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In This Issue

- PCB Tracking With RFID
- New DSW A-OK With IPC

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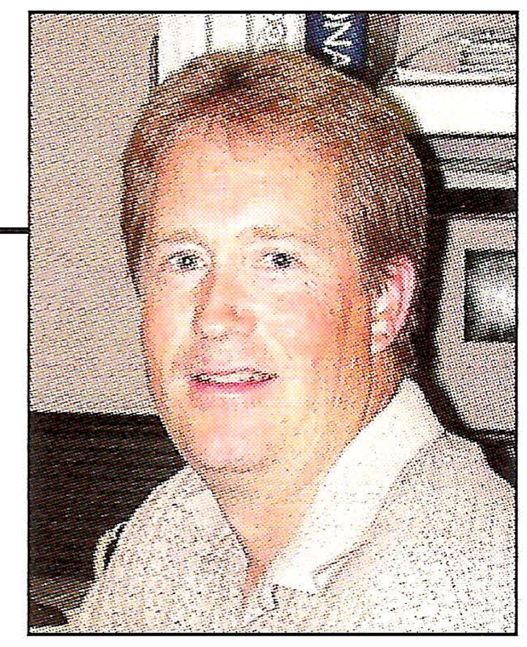
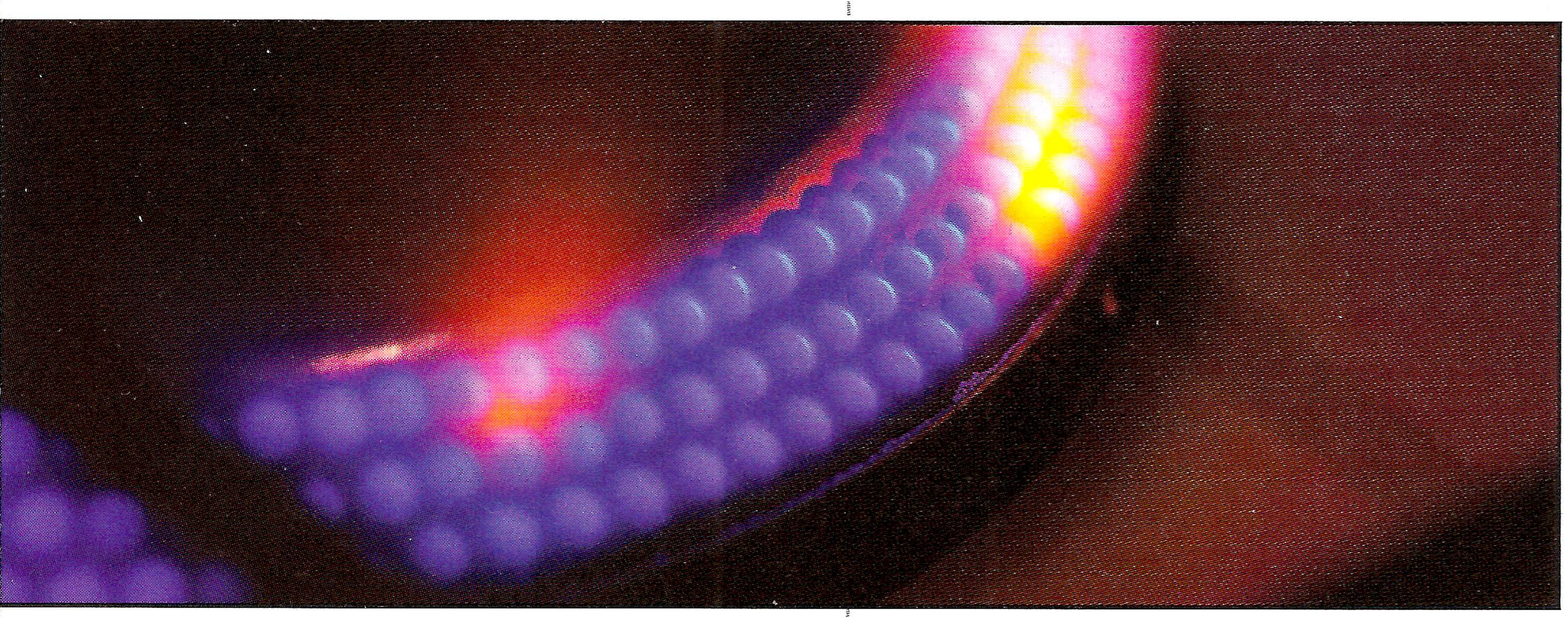


If It Can't Stand the Heat...

Q: ***I am interested in using flex circuit technology in a cryostat operating near liquid nitrogen boiling temperatures (77 K [196 °C]) and in a hard vacuum. What should I expect from the flex in this environment? Will the differential in expansion between copper and polyimide cause the flex to rip apart or curl?***

A: Well, let me start by saying that I thought I had seen pretty much every type of environment imaginable to use a flex circuit. I guess I was wrong. I will have to give you my best guess based on 26 years of watching flex circuits perform, and sometimes fail, in other demanding applications. The environment that you are describing will challenge a flex circuit's mechanical properties to say the least. Let's start with the ultra-low temperatures.



Virtually all flex circuits are constructed from copper, polyimide film, and modified acrylic adhesive. Because copper remains ductile at cryogenic temperatures, the conductors should not be a problem. If you do an Internet search for temperature ratings of the polyimide cover films used by the majority of manufacturers, you will find precious little information. If you REALLY dig, you will find that one major polyimide film manufacturer has published that its films have been used successfully in applications down to −269 °C. While the manufacturer doesn't go as far as calling it a temperature rating, this at least gives you a benchmark to work from. Because all the polyimide film manufacturers use pretty much the same recipe, you can assume that the polyimide will not be the first material to fail. Also, the coefficients of linear expansion between copper and polyimide are very similar (17 E-6 in/in per °C for Cu and 20 E-6 in/in per °C for polyimide), so that should not cause a problem. The adhesive used in virtually every flex application is modified acrylic. Modified acrylic adhesive films are supplied by several manufacturers and are rated down to approximately −60 °C. As you can see, the modified acrylic adhesive is going to be the weak link at extremely low temperatures (FYI, it is also the weak link at high temperatures). At room temperature, modified acrylic adhesive has great bond strength and ultra-high dielectric properties. Unfortunately, it does not perform so well at very high or very low temperatures. In your application, you may want to consider the possibility of using a polyimide or PTFE adhesive to bond the circuit together rather than the modified acrylic. Polyimide and PTFE adhesives are considerably more difficult for the flex circuit manufacturer to process, which will result in a considerably higher circuit cost and a limited number of vendors who can supply your circuits. But because you NEVER want to sacrifice reliability to save costs, one of these adhesives may be your best option.

Another critical factor that you did not mention was whether the circuit would be subjected to any flexing, shock, or vibration while at the ultra-low temp. Although you will be running the circuit close to, or below, the material manufacturer's temperature rating, it is very possible that it would function as long as it was held still. Like most other plastics, the insulating materials in a flex circuit will become stiff and brittle at ultra-low temps, and I can say with a reasonable certainty that if the circuit is subjected to flexing, shock, or vibration, it will not survive. But if the circuit is held still during operation, it could very well continue to function. But when I say held still, I mean NO movement whatsoever. Even the smallest of movements in the flex at those temperatures could cause a crack somewhere in the circuit.

I don't think the hard vacuum will damage the flex circuit, but there may be some out gassing. Flex circuit materials absorb moisture like a sponge and will not readily give it up. I would recommend an extended baking cycle to drive out moisture immediately prior to installation. Depending on the overall circuit thickness, it could take four to six hours at 250 to 300 °F to fully drive out the moisture. The circuits should then be immediately installed or stored in a dry box or nitrogen chamber until you are ready to install them. In a humid environment, flex circuits can reabsorb nearly all their moisture capacity in less than 30 minutes.

Because your application is "out there," it is impossible to say definitively whether the circuit will perform or fail. Your best bet would be to get some flex circuit samples from a manufacturer that approximate the construction and material stack of your design. Then test the heck out of them. If they fail miserably, you will know that you have pushed the limits too far and you will need to look for a different interconnect scheme. On the other hand, if the sample circuits survive the testing without noticeable degradation, you can move to the prototyping stage with some degree of confidence that the final circuit design will perform as required.

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