



Technology Offer

A method and device for reversibly attaching a phase changing metal to an object

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Background

Reversible adhesion can be used to transfer or to manipulate objects. Especially if the objects are small and/or fragile their manipulation become very challenging. Intermolecular forces such as Van-der-Waals can be used to achieve a strong adhesion between the objects. Moreover, surface functionalization and the creation of nano- and microstructures can be used to improve these adhesion properties. Unfortunately, the adhesion becomes insufficient if the surfaces are wet or rough. Another problems that can occur are the need of large forces for the detachment as well as the undesired material transfer. Therefore, an efficient approach to transfer small and fragile objects is highly demanded.

Technology

We offer a new technology to transfer small and fragile objects using switchable adhesive properties of the liquid and the solid phase of a metal. Using a metal with a low melting temperature the phase transformation can be easily manipulated without applying much energy. Gallium (Ga) and Ga-containing alloys are good candidates for this purpose as their melting temperatures ranges from 30°C to 50°C and therefore only a slow temperature increase is required for the phase transformation. Using an elastomer and dipping this elastomer into the liquid metal phase the metal droplet will wet the elastomer surface and attach to it. Then, this stamp with a liquid metal droplet can be brought in contact with an object of interest. By lowering the temperature, the metal droplet will change its phase from liquid into solid. This phase transformation leads to the strong attachment between the object and the elastomer. This state features a strong adhesion and can be used to transfer the object. For detachment it is sufficient to slightly increase the temperature above the melting temperature of the metal (Fig. 1).

Max-Planck-Innovation GmbH
Amalienstr. 33
80799 Munich
Germany

Phone: +49 (89) 29 09 19 - 0
Fax: +49 (89) 29 09 19 - 99
info@max-planck-innovation.de
www.max-planck-innovation.de

Contact
Dr. Bernd Ctorteka
Phone: +49 (89) 29 09 19 - 20
ctorteka@max-planck-innovation.de

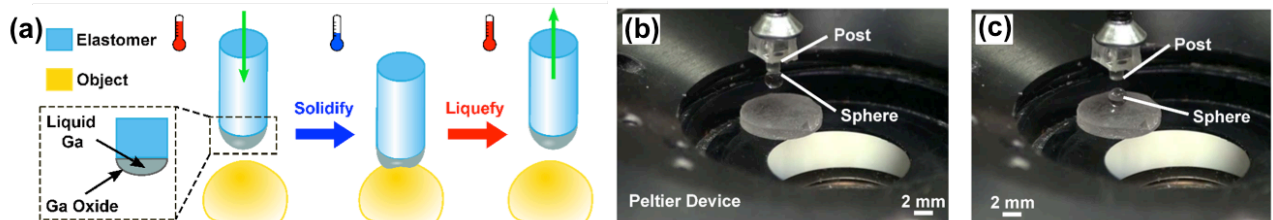


Fig. 1: (a) Method of reversibly attaching an elastomer post coated with a liquid metal (Ga) layer to another surface. An elastomer post is coated with a layer of liquid Ga, which reacts with air, forming a membrane of solid Ga oxide (Ga_2O_3) that prevents mass transfer when Ga is in the liquid phase. To initiate the maximum adhesion, the post is placed in contact with an object and cooled, causing the Ga to solidify around the object's surface. To detach from the surface with minimum adhesion, the Ga layer is heated and liquefied, allowing the object to be easily released. The difference in adhesion between the solid and liquid conditions enabled a reversible adhesive with a large switching ratio. The elastomer post can be replaced by other shapes if desired. (b) The proof-of-concept demonstration to exhibit the potential of Ga as a reversible adhesive for pick-and-place applications. The "pick" portion of the pick-and-place operation. The Ga is solidified in contact with the sphere and the post is retracted, bringing the sphere with it. (c) The "place" portion of the pick-and-place operation. The Ga is melted and the post is retracted, leaving the sphere in the desired position on the substrate without transferring any residue.

Our results (Fig. 2) show that after detachment the metal droplet remains on the elastomer without leaving any rests or contaminations on the object and can be simply reused.

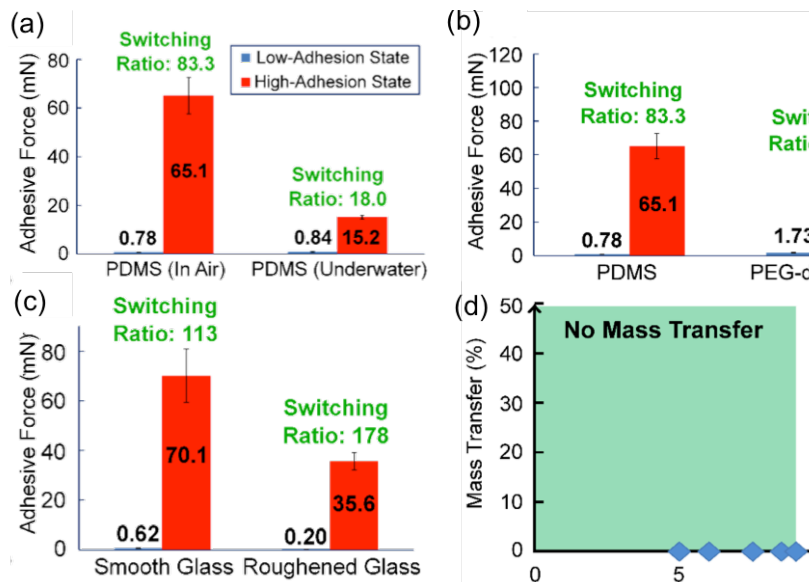


Fig. 2: Experimentally determined adhesion and switching ratios associated with each flat substrate material. The experiments are conducted with a 1.75-mm-diameter post under a preload of 8.33 mN for the PDMS surface, and 5 mN for the other surfaces. The red bars represent the mean maximum adhesion with error bars over 3 trials, while the blue bars represent the mean minimum adhesion with error bars over 20 trials. The switching ratio, indicated in green, is the ratio between the maximum adhesion and the minimum adhesion. (a) Adhesion on smooth PDMS surface under dry and wet conditions. (b) Adhesion on smooth and roughened glass surfaces under dry conditions. The RMS roughness of the smooth and roughened glass surfaces are 3.17 nm and 582 nm, respectively. (c) Adhesion on smooth surfaces made of different materials under dry conditions. (d) The percentage of the total mass of the Ga droplet transferred in the low-adhesion state resulting from various preloads, tested on a flat, smooth PDMS substrate with a 1.75-mm-diameter PDMS post. Below 9 mN (corresponding to 3.9 kPa for the 1.75-mm post) no mass transfer was observed. Above 10 mN, there was significant mass transfer. Each data point represents 20 trials for preload below 9 mN and 1 trial for preload above 10 mN.

Advantages

- Enabling to transfer sensitive and fragile objects
- Enhanced controllability and functionality
- Applicable to wet and rough surfaces
- Repeatedly reusable metal droplet
- Applicable in transfer printing, robotics, electronic packaging, and biomedicine

Literature

Ye, Z., Lum, G. Z., Song, S., Rich, S. and Sitti, M. (2016), "Phase Change of Gallium Enables Highly Reversible and Switchable Adhesion", *Adv. Mater.*
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Patent Information

EP patent application filed in February 2016.