

University of Groningen

## Artificial mini-heart

Zhang, Shuaizhong; Wang, Ye; Onck, Patrick; den Toonder, Jaap

*Published in:*

21st International Conference on Miniaturized Systems for Chemistry and Life Sciences, MicroTAS 2017

**IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.**

*Document Version*

Final author's version (accepted by publisher, after peer review)

*Publication date:*

2020

[Link to publication in University of Groningen/UMCG research database](#)

*Citation for published version (APA):*

Zhang, S., Wang, Y., Onck, P., & den Toonder, J. (2020). Artificial mini-heart: An internal micropump based on magnetically actuated artificial cilia that can induce flows in a microfluidic channel network. In *21st International Conference on Miniaturized Systems for Chemistry and Life Sciences, MicroTAS 2017* (pp. 1125-1126). (21st International Conference on Miniaturized Systems for Chemistry and Life Sciences, MicroTAS 2017). Chemical and Biological Microsystems Society .

### Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

### Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

*Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.*

# Artificial mini-heart : an internal micropump based on a magnetically actuated artificial cilia that can induce flows in a microfluidic channel network

**Citation for published version (APA):**

Zhang, S., Wang, Y., Onck, P., & den Toonder, J. M. J. (2017). *Artificial mini-heart : an internal micropump based on a magnetically actuated artificial cilia that can induce flows in a microfluidic channel network*. Poster session presented at 21st International Conference on Miniaturized Systems for Chemistry and Life Sciences (MicroTAs 2017), Savannah, United States.

**Document status and date:**

Published: 01/10/2017

**Document Version:**

Author's version before peer-review

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

# ARTIFICIAL MINI-HEART: AN INTERNAL MICROPUMP BASED ON MAGNETICALLY ACTUATED ARTIFICIAL CILIA THAT CAN INDUCE FLOWS IN A MICROFLUIDIC CHANNEL NETWORK

Shuaizhong Zhang<sup>1,2</sup>, Ye Wang<sup>1</sup>, Patrick Onck<sup>3</sup>, and Jaap den Toonder<sup>1</sup>

<sup>1</sup>Department of Mechanical Engineering and Institute of Complex Molecular Systems (ICMS), Eindhoven University of Technology, Eindhoven, THE NETHERLANDS, <sup>2</sup>China Scholarship Council, the People's Republic of China, and <sup>3</sup>Zernike Institute for Advanced Materials, University of Groningen, Groningen, THE NETHERLANDS

## ABSTRACT

Here we report the fabrication of an internal micropump based on **magnetically actuated artificial cilia (MAAC)** that functions like an **artificial mini-heart**. The micropump can provide versatile flows in a **microfluidic channel network**, when the MAAC are actuated to perform a **tilted conical movement**. Compared to other pumping methods, this in-situ micro-pump does not need tubing or electrical connections, which reduces the usage of reagents by minimizing “dead volumes”, allows the construction of a more compact system, avoids undesirable electrical effects and accommodates a wide range of fluids.

**KEYWORDS:** Magnetically Actuated Artificial Cilia, Artificial Mini-Heart, In-situ Micropump, Versatile Flows

## INTRODUCTION

In humans and animals, the **heart** cyclically pumps blood through the blood vessels of the circulatory system, providing the body with oxygen and nutrients, as well as assisting in the removal of metabolic waste. Recent years, artificial cilia are reported to be very effective in generating substantial fluid flows in microfluidic devices [1]. Here we report the fabrication of an integrated micropump based on **magnetically actuated artificial cilia (MAAC, Fig. 1a)** which functions like an **artificial mini-heart**. It can provide circulatory flows in microfluidic devices with closed branched channel networks resembling **blood vessel networks (Fig. 1b)** when MAAC are actuated by a home-built rotating magnet to perform a **tilted conical movement** [2]. In addition to circulatory flows, **direction-controllable flows** and **pulsatile flows** can be created by tuning the rotating mode of the magnet.

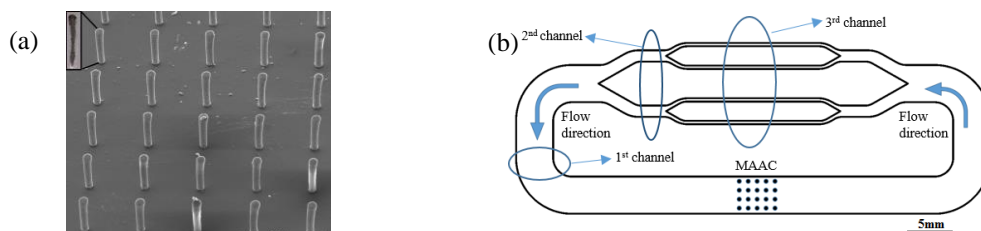


Figure 1: (a) A SEM image of micro-molded MAAC with a length, diameter and pitch of 50, 350, and 350  $\mu\text{m}$  respectively; the insert is the optical image of a single cilium which shows that CIP are linearly aligned within the cilium forming a chain. (b) Schematic of a blood vessel-shaped microfluidic chip with indications of the circulatory flow direction, MAAC area which forms the artificial mini-heart, and observation areas.

## EXPERIMENTAL

MAAC were fabricated using a micro-molding process (Fig. 2) which consists of **six** steps: **(1)** a mold featured with micro-wells was fabricated using photo-lithography with SU-8 as photoresist; **(2)** a homogenous PDMS and carbonyl iron powder mixture (PDMS-CIP) was prepared and poured onto the mold, followed by a degassing procedure; **(3)** the upper part of PDMS-CIP outside of the micro-wells, was removed; **(4)** pure PDMS was poured onto the mold, which would eventually form the base for the cilia; **(5)** the mold was placed on top of a permanent magnet (with a surface field of 0.4T) to align the CIP within micro-wells in order to increase MAAC's magnetic response, and the mold together with the magnet was put into an oven to cure the mixture at 80  $^{\circ}\text{C}$  for 2 hours; **(6)** the cured pure PDMS layer with PDMS-CIP micropillars was peeled off. Finally, we obtained MAAC with a length, diameter and pitch of 50, 350, and 350  $\mu\text{m}$  respectively, “standing” on a transparent PDMS base (Fig. 1a).

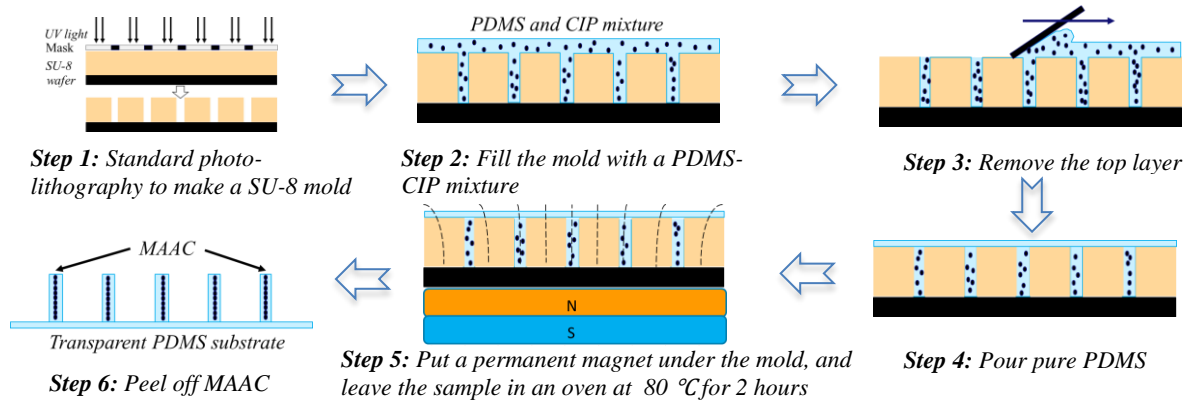


Figure 2: Schematic diagram of the micro-molding process to fabricate MAAC which have a strong magnetic response.

## RESULTS AND DISCUSSION

In order to characterize the fluid flow generation property, MAAC were integrated into a water-filled blood vessel-shaped microfluidic channel network (Fig. 1b) which was created using soft-lithography. The MAAC were actuated to perform a tilted conical motion at 10 Hz (Fig. 3a), and the resulting fluid flow was characterized by tracking seeding particles manually using commercial software named ImageJ. A volumetric flow rate of 0.9  $\mu\text{L}/\text{min}$  was induced, corresponding to maximum velocities of 6.9, 12.7 and 24.4  $\mu\text{m}/\text{s}$  in various parts of the channel network, as shown in Figure 3b. Notably, well-controlled fluid flow, such as direction-reversible and pulsatile flows, can be generated by tuning the motion of the actuating magnet because our MAAC follow the magnetic field swiftly. A video of the cilia motion and corresponding flows in the blood vessel-shaped channel can be found on <https://youtu.be/OUxik9s0fKY>.

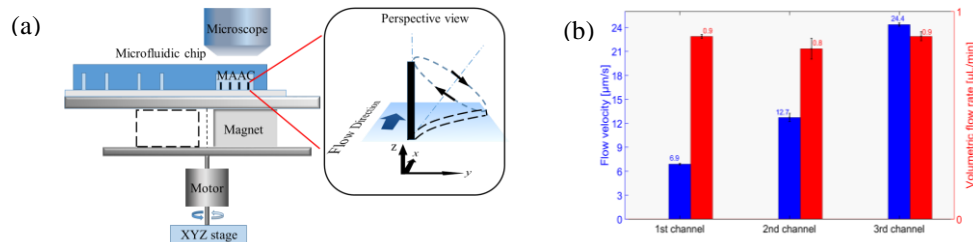


Figure 3: (a) scheme of MAAC; the insert shows the schematic drawing of the tilted conical motion of actuated MAAC in perspective view. Illustrations are not to scale. (b) Flow velocities and volumetric flow rates observed in various parts (designated in Fig. 1b) of the blood vessel-shaped channel network at actuation frequency of 10 Hz.

## CONCLUSION

Magnetically actuated artificial cilia (MAAC) with strong magnetic response have been successfully fabricated. These MAAC are capable of generating versatile flows in closed microfluidic channel networks, mimicking the fluid pumping functionality of our own hearts. Our artificial “mini-heart” could provide a compact and integrated device to create physiologically relevant flow in these microchannels.

## ACKNOWLEDGEMENTS

This research is funded by the Chinese Scholarship Council.

## REFERENCES

- [1] Y. Wang, J. den Toonder, R. Cardinaels, and P. Anderson, “A continuous roll-pulling approach for the fabrication of magnetic artificial cilia with microfluidic pumping capability,” *Lab Chip*, 16, 2277–86, 2016.
- [2] Y. Wang, Y. Gao, H. M. Wyss, P. D. Anderson and J. den Toonder, “Artificial cilia fabricated using magnetic fiber drawing generate substantial fluid flow,” *Microfluidics and Nanofluidics*, 18, 1425-28, 2014.

## CONTACT

\* S.Z. Zhang; phone: +31-40-247-2186; s.zhang1@tue.nl