



Patterning of Indium Tin Oxide Films

The patterns are formed by laser printing directly onto the films.

John F. Kennedy Space Center, Florida

A relatively rapid, economical process has been devised for patterning a thin film of indium tin oxide (ITO) that has been deposited on a polyester film. ITO is a transparent, electrically conductive substance made from a mixture of indium oxide and tin oxide that is commonly used in touch panels, liquid-crystal and plasma display devices, gas sensors, and solar photovoltaic panels. In a typical application, the ITO film must be patterned to form electrodes, current collectors, and the like. Heretofore it has been common practice to pattern an ITO film by means of either a laser ablation process or a photolithography/etching process. The laser ablation process includes the use of expensive equipment to precisely position and focus a laser. The photolithography/etching process is time-consuming.

The present process is a variant of the direct toner process — an inexpensive but often highly effective process for patterning conductors for printed circuits. Relative to a conventional photolithography/etching process, this process is simpler, takes less time, and is less ex-

pensive. This process involves equipment that costs less than \$500 (at 2005 prices) and enables patterning of an ITO film in a process time of less than about a half hour.



A Pattern of Interdigitated Electrodes was formed directly on the ITO-coated surface of a transparent polyester film by use of a laser printer. After etching away of the ITO not covered by the toner, the toner was washed away, leaving the polyester film with the patterned ITO.

In the direct toner process as practiced heretofore, a laser printer or copier is used to print the desired pattern on a water-soluble paper, from whence the pattern is transferred to a circuit board in a sequence of laminating, lift-off, and etching steps. In the present variant of the direct toner process, there is no need for transfer paper: instead, an ITO-coated polyester film is fed directly into a laser printer or copier, where the pattern is printed directly onto the ITO. The patterned polyester film (see figure) is then immersed in a 10-percent (2-normal) solution of H_2SO_4 in water. The sulfuric acid etches away the ITO in the non-printed areas, while the toner in the printed pattern serves as a mask to prevent etching of the underlying ITO. After etching, the toner is washed away by use of acetone, leaving the patterned ITO.

*This work was done by Christopher Immer of ASRC Aerospace Corp. for Kennedy Space Center. Further information is contained in a TSP (see page 1).
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Gimbaled Shoulders for Friction Stir Welding

Digging of edges of shoulders into workpieces would be reduced or eliminated.

Marshall Space Flight Center, Alabama

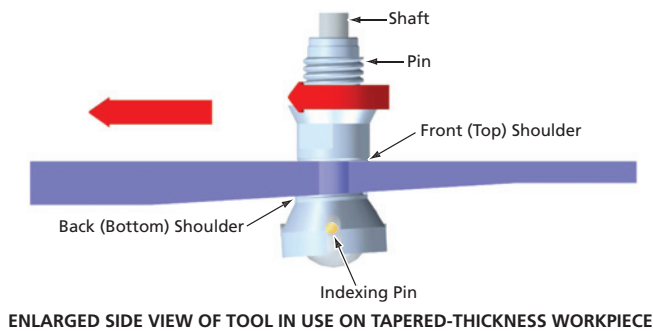
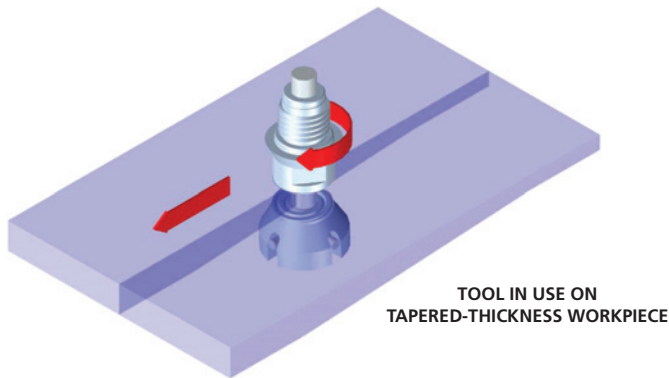
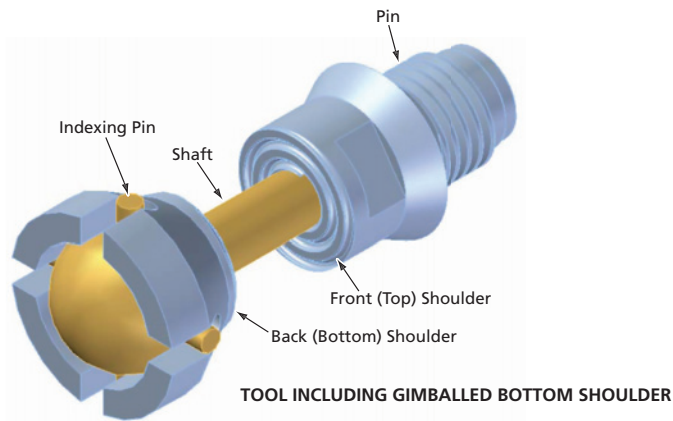
In a proposed improvement of tooling for friction stir welding, gimbaled shoulders would supplant shoulders that, heretofore, have been fixedly aligned with pins. The proposal is especially relevant to self-reacting friction stir welding.

Some definitions of terms, recapitulated from related prior *NASA Tech Briefs* articles, are prerequisite to a meaningful description of the proposed improvement. In friction stir welding, one uses a tool that includes (1) a rotating shoulder on top (or front) of the workpiece and (2) a pin that rotates with the shoulder and protrudes from the shoulder into the

depth of the workpiece. In conventional friction stir welding, the main axial force exerted by the tool on the workpiece is reacted through a ridged backing anvil under (behind) the workpiece. When conventional friction stir welding is augmented with an auto-adjustable pin-tool (APT) capability, the depth of penetration of the pin into the workpiece is varied in real time by a position- or force-control system that extends or retracts the pin as needed to obtain the desired effect.

In self-reacting (also known as self-reacted) friction stir welding as practiced heretofore, there are two shoulders: one

on top (or front) and one on the bottom (or back) of the workpiece. In this case, a threaded shaft protrudes from the tip of the pin to beyond the back surface of the workpiece. The back shoulder is held axially in place against tension by a nut on the threaded shaft. Both shoulders rotate with the pin and remain aligned coaxially with the pin. The main axial force exerted on the workpiece by the tool and front shoulder is reacted through the back shoulder and the threaded shaft into the friction-stir-welding machine head, so that a backing anvil is no longer needed. A key transmits torque between the bottom shoulder and the threaded



The Back Shoulder Would be Gimballled to accommodate local variations in the slope of the lower surface of the workpiece.

shaft, so that the bottom shoulder rotates with the shaft. This concludes the prerequisite definitions of terms.

One consequence of the fixed alignment of the shoulders with the pin is that if the thickness of the workpiece or the slope of either surface of the workpiece varies as the tool moves along the workpiece, then the leading or trailing edge(s) of one or both shoulder(s) tend to dig into the workpiece, generating excessive flashing along the weld. The proposed improvement would be a simple, relatively inexpensive means of preventing or reducing such digging. The gimballing of either or both shoulder(s) would enable the tool to better adapt to curvatures and other local variations in the slopes of workpiece surfaces, without need for a complex, expensive shoulder-angle control system.

The figure depicts a representative tool for self-reacting friction stir welding incorporating the proposed improvement. [In this case, the bottom shoulder (only) would be gimballled. Optionally, both shoulders or the top shoulder (only) could be gimballled.] The shaft would be terminated in a ball, from which indexing pins would protrude radially at angular intervals of 90° in a plane perpendicular to the pin/shaft axis. The indexing pins would define gimbal axes. The bottom shoulder would contain slots that would loosely engage the indexing pins. The configuration of the indexing pins and slots would be such that the bottom shoulder would be forced to rotate with the pin and shaft and the pins would hold the back (bottom) shoulder axially in place against tension, yet the looseness of the pin/slot engagement would allow limited rotation of the bottom shoulder about the gimbal axes to accommodate local variations in the slope of the lower surface of the workpiece.

This work was done by Robert Carter and Kirby Lawless of Marshall Space Flight Center.

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32115-1.