Topics in Mining, Metallurgy and Materials Engineering

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Liquid Metal Soft Machines
Principles and Applications
In recent years, a group of very fundamental discoveries were continuously made on liquid metals which paved new ways for making new generation soft machines even highly advanced transformable robots. Unlike former endeavors of tackling pure liquid metal matters, the new findings revealed that hybrid components with both liquid metal and related solution including certain solid elements together would enable rather complicated machine styles. Along this direction, many pivotal findings were being achieved on shape changeable liquid metals or smart transformers.

Particularly, owing to the discovery of the extraordinary self-powered liquid metal effect, a group of long-lasting and quickly running soft machines which run just like a biomimetic mollusk became now also possible. This new generation machine owns the capabilities of autonomous convergence or divergence during chasing which are hard to image otherwise by conventional machines, even biological systems. And more liquid metal smart machines are still on the way.

In a large extent, the finding of artificial liquid metal machines opens an exciting platform for designing future soft robot, microfluidic systems, and may eventually lead to the envisioned dynamically reconfigurable intelligent soft robots. Aiming for this goal, several years before, we had ever initiated a program named as SMILE (soft machine based on intelligence, liquid metal, and electronics). Clearly, all these machine or robot styles are based on the soft, fluidic, and multi-physical and chemical capabilities of liquid metal.

In fact, with many outstanding material merits inside, the liquid metal is rather promising in making various complicated machine styles whose ultimate goal is definitely biology like robots. The next step for advancing liquid metal machine is therefore to just fully simulate nature. Meanwhile, some newly emerging liquid metal 3D printing methods will also aid for such machine fabrications. It is expected that a wonderful world of liquid metal soft robots will come true in the near future.

To push forward further researches and possible applications along the above important frontier, this book is dedicated to draft a new machine category: the liquid metal soft machines or motors. The major advancements as achieved before will be
summarized and future directions worth of pursuing will be outlined. Representative applications enabled by liquid metal machines from both fundamental and practical aspects will be reviewed. Perspective for future development in the area of liquid metal soft machine was given.

The present book is an output of our lab’s more than 10 years’ continuous academic endeavors. Over the past few years, a group of our faculties, postdoctoral research fellows, graduate students, and collaborators have made important contributions to mold this new area of liquid metal robots. The authors would like to take this chance to express their sincere appreciations to those people who have offered their professional contribution: Dr. Jie Zhang, Dr. Bin Yuan, Dr. Jianbo Tang, Dr. Lei Wang, Dr. Sicong Tan, Dr. Qian Wang, Dr. Yang Yu, Dr. Liting Yi, Dr. Liang Hu, Dr. Shuting Liang, Mr. Youyou Yao, Mr. Xiaohu Yang, Mr. Hongzhang Wang, Mr. Sen Chen, Mr. Yujie Ding, and Mr. Wenqiang Fang. Lastly but not least, the senior author of this book would like to acknowledge the generous support from the NSFC Key Project under Grant No. 91748206, the Frontier Project of the Chinese Academy of Sciences, Special Foundation of President of the Chinese Academy of Sciences, and Tsinghua University Initiative Scientific Research Program. Thanks for all these valuable supports, the present book could now become a reality.

We humbly hope that this book could serve as a start point for the academics to quickly grasp the basics of the liquid metal soft machine and thus better advance the area. We would very much welcome any critical comments and constructive suggestions from the readers for us to further enhance our book which would be incorporated into its future possible updated version.

Beijing, China

July 2018

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Abstract

This book is to present the core principles and practical applications of a latest machine category: The liquid metal soft machines or robots. Along with a brief introduction on the conventional soft robot and its allied materials, the new conceptual liquid metal machines were introduced to revolutionize existing rigid robots either in large or small size. Typical features of the soft liquid metal materials were outlined. Various transformational and locomotion capabilities of liquid metal machines under either external fields or intrinsic driving fuels were illustrated. Meanwhile, a series of unusual phenomena thus disclosed toward making the shape changeable smart soft machines were presented. The related physical or chemical mechanisms to control the liquid metal transformers were interpreted. Important strategies were explained to construct a group of different advanced functional liquid metal soft machines or robots which are hard to fabricate otherwise via rigid metal or conventional materials. With both fundamental and practical importance, this book is expected to serve as basic reference for making future generation smart soft machine or accompanying robots.

Keywords  Liquid metal  ·  Soft machine  ·  Transformable robot  
Smart materials