Opinion

Intelligent liquid metal robot

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In the movie "Terminator 2" in 1991, there appeared a capable and deformable robot called T-1000 who was made of liquid metals. No matter how much damage occurred on the body, T-1000 could get recovered almost instantly and automatically. T-1000 can even adaptively change his body shape and tune his facial features. For years this shape-shifting and intelligent robot has been one of the ultimate goals in the community of robotics and automation. Recently, the team led by Professor Jing Liu, who holds a joint position in the Institute of Physics and Chemistry of Chinese Academy of Sciences and the School of Medicine of Tsinghai University, has made significant progress in their liquid metal research, which has been regarded as a major breakthrough towards the next generation of robot.Liquid metal consists of alloys with very low melting points and is a viscous fluid at room temperature. In March 2015, Professor Jing Liu published a paper entitled "Self-fueled biomimetic liquid metal mollusk" (Advanced Materials 2015, 27, 2648–2655) and reported the world's first self-driven liquid metal machine. Liu's team found that a gallium-based liquid alloy in the electrolyte can "swallow" aluminum as food or fuel to achieve long time high-speed autonomous movement as fast as 5 cm/s for one hour without external power. Interestingly, they observed that this deformable object can not only move freely in space, but also meander in a variety of engineered micro channels. More surprisingly, it can adaptively adjust its shape according to the width of the channel itself and can squeeze to pass smaller gaps and even make turns after a pause as in the science fiction film "Terminator 2" T-1000 hesitated which way to go after encountering obstacles on the road. They named this liquid metal machine as a "self-fueled mollusk" because it owns a series of the unusual characteristics such as "eating" food as fuels, autonomous movement, deformable, and a certain metabolic function (chemical reaction), which is quite similar to a simple mollusk in nature. This research has laid a theoretical and technical foundation for the development of practical intelligent motors, vascular robots, fluid pumping systems, flexible actuators and even more complex liquid metal robots.In a more recent paper entitled "Self-propelled liquid metal motors steered by magnetic or electrical field for drug delivery" (Journal of Materials Chemistry B 2016, 4, 5349-5357), Liu's team reported that assembling a ferromagnetic nickel layer on the surface of the liquid metal by electroplating would allow for smart control of the movement of the liquid metal machine under external magnetic fields or electric fields. Beyond the controllable movement of the liquid metal machine, the magnetically or electrically aided machines can conduct more complex behaviors such as rapid actuation and sudden stop, programmable steering and even acceleration.

Besides, more functionality has been incorporated in to the liquid metal machine. Jing Liu's team recently published a paper entitled "Liquid metal machine triggered violin-like wire oscillator" published in Advanced Science as a cover story (10.1002/advs.201600212, 2016). They reported the very unique self-excited oscillation of a copper wire inside a liquid metal as a result of electrochemical effect, i.e., once the treated copper wire touches the aluminum-containing liquid metal, the copper wire will be quickly swallowed by liquid metal and conduct long term reciprocating shuttle-like movement as the sliding bow of a violin. In addition, they can carry out frequency modulation and amplitude modulation of the copper wire's oscillation behavior by just touching the liquid metal with a stainless steel wire. The mechanism of the above phenomenon is mainly due to the electrochemical reaction between aluminum and alkali solution, which causes the difference of the wetting forces between the liquid metal and two ends of the copper wire. Here, the dynamic coupling between the copper wire, the liquid metal, the electrolyte and the hydrogen produces the rhythmic driving force. This groundbreaking discovery revolutionized the traditional interface science and paved ways for the development of soft intelligent machines as well as the development of innovative control switches for fluid, electrical, mechanical, optical and other systems. Previous liquid metal machines are pure liquid phase; the solid-liquid combination of the above invention firstly introduced functional bones (copper wire) inside the liquid metal machine and will have huge influence on the development of smart machines. The advent of self-driven liquid metal machines led to the introduction of a new concept of deformable machines that will significantly accelerate the development of shape-shifting intelligent robots. At present, research and development towards advanced robots is very hot in the world. If we can grasp and employ the unique properties of liquid metal to its great extent, we will be able to develop novel robotics with artificial intelligence and capabilities surmounting the state of the art. The seminal work and discovery of Jing Liu's group on the liquid metal self-driving effect and the implementation of the corresponding sophisticated functionalities has very important scientific significance and practical application perspectives and has opened up a new way for the future development of advanced intelligent robot technology.

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Conflict of interest

The author declares no conflict of interest.

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