Ultrasound induced two-step physical bonding of PAAm to aluminum

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Recently, hydrogels have attracted much attention as an emerging material. Hydrogels possess three-dimensional molecular network structures formed by cross-linking of polymer chains. By controlling the chemical compositions and cross-linking ways, the physicochemical properties of hydrogels can be conveniently adjusted. This versatility has led to a wide range of applications for hydrogels in biomedical field, used for drug delivery, tissue engineering, and wound dressing, etc. Additionally, hydrogels hold great promise in industrial field such as flexible electronic devices and soft robotics. In these applications, a significant challenge is that hydrogels need to achieve high-strength adhesion to solids like metals. Due to the high content of water, traditional methods such as welding or gluing struggle to achieve ideal bonding strength. Some researchers have used chemical methods to coat solid surfaces with substances, which is capable of forming covalent bonds with hydrogel polymer chains, to realize high-strength bonding. However, these chemical approaches introduce new chemical substances and require specific chemical environmental conditions, such as pH levels. That makes the bonding easily failed. Therefore, we propose a two-step physical method to achieve the bonding between hydrogels and metals. Firstly, we use an ultrasound transducer to design microstructures on the metal surface. Then, hydrogel solution is coated onto the metal surface. With the action of ultrasound, it permeates and contacts the metal surface thoroughly. Then the UV light irradiation induces cross-linking reactions in the hydrogel solution, completing the bonding between the hydrogel and the metal. By designing different structures of the ultrasound transducer, we obtained various surface morphologies on the metal surface. The serrated transducer, for example, formed parallel rows of protrusions and recesses with about 200 micrometers in height on the metal surface, while the micro-needle-shaped transducer generated densely distributed needle-like pits on the metal surface. We conducted lap shear tests on the bonding strength between PAAm hydrogels and aluminum plates with two different surface textures and smooth surface. The results showed that the interface toughness of the needle-like pits was approximately 40 KPa higher than that of the smooth surface. Through the proposed two-step method, we have enhanced the bonding strength between hydrogels and metals. Since the method does not involve chemical processes, the resulting bonding is relatively stable. We believe that the approach has promising future applications in the biomedical field, such as human body punctures.