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HANSER

Special reprint

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Radiation Shielding

Films

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Radiation Shielding

Films. Flexible, transparent, and conductive films are already being utilized for numerous applications, as in displays, touch-keys and touch-screens. Thanks to their special properties, new and interesting areas of application are opening up in the field of electromagnetic shielding.

In an electromagnetic environment, e.g., near radio equipment, cell phones have to be shielded against electromagnetic radiation
(figure: iStock)

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Shielding against what is commonly called EMI, electromagnetic interference, has become a very interesting area of application for flexible, conductive and transparent plastic films. By EMI we mean a negative influence on the function of electrical devices, equipment spaces and facilities in the form of interference stemming from magnetic and electric fields. Effective shielding can protect devices from magnetic, electric and electromagnetic fields, or vice-versa: the surroundings can be protected against fields emitted by such equipment.

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Decades ago, undesirable influence was observed, such as relatively harmless interference with television reception from an unsuppressed vacuum cleaner or coffee grinder. Nowadays such influence would be more serious, if, for instance, cell phones with control units would unintentionally interact with the control units of machines, or if industrial robots were to be influenced by unsuppressed electrical devices.

In Europe, it is currently the case that electrical devices have to comply with special regulations that require them to be equipped with sufficient shielding. Strong legislative standards are in place for this. Thus the EMC (ElectroMagnetic Compatibility) guideline introduced by the European Union in 1989 determines what requirements an electric or electronic device has to fulfill all over Europe. With the mandatory CE label, binding since 1996, and an enclosed EU declaration of conformity, the manufacturer or importer guarantees that any electric device placed on the market has to maintain certain limit values for interference emission and resistance. With everyday life becoming more and more mechanized all over the world, it is apparent that EMI shielding is an issue that will generate large markets with constantly growing demand [1].

Technical Background

It is well known that all moving electric charges generate magnetic fields. These fields do not have to remain within the electrical device under consideration or in the immediate vicinity of a current carrying medium (electrical cable), but can also propagate outside the particular service medium. Such fields can then penetrate other electrical components, actively influencing their functions.

Communications equipment, such as radios or cell phones, utilize such effects by intentionally emitting and/or receiving electromagnetic fields. The relevant electromagnetic spectrum is illustrated in **Figure 1**.

However, electromagnetic influence can also lead to negative effects, such as the above-mentioned interference with sensitive electronic circuitry. In the case of cell phones this can also lead to interference with reception or, in the worst case, to data loss in data processing.
Here we have to distinguish between

- natural sources of strong electromagnetic radiation, e.g., lightening or geomagnetic storms and
- artificial fields, such as are caused by all electrical equipment. Devices not conceived for radio transmission can emit interference if their power supplies (power switching components in particular) are not shielded, or from poorly designed PCBs or suboptimum LCDs. Intentionally emitted interference used for military and intelligence gathering also belongs in this category.

Technical shielding against electromagnetic fields is provided nowadays by electrically conductive shielding materials. Metal film or sheet is often used for this. The actual shielding then functions by the principle of influence, that is, by shifting electrostatic charges. Since electromagnetic waves are time varying processes, eddy currents are generated in the conductive shielding material that counteract and ultimately attenuate an external electromagnetic field.

In order to shield housings, switch cabinets, monitors, computers and electronic assemblies, so-called mu-metal films, plates, sheet and weave are available commercially. Mu-metal, also µ-metal, is a weakly magnetic nickel-iron alloy with high magnetic permeability that has a rather strong shielding effect. However, a certain mechanical sensitivity is viewed critically, since any buckling immediately and severely weakens its shielding properties in terms of permeability.

In view of this, conductive films in the form of metal mesh sheet on a plastic film base present an interesting alternative especially for attenuating electrical and electromagnetic fields.

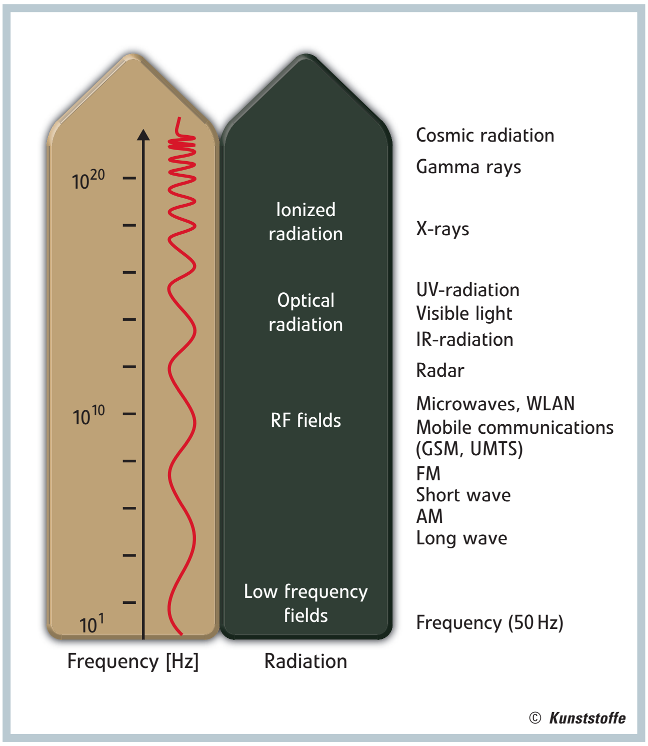

Fig. 1. Electromagnetic spectrum (figures 1 through 4: PolyIC)

In general, the development of new technologies for producing conductive layers is currently an important topic being pursued by numerous research and development facilities around the world. Increasing interest is focusing on transparent types of shielding film. These can be realized by established indium-tin oxide (ITO) based films. Due to certain properties of ITO-base films, however, the trend is in another direction. One main reason for this is that indium may not always be freely available in the future. Additional reasons for considering alternatives to ITO technology are quite obvious. For one thing, various technological properties, such as mechanical flexibility, colorfastness or high conductivity in the layers, are at issue. For another thing, entirely new surface and design concepts are being attempted that are hard to realize using the established technologies.

Newly developed, so-called metal-mesh technologies for producing transparent and conductive layers on films promise interesting advantages in production and processing. Special technological requirements (mechanical, electrical as well as optical) are filled perfectly by these metal-mesh technologies. Transparent and conductive EMI shielding films are especially suitable for use in display elements such as smartphones and tablets.

LC displays were identified above as being critical component in terms of emissions. This is why a transparent and con-

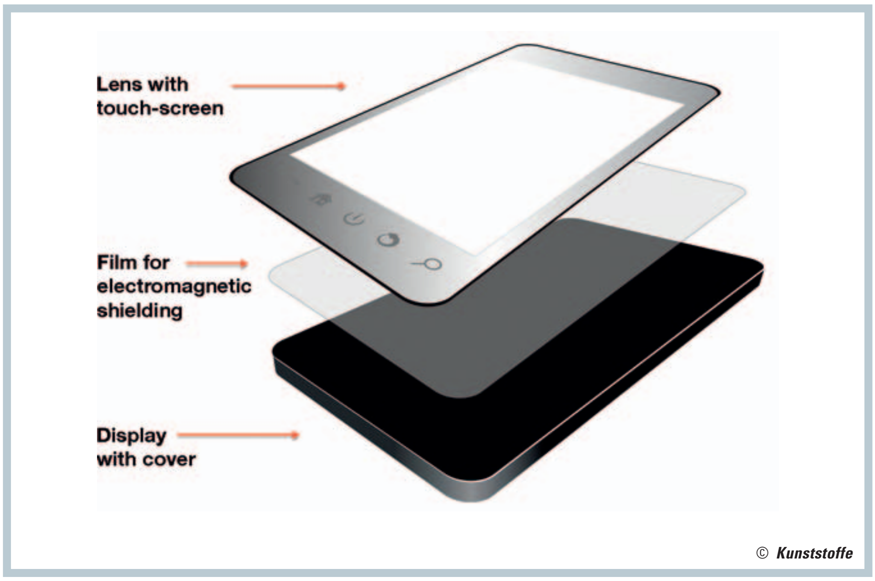

Fig. 2. Transparent metal-mesh film for shielding interference fields in smartphones

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ductive EMI film is inserted between the touch sensor (cover lens) and the unshielded LCD surface of a smartphone, for example, in order to prevent negative influence on the touch sensors by LCD noise **(Fig. 2)**.

Conductive Structures

Pure metals or other, more complex chemical compounds can be used for producing conductive layers on plastic foils. Those used include

- noble metals, such as silver or copper,
- non-stoichiometric compounds based on tin, zinc and indium oxide, such as tin indium mixed oxide (ITO),
- aluminum doped zinc oxide and
- fluorine doped metal oxides.

ITO can be applied to plastic films in the form of ultra-thin layers by various methods, e.g., vacuum evaporation, sputtering, ion plating or chemical vapor deposition (CVD). Where some of the above mentioned examples are concerned, however, it should be noted that extensively applied conductive layers require subsequent structuring by chemical etching methods if such a structured surface is desired in the form of metal mesh.

The most attractive, because most economical approach to manufacturing metal mesh is, therefore, to apply the desired structure directly onto a plastic carrier film by means of the roll-to-roll process.

For example, PolyIC GmbH & Co. KG, Fürth, Germany, a subsidiary of Leonhard Kurz Stiftung & Co. KG, supplies films with shielding effect under the brand name PolyTC. These films consist of an ultra-thin metal mesh on polyester film. In addition to the required electromagnetic shielding, they are extremely flexible and highly transparent to visible light. This enables them to be used where high optical demands are made (e.g., displays and monitors) in addition to the shielding effect **(Fig. 3)**.

These films were originally developed as a base material for printed electronics. In their structured form, they can be utilized successfully as electrode material or as conductor paths for printed radio tags (RFID tags) [2], smart objects [3], printed organic photovoltaics or even in printed memories. It turns out that such structured transparent and highly conductive films can be very successfully used in the production of displays, ultra-thin transparent heating elements and touch sensors, e.g., in the automotive field. Here, use is made of the fact that such films can be applied to curvaceous surfaces thanks to their flexibility [4]. Any number of methods, e.g., lamination or injection molding, can be used to process the film further [5].

PolyTC film is produced by the roll-to-roll method and supplies high-resolution conductive surfaces in the form of metal mesh on transparent plastic film. As previously indicated, polyester, especially polyethylene terephthalate (PET), is a natural choice for the substrate material, since it has a number of interesting properties: it is thin and flexible, highly transparent and, even in thermally stable types, available in bulk at an attractive prices.

The typical conductor path in metal mesh structures is 10 µm wide. Due to this high resolution, the structure is not visible to the naked eye. This process enables film transparency and conductivity to be set precisely via the degree to which the film is covered by conductive material. The end result is an ultra-thin metal layer in the form of a customer-specified layout. A surface coverage of just 5 to 10 % enables very high optical transparency in addition to the desired conductivity. Such films thus offer the main advantage that they can be used as shielding where transparency is a main requirement, especially in displays and as window film.

Fig. 3. Example of a metal mesh film on a roll

Moreover, additional layers, e.g., contact improvement and protective layers, can be applied to the manufactured metal mesh film **(Table 1)**.

Since the attenuation effect on electromagnetic waves depends to a large degree on the configuration of the conductive coating, PolyTC films provides great advantages, since they can be configured to suit the customer. Thus the metal mesh can be arranged in rhombic, square or hexagonal designs and for an individual setting of surface resistance.

Property	Typical value
Transparency	> 80 %
Layer resistance	approx. 3 Ω/□ or customer specified
Structure size (mesh)	15 µm
Gap	300 µm
Attenuation	~ 30 dB
Conductive material (mesh)	Cu (other metals possible)
Substrate	PET film
Form of delivery	Substrate Rolls or sheet (customer specified)

Table 1. Properties of a metal mesh film (e.g., copper mesh PolyTC film)

Attenuation with EMI shielding films can be detected by so-called attenuation measurement according to the standard ASTM D 4935 [6]. Here the electromagnetic transmission by the conductive film under investigation is compared with the transmission by an unshielded control sample made from the same material of the same thickness, i.e., the blank plastic film (0 dB attenuation). The subtraction results in the field strengths of the two attenuation values depending on the frequency. This measurement method has the advantage that the setup required for measuring the electromagnetic far-field is quite simple.

Typical measurement values for a structured, transparent PolyTC film (PET film with copper metal mesh) are presented in **Figure 4**. Attenuation in the vicinity of 30 dB (corresponding to 99.9 % shielding) is detected over a wide frequency range from 30 to over 4,000 MHz, i.e., precisely in the range of great importance for radio communications, GSM, UMTS, WLan to WiMAX.

Conclusion

Plastic films with metallic mesh coating, so-called metal mesh films, are opening up new prospects for shielding electromagnetic fields. Due to their high optical transparency in connection with their shielding effect, they can also be applied wherever full metal films cannot be used. ■

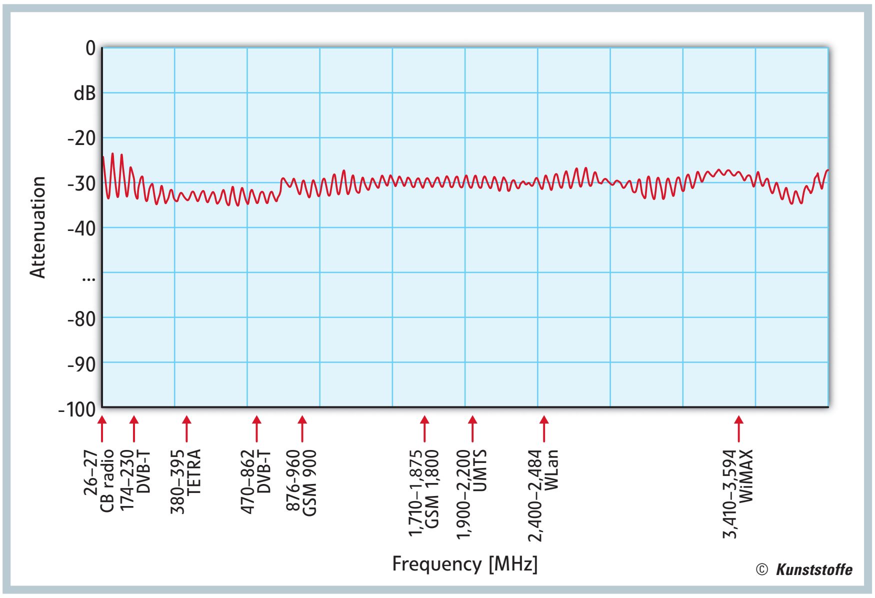

Fig. 4. Attenuation by a metal mesh film (e.g., copper mesh PolyTC film) in the 30 to 4,000 MHz frequency range

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