**Supplementary information**

Table 1s: Chemical composition of base materials

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Mg** | **Si** | **Fe** | **Cu** | **Ti** | **Zn** | **Mn** | **Cr** | **Al** |
| **Top Al plate**  **(2 mm thick)**  **(wt.%)** | 0.8 | 0.4 | 0.5 | 0.18 | 0.05 | 0.1 | 0.03 | 0.03 | Balance |
| **Bottom Al plate**  **(5 mm thick)**  **(wt.%)** | 0.9 | 0.6 | 0.4 | 0.25 | 0.10 | 0.15 | 0.05 | 0.10 | Balance |

Table 2s: Mechanical properties of base materials

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Ultimate tensile stress**  **(N/mm2)** | **Yield stress**  **(N/mm2)** | **Elongation**  **(%)** | **Modulus**  **(N/mm2)** |
| **Top plate**  **(2 mm thick)** | 96.3 ± 1.67 | 95.4 ± 1.35 | 8.55 ± 0.66 | 3233 ± 60.64 |
| **Bottom plate**  **(5 mm thick)** | 106.06 ± 2.67 | 106.06 ± 2.67 | 6.75 ± 0.22 | 2018 ± 28.03 |

**Interlayer preparation**

The graphene interlayer is prepared on the upper surface of the bottom plate (100 mm length, 75 mm width and 5 mm thickness). The GNP content for the formation of interlayer starts with the 0.5 gm which is then reduced to 0.3 gm in the second trial. However, these experimental trials reveals a brittle fracture due to agglomerated GNP clusters in the weld zone. Finally, the GNP content of 0.1 gm revealed a significantly higher weld strength than the weld without GNP interlayer which is reported in the present study. For this purpose, initially, 0.1 gm of GNP is ultrasonicated for 60 minutes in 20 mL distilled water. The solution of 0.1 gm PVA in 20mL distilled water is prepared separately by using a magnetic stirrer at 80°C for 60 minutes. Both solutions are then mixed and again stirred for another 60 minutes at 80°C. The interlayer is obtained by dipping the substrate (5 mm thick) in the solution (dip coating) and holding it inside for 60 seconds. Finally, the PVA is removed by drying it in the vacuum oven at 80°C for 4 hours. After drying, a small part of the interlayer is peeled off from the substrate for thickness measurement by using micrometre. From the measurement the thickness of the interlayer was observed to be ~ 50 μm. The schematic flow chart of the interlayer deposition on the parent metal is shown in Fig. 1s.

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Fig 1s: Schematic flowchart of the interlayer deposition on the 5 mm thick bottom plate

**Sample scheme**

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Fig 2s: Schematic of the tensile specimen and characterization surface. All dimensions in mm.

**Temperature monitoring**

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Fig 3s: Infrared thermal image obtained during the FSW of aluminium (a) with (b) without GNP interlayer