Experimental

A. Sample preparation

Six samples (Tab. 1) were produced under the same conditions during soldering processes to ensure the same initial state. The overlap length for all samples was equal to 30 mm, thus the total length of the samples with overlap joints was equal to 130 mm. After depositing a suitable amount of solder and rosin flux between two tapes, the overlap joint specimen was placed in an Al alloy clamping device. After reaching the peak (maximum) temperature, the clamping device with overlap joint sample was quenched in a water bath.

Tab. 1. Conditions during soldering processes.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Solder</th>
<th>Pressure (MPa)</th>
<th>Reflow time [s]</th>
<th>Peak temperature [°C]</th>
<th>Used flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC45</td>
<td>Sn96.5Ag3Cu0.5</td>
<td>1.7</td>
<td>30</td>
<td>217</td>
<td>200</td>
</tr>
<tr>
<td>TC50</td>
<td>Sn96.5Ag3Cu0.5</td>
<td>1.7</td>
<td>30</td>
<td>217</td>
<td>200</td>
</tr>
<tr>
<td>TC80</td>
<td>Sn96.5Ag3Cu0.5</td>
<td>1.7</td>
<td>30</td>
<td>217</td>
<td>200</td>
</tr>
</tbody>
</table>

B. Thermal cycling

Samples:

- TC45 (45 cycles)
- TC50 (50 cycles)
- TC80 (80 cycles)

Temperatures: 55°C

Dwell time: 5 min

Heating/cooling rate: 125.5°C/min

Temperature range: 251°C

Cycle time: 14 minutes

C. Uni-axial tensile test

Tab. 2. Characteristics of REBCO CC tape.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Conductor width [mm]</th>
<th>l [A]</th>
<th>n-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SuperPower 2.0 HTS SCS4050</td>
<td>4</td>
<td>141</td>
<td>29</td>
</tr>
</tbody>
</table>

Fig. 1: Schematic illustration of the tested sample (not in scale).

Fig. 2: Normalized values of joint resistivity (Rj) and n-value of soldered joints in thermal cycling.

Fig. 3: Joint resistivity of soldered joints exposed to thermal cycling. Comparison of Rj before and after the thermal cycling.

Fig. 4: Cross-sectional IMC morphology of soldered joints after thermal cycling: (a) reference sample, (b) TC45, (c) TC50 and (d) TC80.

Fig. 5: The thickness of IMCs and Sn in particular in soldered joints exposed to different thermal number of cycles.

Fig. 6: Joint resistivity of soldered HTS tapes before tensile tests.

Fig. 7: Stress-strain curve during the sample T23 on the joint and original tape under uni-axial tensile loading.

Fig. 8: Experimental results of the sample T22 with joint under different axial tensile forces: (a) normalised critical current and joint resistivity as a function of applied tensile force, (b) normalised n-value as a function of applied tensile force.

Summary

- The microstructure of the overlap joints consisted of Sn-rich dendrites and small amount of Ag3Sn particles. Cu-Sn and Cu2Sn IMC compact layers grow at both soldering interfaces. The thickness of these IMC layers slightly increased with number of thermal cycles. Moreover, the Kirkendall voids at the interface of Cu-Sn/Cu2Sn were formed after soldering due to the unbalanced diffusion at the interface. The density of voids decreases with number of thermal cycles as a result of interdiffusion during thermal cycling process. We can assume that after 80 thermal cycles, the highest reduction of voids due to the Al alloy clamping device and quenching of Ag3Sn phase with low electrical resistivity.

- As the IMCs are much more fragile than other phases of solder, we applied quick cooling in water bath, which caused fine-grained microstructure and strengthened the solder joint. With the increase in tensile force, the original tape was the first to reach the plastic state. Once the original tape entered the plastic state, the display value of strain in joint region was almost unchanged. It follows, that the mechanical property of the specimen with joint was determined by the original tape. This tendency is supported by the fact that the soldered samples were always teared up during uni-axial tensile test in region of original tape (out of the joint region). As a result, we can consider safety value of tensile loading without degradation of electrical properties for these joints up to 200 N.

References


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Contact

Slovak University of Technology in Bratislava
Faculty of Materials Science and Technology in Trnava
Address: Trnavská 578/27, 821 09 Bratislava, Slovakia
email: eva.michalcova@stu.sk
web: www.mtf.stuba.sk