THE MULTIFUNCTION CONDUCTING MATERIALS BASED ON CEMENT CONCRETE WITH CARBON FIBERS

Pavel Steffan[1], Peter Barath[2,3], Jiri Stehlik[1], Radimir Vrba[1]

[1]Department of Microelectronics, Brno University of Technology, Udolni 53, 602 00 Brno, Czech Republic, phone: +420 541146120, e-mail: steffan@feec.vutbr.cz

[2]Department of Electrical and Electronic Technology, Brno University of Technology, Udolni 53, 602 00 Brno, Czech Republic, phone: +420 541146120, e-mail: peter.barath@phd.feec.vutbr.cz

[3]Institute of Inorganic Chemistry of the ASCR, v. v. i., 250 68 Řež near Prague, Czech Republic

The article describes that the addition of chemical agents and carbon fibers to cement concrete can greatly enhance the conductivity of the concrete. In addition to improving the shielding effectiveness, carbon fibers and chemical agents enhance the tensile and flexural strengths significantly. Conduction of an electrical current in concretes is electrolytic in essential. A high frequency alternating current was employed. Composites with various fiber types were tested and measured. It was concluding that more than conductivity of the fiber material itself; it is the surface area of the carbon fiber in the concrete which is important.

Keywords: Carbon fibers, electrical conductivity, measurement

1. INTRODUCTION

1.1 Measurement Technique

As shown by Nikkanen [1], conduction of an electrical current in concretes is electrolytic in essential. Consequently, chemical reactions take place at the electrodes and hydrogen and oxygen gases are liberated that deposit around the electrodes in the form of thin film. The effect of this thin film is in creating a polarization potential. Establishment of a polarization potential opposes the flow and manifests itself in the form of reduced current for a given applied voltage U,

$$I = \frac{U - U_P}{R} \quad , \qquad (1)$$

where U_p is the polarization potential. It follows that if DC measurements are made, at least two different values of applied voltage U have to be used to determine the two variables U_p and R. The resistivity of the material ρ, which is a material constant, is given by

$$\rho = R\frac{S_S}{L_S} \quad , \qquad (2)$$

Alternatively, the current I, may be determined as a function of the applied voltage U. The linear portion of U = f(I) curve gives the resistance and the finite intercept on the voltage axis is the voltage drop due to polarization effects.

1.2 Uses for Alternating Currents

In order to avoid the problems of polarization, alternating currents are often used for determining the resistivity of electrolytes and hence of cements and concretes. It has been suggested that the polarization effects during the passage of an alternating current are not eliminated but rather manifested in a different form [2]. The polarization is in the form of introducing a capacitor in series or in parallel with the resistance. In any case, for an alternating current, Equation takes the form

$$Z = \frac{U}{I}, \tag{3}$$

where Z is system impedance in ohms. The impedance may be related in to the resistance R and capacitance C in parallel C-R arrangement as follows:

$$Z = \frac{R}{\sqrt{1+\varpi^2 C^2 R^2}} \quad , \tag{4}$$

where $\omega = 2\pi f$, f being the applied frequency in cycles per second and C is capacitance in farads.

1.3 Electrochemical Impedance Spectroscopy

Electrochemical Impedance Spectroscopy (EIS) is a powerful technique for the characterization of electrochemical systems. The promise of EIS is that, with a single experimental procedure encompassing a sufficiently broad range of frequencies, the influence of the governing physical and chemical phenomena may be isolated and distinguished at a given applied potential. In recent years, EIS has found widespread applications in the field of characterization of materials. It is routinely used in the characterization of coatings, batteries, fuel cells, and corrosion phenomena. It has also been used extensively as a tool for investigating mechanisms in conductivity, passivity, and corrosion studies. It is gaining popularity in the investigation of diffusion of ions across membranes and in the study of semiconductor interfaces.

$$|Z|^2 = (\text{Re } Z)^2 + (\text{lm } Z)^2, \tag{5}$$

$$\phi = \tan^{-1}\frac{\text{Im } Z}{\text{Re } Z}, \tag{6}$$

$$\text{Re}(Z) = |Z|\cos\phi \, , \tag{7}$$

$$\text{Im}(Z) = |Z|\sin\phi \, , \tag{8}$$

2. Materials

Cement concrete was reinforced with different type of carbon fibers. The properties and quantity of carbon fibers used are given in Tab. 1. Form specimens is 500 mm x 500 mm x high (10, 20, 40, 60) mm, after indurations the samples were cut to final size 250 mm x 250 mm. Two or four copper electrodes, 0.3 mm thick, were embedded in the fresh mix as shown in Fig. 1. Specimens were stored in the humid room for curing at 25 ± 1 °C and 60 % r.h.

Tab. 1: Measured cement concrete with carbon fibers

Composite materials with carbon fibre									
Type	Sample mark	Geometric dimension							
		250x250x10mm			250x250x20mm	250x250x40mm			250x250x60mm
cement concrete	NKU (2)	10A	10B	10C	20A	40A	40B	40C	60
1,5% carbon fibre Kreca	NKK (3)	10A	10B	10C	20A	40A	40B	40C	60
2% carbon fibre Kreca	NKK (4)	10A	10B	10C	20A	40A	40B	40C	60
1,5% carbon fibre Minko	NKM (5)	10A	10B	10C	20A	40A	40B	40C	
3% metal fibre Fibraflex	NKF (6)	10A	10B	10C	20A	40A	40B	40C	60
4% metal fibre Fibraflex	NKF (7)	10A	10B	10C	20A	40A	40B	40C	60

Composite materials with carbon powder									
Type	Sample mark	Geometric dimension							
		250x250x10mm			250x250x20mm	250x250x40mm			250x250x60mm
+ 10% carbon powder	NKG(8)	10A	10B	10C	20A	40A	40B	40C	60
+ 20% carbon powder	NKG(9)	10A	10B	10C	20A	40A	40B	40C	60
+ 10% ground sungit	NKŠ(10)	10A	10B	10C	20A	40A	40B	40C	60
+ 15% ground sungit	NKŠ(11)	10A	10B	10C		40A	40B	40C	
+ 20% ground sungit	NKŠ(12)	10A	10B	10C	20A	40A	40B	40C	60

Fig. 1: Form for Resistivity Measurements

3. RESULTS

Fig. 1 shows the relationship between *I* and *E* in cyclic voltammograms of various carbon materials and compared four different carbon materials. The same materials were compared by 3 probe measured in electrolyte with pH 8. Carbon was deposited on metal screen as working electrode, reference electrode was Hg-HgO and counter electrode was made by Pt.

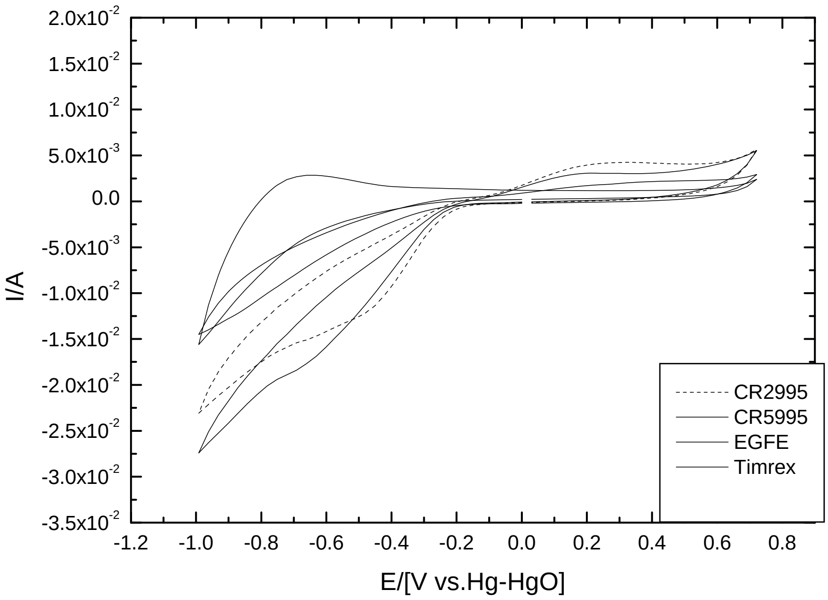

Fig. 2: Comparison of Cyclic voltammograms of various carbon materials

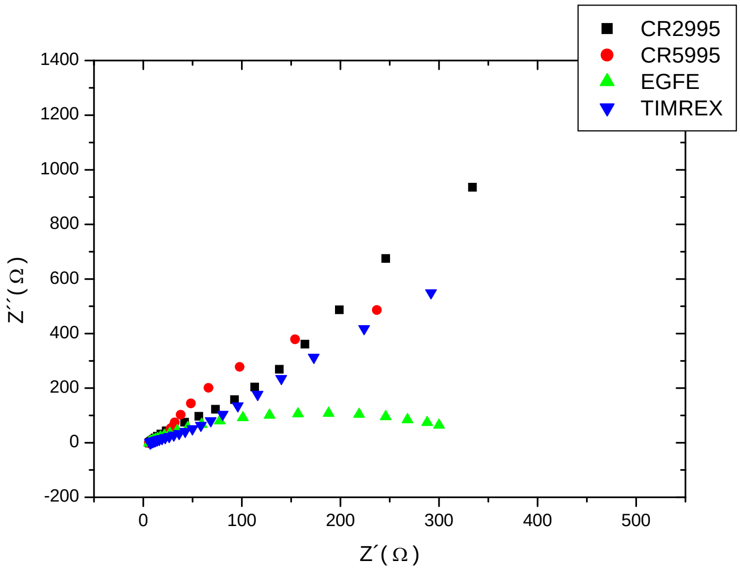

Fig. 3: Nyquist diagram of various carbon materials

The impedance decreased dramatically (Fig. 4) with an increase in applied frequency leveling off to approximately constant values at frequencies greater than about 9 kHz. Consequently, a frequency of 20 kHz was adopted as the measurement frequency and the calculated impedance was assumed equal to the resistance.

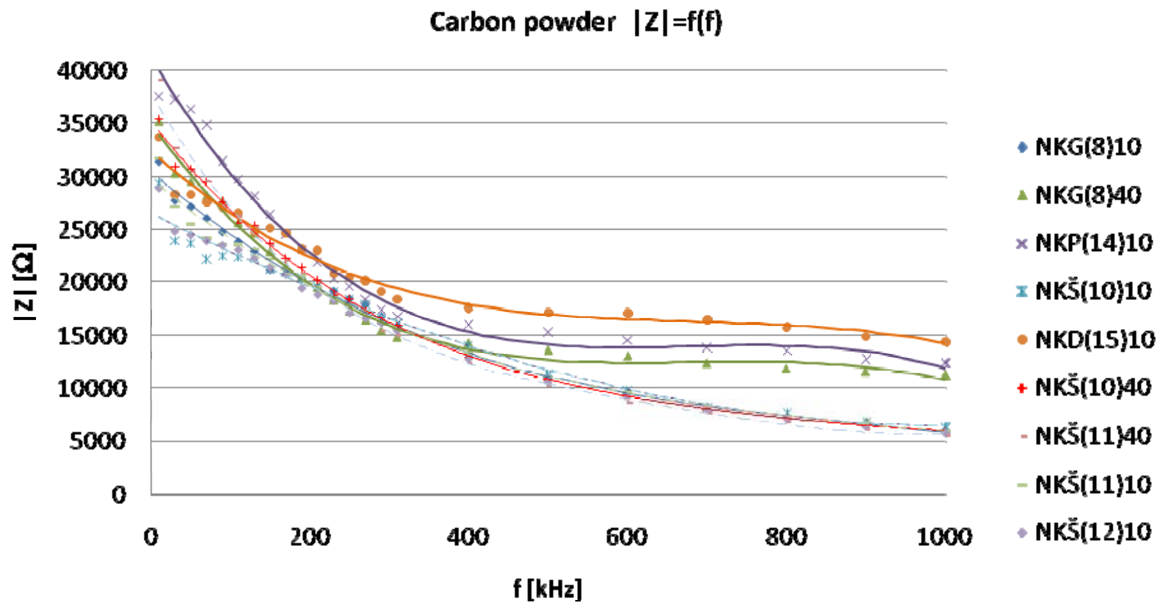

Fig. 4: Influence of Applied frequency on the Measured Impedance

4. Conclusion

The ingredient of cement with conductive fibers of carbon and steel produced highly conductive composites. In the mono-fiber composites, carbon fibers are significantly more effective in improving the conductivity than steel fibers as show in Fig. 4. It was concluding that more than the conductivity of the fiber material itself; it is the surface area of the carbon fiber in the concrete which is importance.

5. Acknowledgments

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