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나노종합기술원, 나노코리아, 디에스세미콘, 멤스기술연구조합, 비에스이, 서울대학교 한국 Bio-IT 파운드리 서울센터, 성균관대학교 스마트부품 도금 RIS 사업단, ㈜센플러스, 셀로코 주식회사, 셈소닉, ㈜알트소프트, 에이씨티테크놀로지㈜, 에이엔엠티, 엑사테크, 연세대학교 인체에너지변환 융합파이오니어 연구단, 우원테크놀러지, 주식회사 나우, ㈜에스이테크, ㈜이디앤씨, 지멤스, 지앤피테크놀로지㈜, ㈜케이원솔루션, ㈜펨토사이언스, 프리엠텍, ㈜플리어시스템코리아, 한국과학기술연구원 마이크로나노팹센터, 한국기계연구원 자원절약형 고종횡비 형상 공정기술 기반구축센터 한국이브이그룹 유한회사, 한국전자통신연구원, ㈜항소, 현대건설㈜, IntelliSense, ㈜TUV-SUD KOREA

MICRO ELECTRO MECHANICAL SYSTEMS

2013년도 제15회 한국 MEMS 학술 대회 일정

날짜	시간	내용	장소
4월 4일 목요일	16:00~18:00	등록	로비(그랜드볼룸앞)
	17:30~19:00	리셉션	로비(그랜드볼룸앞)
4월 5일 금요일	07:30~18:00	등록	로비(그랜드볼룸앞)
	08:00~09:20	구두 발표 FO-1 (Bio/Biomimetic MEMS)	그랜드볼룸 좌장: 김상효, 박재성
	09:20~09:30	휴식	
	09:30~09:50	개회식	그랜드볼룸
	09:50~10:20	초청강연 (Invited talk) 이상훈 (고려대학교)	그랜드볼룸 좌장: 이대식, 최낙원
	10:20~11:30	포스터 발표 FP-1	무궁화룸,로즈룸,동백룸 좌장: 임시형, 이정철
	11:30~12:00	특별강연(강관형 교수 추모) 김성재 (서울대학교)	그랜드볼룸 좌장: 서갑양
	12:00~13:20	중식	
	13:20~14:40	구두 발표 FO-2 (Micro Sensors)	그랜드볼룸 좌장: 윤준보, 백창욱
	14:40~15:00	휴식	
	15:00~15:30	초청강연 (Invited talk) 홍병희 (서울대학교)	그랜드볼룸 좌장: 김종백, 박재형
	15:30~16:50	구두발표 FO-3 (Nano/Micro Materials and Fabrication Technology)	그랜드볼룸 좌장: 김준원, 이성호
	16:50~18:00	포스터 발표 FP-2	무궁화룸,로즈룸,동백룸 좌장: 정기훈, 지창현
	18:30~20:30	만찬	그랜드볼룸
4월 6일 토요일	07:30~12:00	등록	로비 (그랜드볼룸앞)
	08:00~09:20	구두발표 SO-4 (Optical MEMS, RF MEMS, Power MEMS and Miscellaneous)	그랜드볼룸 좌장: 박재영, 조일주
	09:20~10:30	포스터 SP-3	무궁화룸,로즈룸,동백룸 좌장: 박정열, 정석
	10:30~11:50	구두발표 SO-5 (Microfluidics)	그랜드볼룸 좌장: 서태석, 한기호
	11:50~12:00	우수논문 시상 및 폐회	그랜드볼룸

Nano/Micro Material and Fabrication Technology

Gas Permeable PDMS Based Coplanar Microfluidic Channels for Surface Modification of oxidized Galinstan®

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Abstract

We report a novel device having gas permeable PDMS (polydimethlysiloxane) microfluidic channels for surface modification of oxidized Galinstan®. The microfluidic channel injected Galinstan® is surrounded by another coplanar HCl filled channel. Due to excellent permeability of PDMS, the HCl vapor can pass through thin PDMS wall between two channels (interchannel PDMS wall) to achieve continuous chemical reaction with oxidized Galinstan®. The interchannel wall thickness is optimized after HCl permeability study through different thickness of PDMS films. Later this novel but simple device is easily fabricated using conventional micro-molding technology compared to non-planar structures. Considering the handling of highly concentrated HCl, efforts are made to lower the concentration of HCl while maintaining same performance standard. The experimental results demonstrate that the method easily removes the oxide layer of oxidized Galinstan® and can move HCl-treated Galinstan® in microfluidic without any difficulty.

Keywords: ***Galinstan®, Microfluidic Channel, PDMS, HCl***

1. Introduction

Galinstan® is a low-toxic liquid metal eutectic GaInSn alloy (68.5%, 21.5 and 10% by weight, respectively). Because of its outstanding properties such as higher boiling point(1300℃), thermal conductivity (16.5W/m•K), low electrical resistivity (0.435μΩ•m) and low toxicity, Galinstan® can be excellent replacement of highly toxic mercury. One of the many applications is tunable frequency selective surface (FSS) device [1]. The working mechanism of tunable FSS device can be represented with equivalent circuit based on variation in capacitance and/or inductance. The variation in capacitance depends largely on the movement of Galinstan®. Hence, the easy movement of Galinstan® is of utmost importance.

However, the surface of Galinstan® is easily oxidized in air and it behaves more like gel rather than true liquid. This superfast oxidation is a challenging problem to overcome. The viscous nature is largely originated from gallium oxide (Ga_2O_3) and it has a significant problem for easy movement of liquid metal. In recent years, some methods have been developed to solve this problem. According to T. Liu *et al.*, Galinstan® behaves like true liquid metal in sub-ppm oxygen environment [2]. However, this requires a vacuum sealed hermetic packaging which can be extremely costly. Hence, efforts are made to use either oxidized Galinstan® or to remove the oxide layer. D. Kim *et al.* reported a micro pillar array based super-lyophobic polydimethlysiloxane (PDMS) micro-tunnel for oxidized Galinstan® [3]. However, this has a limitation in applying to 3-dimensional structures. D. Zrnic *et al.* found that the oxide layer can be removed by the treating the surface with diluted hydrochloric acid (HCl) [4]. Unfortunately, the surface of Galinstan® is easily oxidized again in the air.

In the present paper, a novel device having gas permeable PDMS microfluidic channels for surface modification of oxidized Galinstan® is presented. Galinstan® moved in the microfluidic channel can be constantly maintained in a true liquid phase at room temperature when it is treated by HCl filled in the coplanner surrounding channel. The easy movement of Galinstan® helps us to realize MEMS based FSS device.

2. Experiment

To demonstrate the movement of HCl vapor treated Galinstan®, a coplanar microfluidic channel based PDMS device is designed and fabricated using conventional micro-molding technology outlined in Fig.1. The thickness of the channel wall is finalized after studying HCl vapor permeability through PDMS films. For this, we have made 4-inch circular polymer films of varying thickness (200μm, 300μm, 400μm, 550μm and 850μm) and measured the contact angle changes of Galinstan® droplet on PDMS. The contact angles are measured using CCD camera along with in-house developed image processing MATLAB program.

The device comprised of two coplanar microfluidic channels with the cross-sectional area of 600μm*100μm (width*high). Galinstan® is injected in to a channel using Labview based syringe pump system, as can be seen in Fig. 2. The Galinstan® channel is surrounded by a channel filled with HCl. The HCl concentration as well as the thickness of interchannel PDMS wall can be deciding factors in oxide removal of oxidized Galinstan®. After the careful study of HCl permeability through PDMS films of different thickness, the interchannel wall for 37% HCl concentration is optimized at 200 μm. When Galinstan® is moved in microfluidic channel; air flow (60ml/min) is applied for cutting Galinstan® into slugs as shown in Fig. 2. At the same time, camera is used for recording the motion of Galinstan® slug. The separation of Galinstan® can be important, considering the long serpentine structure of microfluidic channel over the large area of FSS device.

3. Results and discussion

The effect of 37% HCl over the contact angle between Galinstan® (before/ after the acid treatment) and PDMS surface is discussed in Fig. 3. It shows ~8 μl Galinstan® droplet contact angle variation (from 120° for oxidized Galinstan® to 150° in case of HCl treated Galinstan®) with time for different PDMS films. HCl vapor quickly passes through 200μm PDMS film compared to other higher thickness PDMS films. As expected, the thinner PDMS film, the less time required to remove the oxide layer of oxidized Galinstan®. However, the use of maximum concentrated HCl poses the safety problem. Hence, the next experiment is to use the lower concentration of HCl while maintaining the same performance standard.

Fig. 4 shows the variation in Galinstan® slug velocity with varying HCl concentrations. The velocities of Galinstan® slug, surrounded by various concentration of HCl (37, 30, 23 and 16wt%) solutions, can be easily calculated using image processing MATLAB program. The velocity of Galinstan® slug is the highest for the most concentrated HCl (i.e. 37%) providing excellent acceleration rate but can be difficult to handle and can pose safety problem. Presently, the time to record velocity data is limited due to length of microfluidic channel. The increase in length microfluidic channel will help us to find the necessary time required to get the highest velocity (26.5mm/sec). However, the HCl concentration such as 23% and 30% provide comparatively faster oxide removal rate compared to 16% and are still less dangerous to handle than 37% HCl.

4. Conclusion

In this study, coplanar microfluidic channels using gas permeable PDMS is applied for surface modification of oxidized Galinstan®. The microfluidic channel injected Galinstan® is surrounded by another HCl-filled coplanar channel. The interchannel PDMS wall thickness is optimized after the HCl permeability study through different thickness of PDMS films. Due to good permeability of PDMS, the HCl vapor can pass through the interchannel PDMS wall to achieve continuous chemical reaction with oxidized Galinstan®. Based on this design, the simple device was fabricated using conventional micro-molding technology. The Labview based syringe pump system is used for controlling the movement of HCl vapor treated Galinstan® in microfluidic channel in common microfluidic environment. Finally, we have obtained the velocities of Galinstan® surrounded by various HCl concentrations. The experiment results demonstrate that this novel microfluidic platform can easily remove the oxide layer of oxidized Galinstan® and make Galinstan® a non-wetting, Newtonian liquid metal.

Acknowledgment

This work was supported by the WCU (World Class University) program through the National Research Foundation of Korea (NRF) grant funded by Korean government (MEST) (No. R32-20087). The National Research Foundation of Korea (NRF) grant through the Korean government (MEST) (No. 2012R1A2A2A01014711) have also funded in the present study.

References

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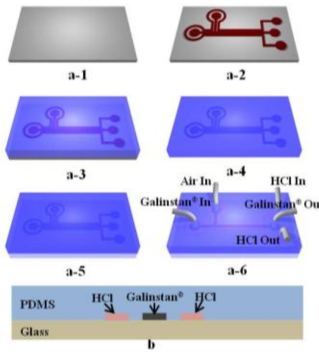

Fig.1 Fabrication sequence of PDMS channel: (a-1,a-2) SU-8 PR mold, (a-3) PDMS coating, (a-4) peeled off from the mold, (a-5) PDMS-Glass bonding, (a-6) Channel injected Galinstan® surrounded by another coplanar channel filled with HCl. (b) Cross-section of structure.

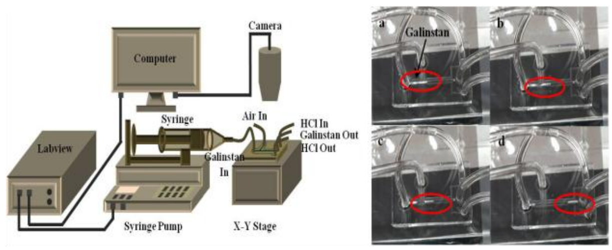

Fig. 2 The sketch of experiment system and movement of HCl vapor treated Galinstan® in microfluidic channel

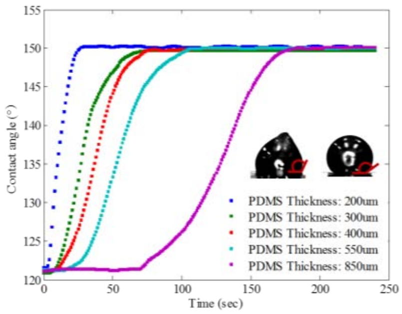

Fig. 3 Galinstan® droplet contact angles as a function of diffusion time of 37 wt% HCl for various PDMS membrane thicknesses

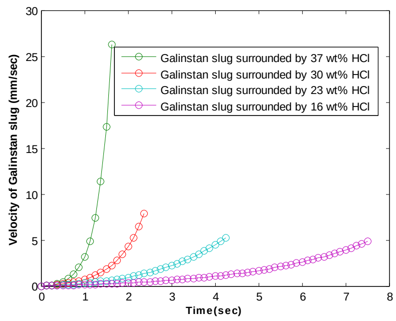

Fig.4 Velocity of Galinstan® slug