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Advanced Circuit Materials

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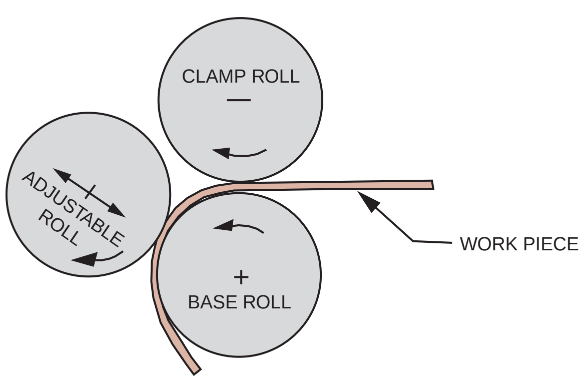
Bending Etched Antenna Boards

Non-woven glass/Polytetraflourethylene (PTFE) substrate is particularly suited for microstrip antennas formed to a cylindrical shape for missile telemetry applications. Bending can be done without measurable damage to the micro structure or the mechanical and electrical properties. Three methods are used: use of forming rolls, heating a board clamped on a mandrel and bonding thinner boards together around mandrel.

Ceramic-PTFE materials should be easier to bend than the non-woven glass microfiber-PTFE composites. We have had little experience with bending composites such as RT/duroid® 6002, 6006, or 6010, RO3000® series high frequency circuit materials. We have observed that RT/duroid 6002 etched free of copper will accept a sharp crease with whitening of the outer surface but with no fracturing. The major concern with any bendable PTFE composite, ceramic or non-woven microfiber, is the deformation forced on the copper foil cladding or etched pattern. Too much compression on the concave side can cause wrinkles and lifting. Too much stretching on the convex side can cause fractures or work hardening leading to later fracturing in service.

1. Forming rolls

Sheet metal workers commonly use forming rolls for bends with a radius much larger than the metal are two nips along the circumference of the base roller. Material fed into one nip so that the second nip catches the leading edge is forced to conform to the radius of the base roller. The nips can be opened to increase the radius of curvature by forcing less conformance.



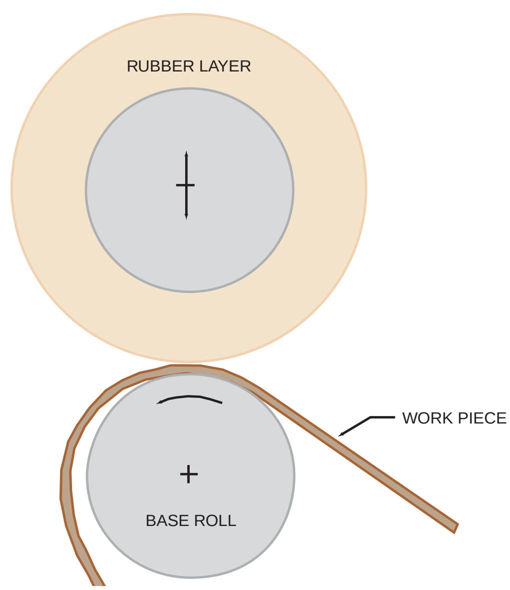


Figure 2. Rubber roll forming device not to scale.

In a second type of forming roll apparatus, a metal base roll works against a rubber roll. By adjusting the roll axes together, one causes the rubber roll to deform along the circumference of the base roll. Material fed into this nip is conformed to the radius of the base roll to an extent controlled by how tightly the rolls are pressed together.
The principle is the same for either type of apparatus-sheet material conforms for a short time to a radius. If the radius is small enough that strain near sheet material surfaces exceeds the elastic limit of the sheet material , a degree of permanent deformation results in a smooth curved shape. When the conforming force is removed a certain amount of elastic spring back occurs. Thus for a given radius, the material must be overbent to a smaller radius, held there for perhaps 0.25 second and then released. The smaller radius could be as small as 1/3 or 1/4 the desired final radius.

If you apply the method to copper foil clad PTFE substrate with one side etched to form an antenna pattern, you need special care to avoid deformation damage in the roll forming operation. The copper on inner and outer surfaces is forced to accommodate the oppositely signed changes in length of these surfaces. It either elastically and permanently deforms the imposed amount or it fractures and buckles.

Deformation of a typical sheet metal resolves itself almost instantly into permanent and elastic portions. The elastic portion accounts for springback. With a bisco-elastic material the instantaneous, small magnitude ration of permanent to elastic portions of the deformation will increase with time held at the deformed shape. The instantaneous permanent/elastic ratio and its rate of increase are both greater at higher temperatures. Thus the amount of overbending needed in a roll forming operation may be reduced by preheating the board and by slowing the speed of the forming rolls. Heating above the 130°C Tg of PTFE is advised. Tg refers to the transition temperature between glassy and rubber states of the amorphous phase of the polymer.

2. Heat forming on a mandrel

A board clamped around a mandrel somewhat smaller than the desired radius of curvature is held at an elevated temperature to allow strain relief to occur. While this is slower than roll forming, it requires a lesser degree of over bending, as would follow from the previous discussion. For a given substrate thickness, smaller diameter bends can be more practically obtained by heat forming than by roll forming. The two processes differ in time and temperature of conformation imposed on the material.

We performed a laboratory experiment in heat forming with a 4.5 inch (114 mm) diameter mandrel and 0.062 inch (1.57 mm) thick RT/duroid® 5870 microwave laminate. This laminate consists of a substrate composite of non-woven glass microfibers in a PTFE matrix, clad both side with 1 oz/ft^2 (34 micrometer thickness) copper foil. The mandrel radius to substrate thickness ratio selected was just large enough to avoid immediate damage to specimen board clamped around it.

Specimens were masked and copper etched to leave a narrow conductor trace one side, the other fully clad. Experiments were run with the specimen trace oriented circumferentially on the mandrel either inside (concave) or outside (convex). After a specified holding period at elevated temperature the specimen clamped on the mandrel was cooled, then released from the mandrel and allowed to stand in standard laboratory conditions for 16 or more hours before its curvative was measured. Curvature retention was calculated as the ratio of the mandrel radius to the final specimen radius of curvature. Copper foil damage (Table 1) was also noted and was found to be the same with the ground plane on either side.

For less severe bends no defects in the copper cladding are expected at forming temperatures up to 170°C for times of 9 or more hours. With protection from oxygen, higher temperature could probably be used to improve curvature retention without copper foil damage, but this is not likely to be worth the effort since mandrel size can be adjusted to get a desired curvature at lower temperature with no cost in time required.

3. Bonding Layers on a mandrel

The process includes heat forming on mandrel since heat is used to activated the bond.

A microstrip antenna is assembled from two or more boards that are interleaved with bonding film and clamped around a mandrel for thermal cycle to activated to bonding film. A direct bond procedure omitting bonding film has also been demonstrated and was reported in SP8006 based on internal TR2747 of 1980 January 7. Film bonding processes follow the principles outlined in Rogers product literature item RT4.4.1 “Bonding Boards of RT/duroid® PTFE Materials for Microwave Stripline Circuits”.

One can achieve a higher total thickness to radius ratio than practical with a single board. Curvature retention is very good and strain in individual layers is low. Springback from individual layers is offset by the fact that circumferential distance differences between inner and outer layers is locked in by the bond line.

This process is often used for microstrip antennas requiring a protective radome, where one board requiring a protective radome, where one board carries the ground plane and antenna pattern and the second, etched free of copper foil is on the outside.

For very high ratios of thickness to radius, one can combine several boards in an assembly so that the innermost board includes the ground plane and the outermost board, not counting an optional radome cover, carries the antenna pattern.

Table 1: Summary of Mandrel Heat Forming Investigation

Temperature, °C	23	177		260		302	
Time, hours	24	1	9	1	9	1	9
% retention of curvature							
Ground plane concave side	43	77	76	86	85	88	96
Ground plane convex side	39	73	76	86	87	94	99
Defects in copper trace*	0	1	1	3	2	5	4

*Note: 0 to 5 represent subjective ratings of none, slight, few, much and severe.

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