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Interfacial Molecular Motion and Chemical Characteristics of Polymer Jointed to Metal by Chemical Bonding

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Abstract

The adhesion of metals and polymers has wide industrial applications; interface bonding and adhesion mechanisms are essential for determining the final properties of polymer composites. A triazine-based silane coupling agent was used to treat aluminum and polydimethylsiloxane (PDMS) to form metal–polymer interface bonds through chemical bonding. Bonding strength tests, swelling experiments, rubber curing degree measurements, and dynamic viscoelastic analyses were performed on Al/PDMS samples of different thicknesses to investigate the molecular motion of the formed Al/PDMS interface. The influence of the PDMS thickness on the molecular motion of joint was studied. The bonded Al/PDMS interface had a higher degree of cooperation of molecular motion corresponding to stress relaxation than that of unbonded rubber, whose molecules restrain molecular motility. Swelling experiments revealed that only a specific thickness of the PDMS can chemically bond with Al, and below this thickness, the solvent, toluene, cannot penetrate the bonding interface. This study provides basic insights about metal–polymer interface mechanisms at a molecular level.

Key-words: *Silicon rubber, Chemical bonding interface, Direct adhesion, Swelling, DMA, Molecular motion*

1. Introduction

Interfaces between metals and crosslinked polymers play a significant role in many fields such as splicing, assembly and coating, plastic metallization, microelectronics, micro-system technology, and nanotechnology¹⁻³⁾. Achieving a high polymer/metal adhesion strength is an ongoing challenge, especially in the harsh environments of many technical applications. Moreover, all organic coatings applied to metals such as steel, zinc-coated steel, aluminum, and magnesium require strong interfacial adhesion strengths to withstand severe forming operations and prolonged exposure to corrosive environments^{4,5)}. For example, the most basic anti-corrosion performance criterion for metals is to meet the requirements for ensuring normal operations in water, air, salt water, and organic solvents^{6,7)}. However, many organic coatings lose their adherence to the metal substrate due to problems such as swelling of the polymer or gas blistering caused by corrosion in a humid or solvent environment^{8,9)}. The basic conditions that the metal surface needs to withstand to confirm the anti-corrosion effect of the organic coating, the mechanism by which molecules of the organic

layer move when water or solvent molecules penetrate the interface, the reason why the interface between the metal and organic layer affects the bonding force and durability, and the effects of anti-corrosion properties are all questions that need to be answered through research.

Molecular chain mobility is important in determining the interfacial strength, durability, and corrosion resistance of composite materials formed by dissimilar material bonding (for example, a bond between a metal and polymer)^{10,11)}. There have been many studies on the interactions between metals and organic materials¹²⁻¹⁴⁾: the interface characteristics of metals and organic materials¹⁵⁻¹⁸⁾, direct combinations of metals and organic materials, and the applications of composite materials¹⁹⁻²²⁾. The combination of a metal and organic molecules is based on the thermodynamic concept of adhesion at the molecular level, which is used to study and explain the phenomenon of interfacial bonding⁴⁾. The ideal state of the combination is the integration of the different materials, which is key to ensure the various properties of the composite material. Recently, research using non-destructive methods, such as ultrasonic and electromagnetic testing, as well as thermography, to evaluate adhesion interfacial properties has been reported^{23,24)}. However, it is difficult to perform a non-destructive analysis of molecular motion for the bonding interface after integration²⁵⁾. The molecular motion of the

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