# Progress Report - 1

## Stiffness Characterization of Copper/Epoxy Composites at Room and at Liquid Nitrogen ($LN_2$) Temperatures

The goal of this part of the research was to determine the change in the stiffness due to epoxy impregnation of stranded copper wires and then compare those value with that of the neat copper at room and at LN2 temperatures. For this purpose two types of bending experiments, 3-point bend and cantilever bend experiments were conducted on rectangular specimens of approximate dimensions of 1.2 x 1.6 x 20 cm.

**3-POINT Bend Tests**

The 3-point bend was mounted with one strain gage on the tension side of the beam (see Figure 1).

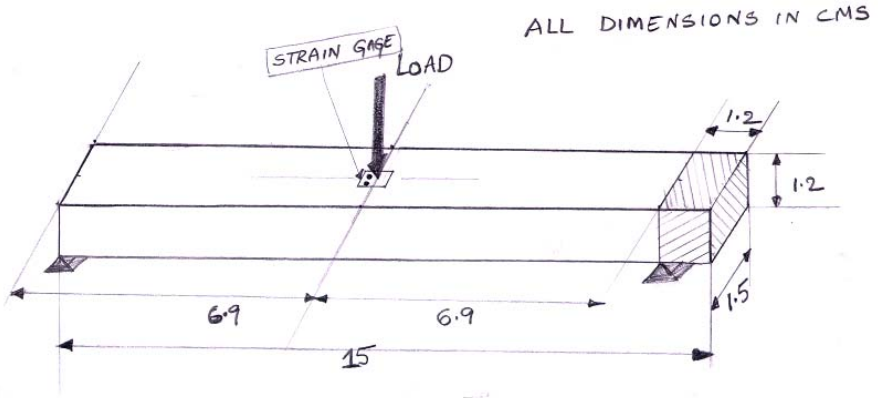


*Figure 1. Specimen dimension and strain gage location for the 3-point bend specimen. The strain gage is at the bottom of the specimen.*

Load was applied at the middle of the specimen by looping a string around the middle and hanging known weights on the string. The load was increased in increments of 10 N up to 120 N. For each load increment, the corresponding strain reading was recorded from the strain gage. The load (P) was plotted against the strain (ε) as shown in Figure 2. Using the beam bending equations, the slope of P-ε curve is equal to:

$$\text{Slope} = \frac{2}{3}\frac{wh^2E}{L} \qquad \text{----------(1)}$$

where specimen width w = 1.5 cm, height h = 1.2 cm, and length L = 13.8 cm, and E is bending stiffness.

The slope of the P-ε line was calculated by best fitting a linear line to the data. Then the bending stiffness E calculated from Eq. (1) was 81.6 GPa. Compared to the stiffness of pure copper (= 110 GPa), the stiffness of copper/epoxy specimen was about 26% lower.

**CANTILEVER BEAM TESTS**

A cantilever beam loading fixture was designed to allow experiments at LN2 temperature. A 3-D rendering of the fixture is shown in Figure 3. The fixture consists of a housing in which a rectangular specimen is fixed at one end by inserting the specimen in a rectangular cavity and holding it in its place by means of a screw. The specimen is loaded by means of a metal hook, one of which is looped around the free end of the specimen and the other end is gripped in the upper grip of a loading machine. The housing is gripped to the lower grip. The rectangular cavity of the housing is filled with LN2 during the experiment. In order to stabilize the temperature around the specimen, the housing was insulated by means of 1-inch thick Styrofoam insulation. The actual photograph of the loading fixture is shown in Figure 4. A photograph of copper/epoxy specimen with strain gages mounted on it is shown in Figure 5. Figure 6 shows the fixture (with specimen inside it) gripped into

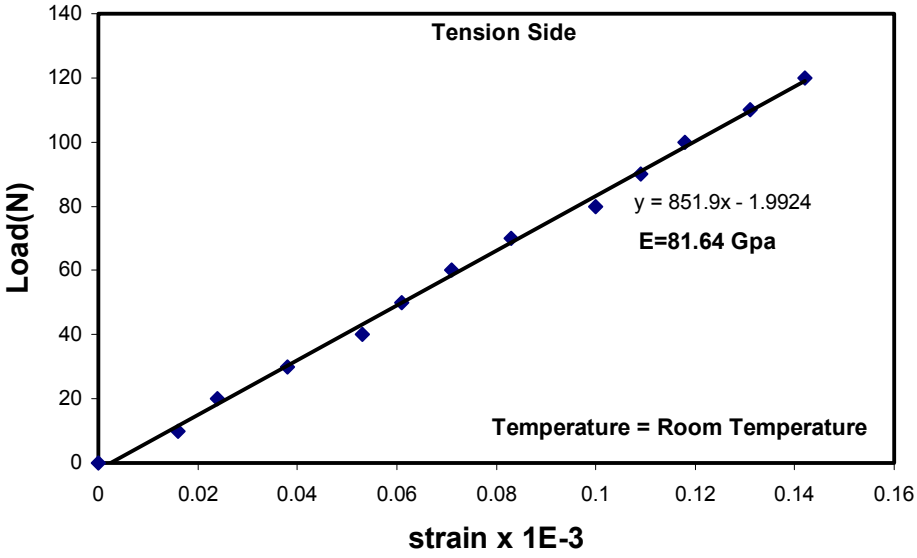


*Figure 2. Load-Strain data used to calculate bending stiffness of copper/epoxy a 3-point bend specimens. Blue squares are experimental data and the solid line is the linear best-fit line.*

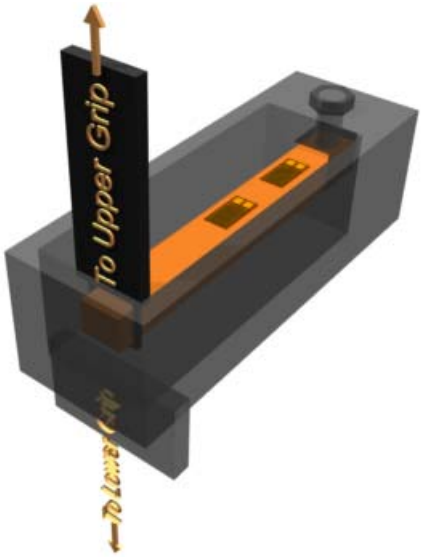


*Figure 3. A 3-D rendering of the cantilever beam bending fixture designed to determine bending stiffness at LN2 temperature. Outer housing is shown partially transparent to reveal the inside assembly of the fixture.*

*Figure 4. Top view of the photograph of the cantilever beam bending fixture (without a specimen). The fixture is insulated by means surrounding it with a 1-inch thick Styrofoam.*