Human Sensing”, and a Grant-in-Aid for Scientific Research (A) from the ministry of Education, Culture, Sports, Science, and Technology, Japan.

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