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Enhancement of bonding strength of metals /organic materials direct bonding via non-equilibrium atmospheric pressure plasma irradiation

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In recent years, the joining of dissimilar materials, particularly metals and organic materials, has garnered attention across various fields. In the automotive and aerospace industries, in particular, the concept of multi-material integration has attracted interest. By combining materials in appropriate locations according to their respective strengths, it becomes possible to develop components and products with enhanced overall performance. To this end, the incorporation of organic materials is being considered to achieve weight reduction in vehicle and aircraft structures.

In the field of electronics, there is a growing demand for technologies that enable the formation of wiring on organic substrates, such as those used in wearable devices. Furthermore, in preparation for sixth-generation (6G) communication technologies, there is increasing interest in low-loss, high-frequency flexible printed circuit boards (FPCBs) based on fluororesins—materials known for their poor adhesion characteristics. These applications require technologies that can directly and robustly join fundamentally dissimilar materials such as metals and organic compounds.

One method for joining metals to organic materials is thermal compression bonding, which involves heating the organic material to near its melting point and bonding it in a molten state. Although this technique does not require additional components such as rivets or adhesives, its applicability is limited to thermoplastic resins with polar functional groups.

To address these limitations, we have been conducting research on the direct bonding of metals and organic materials using surface treatment via a high-density atmospheric-pressure non-equilibrium plasma jet (Figure 1), which functions both as a heat source and a radical source. This approach aims to introduce polar functional groups onto the surfaces of organic materials and to directly heat them through plasma irradiation.

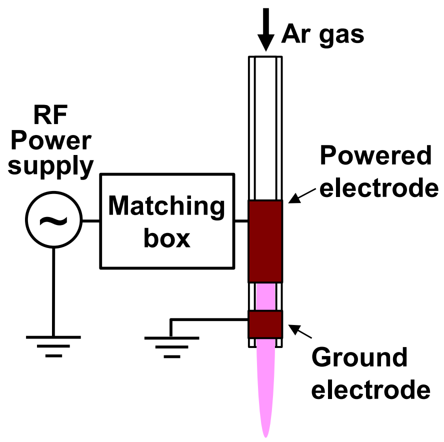

Figure 1. Diagrams of an atmospheric pressure RF plasma jet

We have previously demonstrated that plasma irradiation can introduce polar functional groups onto polyethylene, a polymer that lacks such groups in its chemical structure, enabling direct thermal compression bonding with stainless steel. Furthermore, we have confirmed that plasma treatment can enhance bonding strength even for organic materials that already contain polar functional groups. The direct joining of SUS304 stainless steel and polycarbonate (PC), an engineering plastic with a low glass transition temperature, has been demonstrated by combining surface treatment and heating with an atmospheric-pressure RF plasma jet without an external heating source apart from the plasma itself [1]. In direct metal-polymer bonding, the chemical effects of plasma irradiation have a greater impact on bonding strength than physical effects such as surface morphology has been demonstrated [1]. Furthermore, aluminum alloys A1050 and A5052, pure titanium TP340, and engineering plastic polyetheretherketone (PEEK) were directly joined by hot pressing following surface pretreatment with atmospheric-pressure RF plasma jets, confirming the effect of plasma treatment on bond strength [2-4].

In this presentation, we report on the enhancement of bonding strength achieved through plasma treatment using an atmospheric-pressure non-equilibrium plasma jet for the direct joining of metals and organic materials. The focus is placed on materials commonly used in the automotive and aerospace industries.

References

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