Development of High-Efficiency EMI Shielding: A Case History

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INTRODUCTION

In the early 1980s, an investigation of electromagnetic shielding phenomena began. The work was prompted by the need for better shielding in a number of applications: communications cables, field-intensity sensors, secure computer rooms, and shielded test enclosures.

Because so many variables are involved in the design of an EMI shield, no single laboratory test can be expected to predict the performance of a material in practical applications. On the other hand, theoretical methods based on the solution of Maxwell's equations are usually impractical, and other theories yield only approximate results. The complexity of predicting shielding performance has led many to regard shielding as an art rather than as a science.

For these reasons, both theoretical analysis and laboratory testing were employed in the program. Materials were characterized by means of actual shielding experiments, and the results extrapolated to different application conditions by the use of theoretical relationships. The experimental investigation was greatly facilitated by the cooperation of a corporation which provided high performance ferromagnetic alloys and even produced unique and exotic alloys on request.

CLAD METALS

The materials studied are clad metals in a continuous strip form. These materials are produced by a process of roll bonding followed by diffusion annealing which provides a complete metallurgical bond at the atomic level. The bond contains no layers of braze or solder materials.

Clad metals in a continuous strip have been the subject of extensive study.

DEVELOPMENT PROCESS

The rationale for clad metal development has been, since its origin, the need to produce properties in a clad combination which are superior to any individual metal or alloy. It was natural for applications engineers to begin thinking of metal combinations when considering the problems of electromagnetic shielding materials.

The cladding process is applicable to virtually all metals and alloys which show a modest amount of ductility (1-2% tensile elongation minimum) and the resulting composites can be made in formats from two layers to several hundred layers depending on need and application.

Early in the work it became apparent that no single metal or alloy possessed all of the characteristics necessary for shielding over a wide range of frequencies. At very low frequencies, maximum magnetic permeability proved to be the only property important to shielding. As the frequency increased, however, electrical conductivity became increasingly essential to high performance, and the effectiveness of ferromagnetic materials declined because of the time lags and energy thresholds inherent in the displacement of domain boundaries. It was decided, therefore, to concentrate the investigations on multilayer composites of conductive and ferromagnetic metals. Later analysis and experimentation showed that the positioning of the various layers could alter effectiveness by as much as 50%, probably because of internal reflections due to differences in surface impedances at the inter-layer boundaries.

As is frequently the case, solutions to the problems of shielding effectiveness did not appear overnight; it was not until 1986 that all the elements of an effective solution were available. Three components were developed: a convenient laboratory tester usable with small material samples over a wide range of frequencies; a computer analysis program based on Schelkunoff's theory, enabling the prediction of effectiveness for different materials and extrapolation from bench test to full-scale application results; and a high-performance, three-layer shielding material consisting of a nickel-iron alloy core with an outer layer of copper on both sides.

The bench test apparatus, because it measures the shielding properties of a few square inches of material, made it possible to evaluate literally hundreds of material combinations. It also permits measurements of shielding geometry elements, such as joints, that cannot be practically tested in the usual apparatus which requires samples that measure two or four feet square. Because the bench test apparatus is portable and is not dependent upon the effectiveness of an enclosure, materials can easily be measured that have higher attenuations than those of almost any existing laboratory enclosure.

The computer prediction program, based on well-known analysis, provides a convenient basis for comparing the results obtained from the bench tester to those of a variety of accepted shielding effectiveness tests. It permits a growing confidence in the validity of laboratory test results as a basis for predicting application performance.

The copper-clad material proves superior in most commercial applications, partly because the ready solderability of the surface lends itself to simple methods of sealing joints and seams. However, effective shielding can be obtained from a variety of other metal combinations that preserve the 3-layer conductor-ferromagnetic-conductor structure.

Table 1 shows typical attenuation as a function of frequency for a standard copper/49/copper shielding material. This attenuation data is based on material at a gauge of 0.014".

CONCLUSION

The ultimate result of the long-term program to develop shielding based on metallurgical bonding capability is a unique family of EMI shielding materials. The clad-metal technology is based on multilayer design and broad-banded with performance in the high attenuation range. None of these materials is thicker than 0.015" (but can be made thicker for special applications). They are effective in any EMI field where the magnetic vector component of the radiation is not in excess of approximately 10 gauss measured at the point of incidence. The 10-gauss level is adequate to cover 95% of all shielding applications.

The validity of these elements has been verified by tests conducted in cooperation with a number of independent laboratories. Descriptions of test equipment, test results, theoretical analyses, and materials tested have been reported in the papers listed below. In addition, certain computer programs useful in predicting shielding performance are available as "share-ware."

FREQUENCY	FIELD	ATTENUATION dB
1 kHz	H	35
3 kHz	H	55
10 kHz	H	78
30 kHz	H	95
100 kHz	H	114
200 kHz	E	>130
1 MHz	E	>130
18 MHz	E	>130
400 MHz	PW	>120
1 GHz	PW	>120
10 GHz	PW	>110

***Table 1**. Typical Attenuation of 3-Layer Copper Shielding Material.*

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NOTES ON SHARE-WARE: *Texas Instruments will be happy to share their program on the evaluation of shielding effectiveness of various materials in the form of an IBM-compatible 3.5" disk. These disks will be available in June 1994 and a copy may be obtained by writing to TI on company letterhead. Requests should be addressed to: Mr. Roland Onorato, Texas Instruments Inc., Materials & Control Group, 34 Forest Street, M/S 20-24, Attleboro, MA 02703.*

FRANÇOIS PADOVANI *joined Texas Instruments in 1964. He initially did basic work on Schottky barriers before directing a silicon material research group, where the main emphasis was the development of impurity controls. His next assignment was the development and demonstration of a new silicon manufacturing process. In 1976, he was transferred to the Texas Instruments Materials & Control Group (M&C) in Attleboro, MA, where he is in charge of Advanced Development and insuring technical liaison among the M&C sites. (508) 699-1100.*

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GEORGE (YURY) TRENKLER *was a member of the Technical Staff, Advanced Development, Texas Instruments. He was born and educated in the U.S.S.R. Yury worked for TI from 1965 until his retirement in January, 1990, and his responsibilities included the development of expanded clad metals, composite EMI shielding materials, electronic testing systems, and work in the design of reinforced metals. He holds 30 U.S. patents and currently is involved in consulting work with TI in the areas of magnetics, metallurgy, and electronics. (401) 434-7787.*