EMERSON & CUMING
MICROWAVE PRODUCTS

RoHS Compliant

ECCOSORB® MF

Lossy, Magnetically Loaded, Machinable Stock

Material Characteristics

- Rigid magnetically loaded epoxide stock
- For increased temperature handling to 260 °C, refer to the electrically equivalent ECCOSORB® MF500F
- With products such as these, it is necessary to be conversant with the dielectric and magnetic properties of the materials, which are therefore listed in this technical bulletin and are in values normalized with respect to free space, *see Typical Properties table*
- Can be machined via many operations, *see Machining Recommendations below*
- Does not support fungal growth per MIL-STD-810E

Applications

- For assistance in termination design, *see Termination Design Considerations below*
- ECCOSORB® MF is widely used as absorbers, attenuators, and terminations in waveguides and coaxial lines
- It has also been successfully used as a high-Q inductor-core material in such devices as slug tuners. It is also useful in many other magnetic components.
- Simple RF filters can be formed by passing filament leads through small blocks of ECCOSORB® MF, or by casting appropriate sections of the material around such leads by using one of the electrically equivalent castable absorbers.
- There are also applications in antenna elements and in certain free-space absorbers

Availability

- ECCOSORB® MF is available in the following standard stock sizes:
- Sheets 12” x 12” (30.5cm x 30.5cm) in thicknesses of 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, 1.0, 1.5, 2.0, 2.5 & 3.0” (0.32, 0.64, 0.95, 1.27, 1.59, 1.91, 2.54, 3.81, 5.08, 6.35, 7.62 cm).
- Rods 12” long (30.5cm) in diameters of 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, 1.0, 1.5, 2.0, 2.5 & 3.0” (0.32, 0.64, 0.95, 1.27, 1.59, 1.91, 2.54, 3.81, 5.08, 6.35, 7.62 cm).
- Bars 12” long (30.5cm) in squares of 1/4, 3/8, 1/2, 5/8, 3/4, 1.0, 1.5 & 2.0” (0.64, 0.95, 1.27, 1.59, 1.91, 2.54, 3.81, 5.08 cm).
- Other sizes, shapes, thicknesses, and configurations are available on special order.
- In some cases, depending on which ECCOSORB® MF series is being used, casting of certain configurations can be done during manufacturing.

Related E&C Products

- ECCOSORB® MF500F - Electrically similar MF product line but with increased service temperature capability to 500°F
- ECCOSORB® MF-UHF - Identical physical properties to that of the ECCOSORB® MF product line with altered electrical characteristics for use in the upper UHF band.
- ECCOSORB® MFS - Silicone rubber sheet, bar and rod stock with electrical properties of ECCOSORB® MF-117 and MF-124 only in the listed stock sizes. Temperature capability to 160°C. Slight flexibility of the material makes it useable in impact applications or where differential expansion between material and metal would normally break the bond to the conventional ECCOSORB® MF
- ECCOSORB® CR - Epoxy casting-resin version for rigid shapes with electrical properties of ECCOSORB® MF. Good to 180°C. Works well for intricate shapes or cavity filling.
- ECCOSORB® CRS - Castable RTV silicone rubber like ECCOSORB® CR. Electrical properties of ECCOSORB® MF-117 and MF-124 only. Flexible and tough. Good at high temperature to 260°C

Typical Properties

Frequency Range	1-18 GHz
Color	Dark Gray
Service Temperature, °F (°C)	<356 (<180)
Density, g/cc	1.6 - 4.9
Durometer, Shore D	85
Tensile Strength, psi (kg/cm^2)	>8000 (560)
Thermal Expansion per °C	~30 x 10^{-6}
Water Absorption, % 24 hours	<0.3
Thermal Conductivity (cal)(cm)/(sec)(cm^2)(°C) (BTU)(in)/(hr)(ft^2)(°F)	 ~0.003 ~10.0

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Typical Electrical Properties

	GHz	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	1.0	3.0	8.6	10.0	18.0
MF-110	K'	18	16	15	13	11	9	7	5	3.2	3	2.9	2.8
	tan δ_d	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.04	0.04
	K"	0.18	0.16	0.3	0.26	0.33	0.27	0.28	0.2	0.16	0.15	0.12	0.11
	M'	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1	1	1
	tan δ_m	0	0	0	0	0	0	0	0	0	0.1	0.1	0.2
	M"	0	0	0	0	0	0	0	0	0	0.1	0.1	0.2
	dB/cm	0	0	0	0	0	0	0.01	0.09	0.26	2	2.2	6.6
	dB/in	0	0	0	0	0	0	0.03	0.23	0.66	5	5.6	17
	$\lvert Z\rvert/Z_0$	0.26	0.27	0.28	0.3	0.33	0.37	0.4	0.47	0.59	0.59	0.59	0.6
MF-112	K'	20	18	16	14	12	10	8	6	5.2	5	4.8	4.6
	tan δ_d	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.04	0.03
	K"	0.4	0.36	0.48	0.42	0.36	0.4	0.32	0.24	0.26	0.25	0.19	0.14
	M'	2	1.9	1.8	1.7	1.6	1.5	1.5	1.4	1.4	1.1	1.1	1
	tan δ_m	0	0	0	0	0	0	0.01	0.02	0.03	0.22	0.23	0.26
	M"	0	0	0	0	0	0	0.02	0.03	0.04	0.24	0.25	0.26
	dB/cm	0	0	0	0	0	0	0.02	0.16	0.59	4.9	5.6	10.1
	dB/in	0	0	0	0	0	0	0.05	0.41	1.5	12.4	14.2	25.7
	$\lvert Z\rvert/Z_0$	0.32	0.32	0.34	0.35	0.37	0.39	0.43	0.48	0.52	0.47	0.48	0.47
MF-114	K'	22	21	19	18	16	14	12	11	9.9	9.8	9.7	9.6
	tan δ_d	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.05	0.05
	K"	0.88	0.84	0.76	0.72	0.8	0.7	0.6	0.55	0.59	0.59	0.49	0.48
	M'	2.8	2.8	2.7	2.6	2.5	2.4	2.3	2.1	1.9	1.3	1.1	1
	tan δ_m	0	0	0	0	0	0	0.04	0.08	0.13	0.33	0.4	0.45
	M"	0	0	0	0	0	0	0.09	0.17	0.25	0.43	0.44	0.45
	dB/cm	0	0	0	0	0	0	0.04	0.57	2.2	10.8	13.2	24.9
	dB/in	0	0	0	0	0	0	0.1	1.4	5.6	27.4	33.5	63.2
	$\lvert Z\rvert/Z_0$	0.36	0.37	0.38	0.38	0.4	0.41	0.44	0.57	0.44	0.37	0.35	0.34
MF-116	K'	40	35	30	26	23	20	18	17	16.5	16.2	16	15.8
	tan δ_d	0.06	0.06	0.07	0.07	0.08	0.09	0.08	0.07	0.06	0.07	0.06	0.05
	K"	2.4	2.1	2.1	1.8	1.8	1.8	1.4	1.2	0.99	1.1	0.96	0.79
	M'	4.6	4.5	4.4	4.4	4.3	4.2	4	3	2.8	1.6	1.5	1.4
	tan δ_m	0	0	0	0	0	0	0.04	0.13	0.21	0.47	0.68	0.73
	M"	0	0	0	0	0	0	0.16	0.39	0.59	0.75	1.02	1.02
	dB/cm	0	0	0	0	0	0	0.09	1.3	5	21	32	57
	dB/in	0	0	0	0	0	0	0.23	3.3	12.7	53	81	145
	$\lvert Z\rvert/Z_0$	0.34	0.36	0.38	0.41	0.43	0.46	0.47	0.42	0.42	0.33	0.33	0.33

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Typical Electrical Properties

	GHz	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	1.0	3.0	8.6	10.0	18.0
MF-117	K'	195	158	120	85	62	48	38	28	22.9	21.4	21	20.6
	tan δ_d	0.18	0.21	0.23	0.24	0.22	0.18	0.12	0.09	0.06	0.02	0.02	0.02
	K"	35	33	28	20	14	8.6	4.6	2.5	1.4	0.42	0.42	0.41
	M'	5	5	5	5	5	5	4.8	4.1	3.4	1.2	1.1	1
	tan δ_m	0	0	0	0	0	0	0.1	0.2	0.39	1.36	1.5	2
	M"	0	0	0	0	0	0	0.48	0.82	1.33	1.63	1.7	2
	dB/cm	0	0	0	0	0	0.03	0.27	2.8	11	46	56	119
	dB/in	0	0	0	0	0	0.08	0.69	7.1	28	117	142	302
	$\|Z\|/Z_0$	0.16	0.18	0.2	0.24	0.28	0.32	0.36	0.39	0.4	0.3	0.31	0.33
MF-124	K'	260	205	145	95	70	52	40	32	25.8	23.8	23.6	23
	tan δ_d	0.4	0.39	0.36	0.31	0.26	0.2	0.14	0.08	0.07	0.05	0.03	0.04
	K"	104	80	52	29	18	1	5.6	2.6	1.8	1.19	0.71	0.92
	M'	7	6.9	6.8	6.7	6.6	6.3	6	5	3.8	2.5	1.5	1
	tan δ_m	0	0	0	0	0	0	0.2	0.45	0.69	1.1	1.4	2.5
	M"	0	0	0	0	0	0	1.2	2.3	2.62	2.75	2.1	2.5
	dB/cm	0	0	0	0	0	0.03	0.48	6.5	20	63	67	149
	dB/in	0	0	0	0	0	0.08	1.2	1.7	50	160	170	378
	$\|Z\|/Z_0$	0.16	0.18	0.21	0.26	0.3	0.34	0.39	0.42	0.42	0.39	0.33	0.34
MF-175	K'	320	250	170	105	78	56	42	36	27	25	24	24
	tan δ_d	0.5	0.49	0.46	0.41	0.36	0.26	0.16	0.06	0.05	0.03	0.02	0.02
	K"	160	123	78	43	28	15	6.7	2.2	1.35	0.75	0.48	0.48
	M'	8	7.9	7.8	7.7	7.6	7.3	7	6	4.4	1.8	1.3	1.1
	tan δ_m	0	0	0	0	0	0	0.4	0.6	0.8	1.4	1.6	3
	M"	0	0	0	0	0	0	2.8	3.6	3.52	2.5	2.1	3.3
	dB/cm	0	0	0	0	0.01	0.05	0.87	8.6	24	65	69	177
	dB/in	0	0	0	0	0.03	0.13	2.2	22	61	165	175	450
	$\|Z\|/Z_0$	0.15	0.17	0.2	0.26	0.3	0.36	0.42	0.44	0.46	0.35	0.32	0.38
MF-190	K'	380	295	195	115	86	60	44	40	28	26	25	25
	tan δ_d	0.6	0.59	0.56	0.51	0.46	0.32	0.18	0.07	0.04	0.04	0.02	0.02
	K"	228	174	109	59	40	19	7.9	2.8	1.12	1.04	0.5	0.5
	M'	9	8.9	8.8	8.7	8.6	8.3	8	7	4.5	2	1.5	1.1
	tan δ_m	0	0	0	0	0	0	0.6	0.8	0.9	1.4	1.6	4
	M"	0	0	0	0	0	0	4	5.6	4.05	2.8	2.4	4.4
	dB/cm	0	0	0	0	0.01	0.06	1.3	12.6	27	70	75	217
	dB/in	0	0	0	0	0.03	0.15	3.3	32	69	179	190	551
	$\|Z\|/Z_0$	0.14	0.16	0.2	0.26	0.3	0.36	0.46	0.47	0.47	0.36	0.34	0.43

Typical Electrical Properties Legend

K'	Real part of the permittivity (dielectric constant)
tan δ_d	Dielectric loss tangent
K"	Imaginary part of the permittivity (loss)
M'	Real part of the magnetic permeability
tan δ_m	Magnetic loss tangent
M"	Imaginary part of the magnetic permeability (loss)
dB/cm	Attenuation per unit distance
dB/in	Attenuation per unit distance
IZI/Z_0	Normalized impedance magnitude ratio

Most of the definitions and equations are included in the Emerson & Cuming publication "ENERGY PROPAGATION IN DIELECTRIC AND MAGNETIC MATERIALS." In this technical bulletin, M' is used for the real part of the magnetic permeability and M" for the magnetic loss factor. Beyond the definitions in the reference above, the following clarification of the terms dB/cm or dB/in and |Z|/Z_o are offered. These characteristics are not in themselves directly applicable to the calculation of transmission and reflection coefficients as they are defined on pages 3 & 4 of the reference. For these calculations, the complex dielectric constant (K'-jK' tan δ_d) and complex magnetic permeability (M'-jM' tan δ_m) are used as listed in the Tables. The definition of dB/unit length is included in the reference, both in mathematical form and in words. The value is useful in comparing one material against another to determine which offers the most loss independent of interface reflection coefficients. Similarly, |Z|/Z_o, the normalized impedance magnitude ratio, can be used as a qualitative measure of the impedance match between free space and the material. An impedance ratio that is closest to 1 is the most desirable because at that ratio, the impedance match between the material and free space is perfect.

The significant features of the property tables are:
1. In every case, K' decreases with increasing frequency.
2. Almost without exception, the dielectric loss tangent and dielectric loss factor decrease with increasing frequency. The exception occurs at the low end of the frequency band, and can be ignored in most applications.
3. The magnetic loading increases from a minimum in MF-110 to a maximum in MF-190. There is a corresponding increase in K', K", M', tan δ_m and M".
4. The 0 values in the table indicate that the number is less than 0.01.
5. The values given in the table are nominal values and should not be used by customers in the writing of procurement specifications. If specifications are needed, the customer should consult with the Emerson & Cuming Sales Department. The use of dielectric/magnetic properties for Quality Control, i.e., incoming or outgoing inspection, is not recommended, because the measurement of these properties is very time consuming and complicated. It is recommended to monitor the density.

Termination Design Considerations

- The most widely used member of the ECCOSORB® MF series is MF-117. It is an excellent material to start experimentation. Most designs of terminating and attenuating elements depend heavily upon cut-and-try procedures. A preliminary design is established by experience or rough estimates of probably satisfactory dimensions, a piece of ECCOSORB® MF is machined and tested for VSWR and/or attenuation and the design is then modified as required.
- In coaxial, waveguide and stripline terminations, either step-tapered or uniformly tapered configurations can be used.
- Step-tapered terminations are narrow-banded and highly critical dimensionally. They are recommended only where essentially single-frequency operation is anticipated. Increasing the number of steps beyond two can increase the usable band-width and such designs are helpful when limited length is available in the direction of propagation. Reproducibility of the performance of step-tapered terminations may be difficult because of their sensitivity to small changes in magnetic and dielectric properties.
- Uniformly tapered terminations are generally preferred because of the low VSWR which is possible to achieve over a wide frequency range. Dimensions are reasonably non-critical and performance is reasonably insensitive to magnetic and dielectric properties. In general, the more gradual the taper, the lower the VSWR. A length-to-base-width ratio of 10:1 is highly desirable for VSWR as low as 1.01 over a full waveguide frequency band, particularly with materials having the higher values of M' and K'. A sufficiently long taper must be used so that very little energy reaches the base mounting plate where it can be reflected back into the line. The one-way attenuation should be at least 25 dB for VSWR as low as 1.01.
- Wall-type uniform tapers offer maximum heat-transfer efficiency and are recommended for high-power applications.

Machining Recommendations

Most of the discussion below applies not only to the basic ECCOSORB® MF series of materials, but also to several high temperatures, castable and molding-powder equivalents. ECCOSORB® MF can be formed readily to close tolerances with standard metal-working machine tools, i.e.: lathes, milling machines, drills, saws, grinders, generally using conventional techniques but observing the precautions and limitations described below.

Tooling

- For turning, milling, drilling and tapping, carbide tools should be used, for example Type 883, a general purpose carbide that works well under most conditions. Use solid carbide taps for long life. Standard size tap drills should be satisfactory.
- External threads are formed best, not with conventional thread-cutting dies but by lathe turning or grinding, with light feeds and shallow cuts.
- Sawing can be done with best finish and tolerance using circular saws, 8 to 10 inches (20.3 to 25.4 cm) diameter, with grinding coolant and high RPM. Thin carborundum wheels, (e.g.: 1/32" [0.079 cm] thick) or carbide saws may be used where requirements are less stringent. Best results are attained by moving the saw and keeping work stationary, with saw rotating so it tends to climb into the work.
- Surface finishing of flat sheets, etc. is best performed with a Blanchard grinder. ECCOSORB® MF is held readily with magnetic chucks. Sheet size is limited by the size of the machine.

Coolants

- Use of a coolant liquid is recommended, especially for all close tolerance operations. Commercial grinding fluid is preferred, or water-soluble oil, with rust-resisting properties to protect the machines. Spark producing operations in particular must not be run dry, since smoldering fires might result.
- Where coolant run-off is collected for recirculation, a two-cavity recovery system should be used to minimize pick-up of grinding dust, sawdust or chips by the coolant pump. Where a recirculating system is not available, best results will be obtained with air-powered spray or mist equipment.

Use of tapped metal inserts should be considered where electrical performance will not be degraded. Inserts may be cast in place, or bonded with castable material of suitable composition

Suggested Speeds and Feed Rates

The following speeds and feed rates are suggested to be modified as necessary to suit job conditions:

OPERATION	SPEED	FEED
Sawing, turning	70 - 90 ft/minute (21.3 - 27.4 m)/min.	.005 - .008 in/revolution (0.13 - 0.20 mm)
External threading	70 - 90 ft/minute (21.3 - 27.4 m)/min.	.001 in/pass (0.038 mm/pass)
Tapping	450 rpm	Tapping Head
Milling	70 - 90 ft/minute (21.3 - 27.4 m)/min.	.0015 - .003 in/tooth (0.038 - 0.076 mm)/tooth