DEPOSITION OF NICKEL ON CARBON FIBRES BY GALVANIC METHOD

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Resume

The investigation of coating parameters in quasi-static coating of Ni layer on carbon fibre tow by galvanic method is presented. The tow of fibres was immersed in typical galvanic bath based on $NiSO_4$, $NiCl_2$, Na_2SO_4 and H_3BO_3 and current to carbon fibres was supplied by two leading metal rolls which are parts of continuous coating apparatus. The main parameters were current of 1 A, electrolyte temperature of 50 °C and the distance from power contacts to level of galvanic bath (8 or 13 cm). The amount and structure of deposited Ni layer at coating time 15 and 90 seconds of exposure in electrolyte and depth of immersion of tow into bath were discussed.

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1. Introduction

Carbon fibres possess excellent mechanical properties and very low thermal expansion. They are widely used in polymer composite production because of the reactions between the fibre and polymer which do not lead to the degradation of fibre properties. Using PAN based or pitch based carbon fibres, nickel coated carbon fibres (NCGF), vapour grown carbon fibres (VCF), silver coated graphite fibres and carbon nanotubes (CNT) can lower resistivity to 10^{-4} to 10^{-5} ohms which is excellent for electromagnetic interference (EMI) shielding of polymer composites. Electromagnetic interference shielding problems are very common now and because of its interference with other electronic devices, these issues have become the focus of attention. Hasty development of appliances and devices in the field of electronic information and communication has radically placed the general population under the threat of EMI or radio frequency interference. Short carbon fibres composites are much more effective in EMI shielding than particulate composites and relatively less loading is required [1].

The different situation is in the field of metal matrix composites. The carbon fibres react with many metals to produce carbides (for example Cr, W, Al, Ti, etc.). In some metals (Ni) carbon is diluted and some metals (Cu) are inert in relation to carbon surface and do not wet the carbon. Due to poor wettability and low adhesion between composite components the transfer of load from matrix to fibres is poor and very low values of shear and transverse strengths in unidirectional composite are obtained. The carbon fibres due to unfavourable interaction with many metals are to be protected by coatings. Some of these layers have also other function, for example to improve wetting of fibres by metals. Several methods of layer deposition on fibres are used (chemical vapour deposition, physical vapour deposition, sol-gel and others). The galvanic metal coating is a widely used method in which large thicknesses can be obtained, from about several tenths of micrometer up to

micrometers which should be enough to produce matrix of the composite.

The main objective of this study has been the optimisation of our laboratory technique for galvanic Ni coating of carbon fibre tow with acceptable quality in plating uniformity and minimal fibre damage and with an aim to achieve defined speed of tow transport and coating thickness.

2. Experimental procedure

In our experiments we used high strength carbon fibres HexTow ASC4 [2] produce by Hexcel corporation with 12000 monofilaments in tow (diameter of a filament is about 7 μm) – Fig.1. The fibres after activating process were continuously galvanically coated in electrolyte with $NiSO_4$, $NiCl_2$, Na_2SO_4 and H_3BO_3 [3] at the temperature of 50°C in the coating apparatus described by Simančík and Šebo [4]. Three galvanic units for gradual metal layer growth are powered by three independent electric current supplies with adjustable current input and output in the range 1 – 5 A. The current on carbon fibres for formation of Ni layer by galvanic method was supplied by two leading metal rolls. The distance between the contacts for supplying of current onto fibre and the electrolyte level is marked as h. The length of tow in electrolyte was 40 cm at h = 8 cm and/or 30 cm at h = 13 cm. Structural observations were performed with scanning electron microscopy (SEM – JEOL JSM 5310).

3. Results and discussion

The most important factor affected the quality of Ni layer is the formation of the growth nuclei at optimal parameters which are mainly value of direct-current, potential and temperature of electrolyte. The highest amount of nickel is formed at higher galvanic current, but the fibres between metal leading roll and electrolyte level can be overheated and even burn and also deposited layer is not uniform at higher values of current. Thus the optimum value of current has to be determined.

The quasi-static experiments were performed to understand which parameters are optimal for formation of good quality layer with acceptable speed of Ni layer growth. The surfaces of C fibres were coated with nickel in the galvanic unit using different time, currents and distances of electric contact from the electrolyte level. The coating time included 15 and 90 seconds of exposure in electrolyte with current of 1 A.

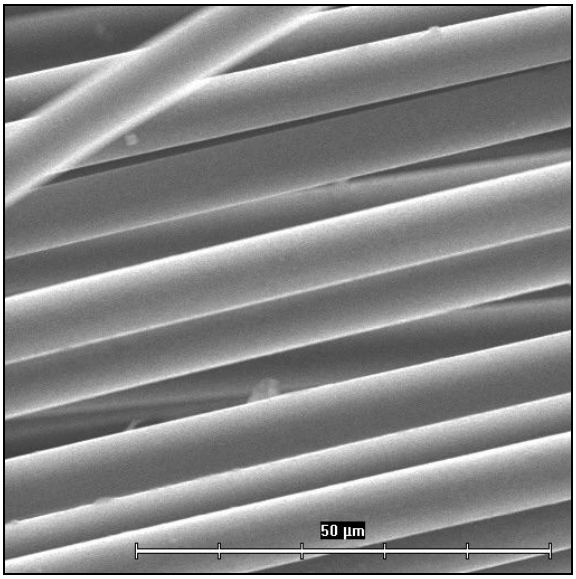

Fig. 1. Surface of original ASC4 carbon fibres

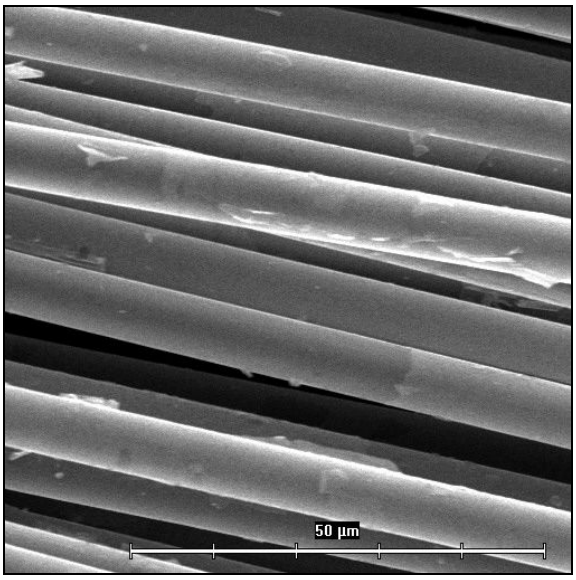

Fig. 2. Nickel coating formed just below the electrolyte level after the 15 sec/1 A exposure

Morphology of Ni coating formed after 15 seconds of exposure in electrolyte with current

1 A (15 sec/1 A) just below the electrolyte level is shown in Fig. 2. As can be seen no continuous coating is formed under these parameters.

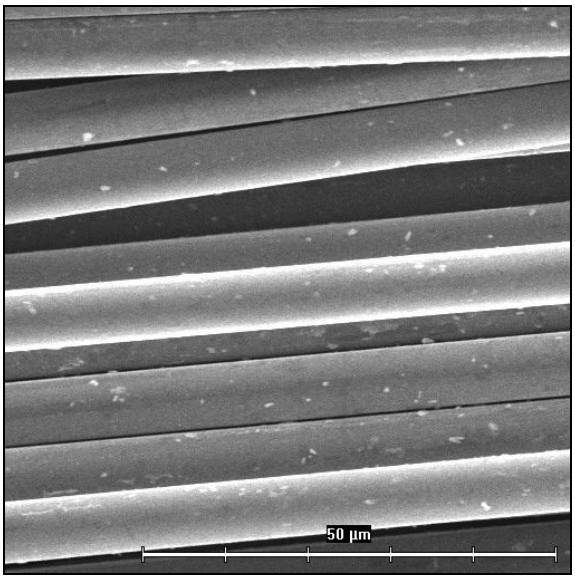

Fig. 3. Nickel coating formed 60 mm below the electrolyte level after the 15 sec/1 A exposure

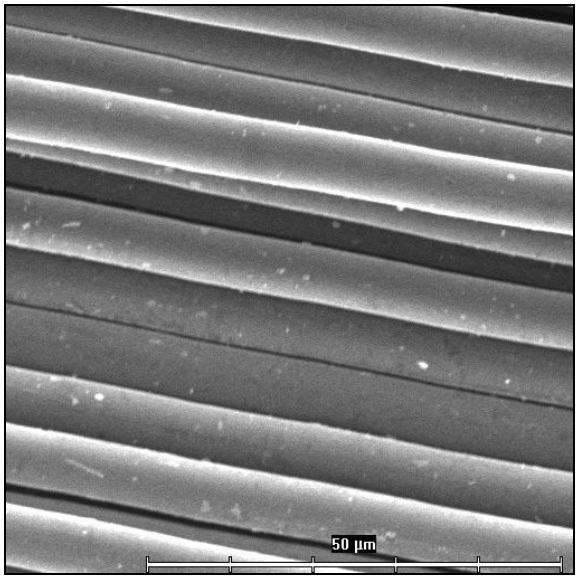

Fig. 4. Nickel coating formed 95 mm below the electrolyte level after the 15 sec/1 A exposure

Structure of the coating formed 60 mm below the electrolyte level is shown in Fig. 3. Only isolated islands of nickel can be found on the fibre surfaces in this case. The fibres under the 95 mm below the electrolyte level (Fig. 4) appear to be practically Ni-free what means that at this distance from the electrolyte level no actual coating takes place under the applied coating parameters (15 sec/1 A).

Typical structure of Ni coating formed just below the electrolyte level after 90 seconds of coating with 1 A current is shown in Fig. 5.

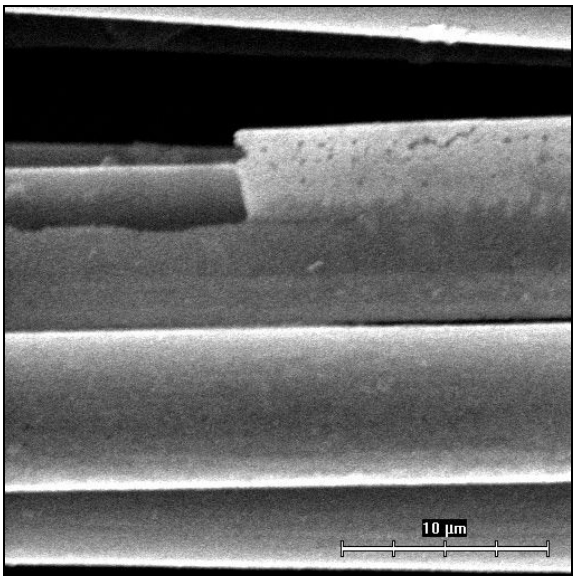

Fig. 5. Nickel coating formed just below the electrolyte level after the 90 sec/1 A exposure

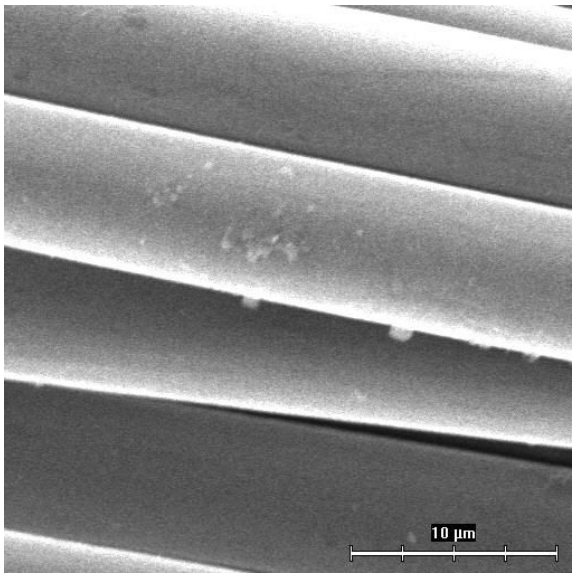

Fig. 6. Isolated Ni islands found on the surface of carbon fibres 190 mm below the electrolyte level after the 90 sec/1 A exposure

As can be seen continuous coatings on individual fibres are formed under these conditions. The extended time of exposure leads to the formation of Ni coating much deeper from the electrolyte level as in the previous case (15 sec). Typical structure of nearly continuous coating is formed 95 mm below the electrolyte

level. Structural observations revealed that continuous nickel coating can be found even 155 mm below the electrolyte level. The initial stages of Ni coating formation were found 190 mm below the electrolyte level. Typical examples of isolated Ni islands are shown in Fig. 6.

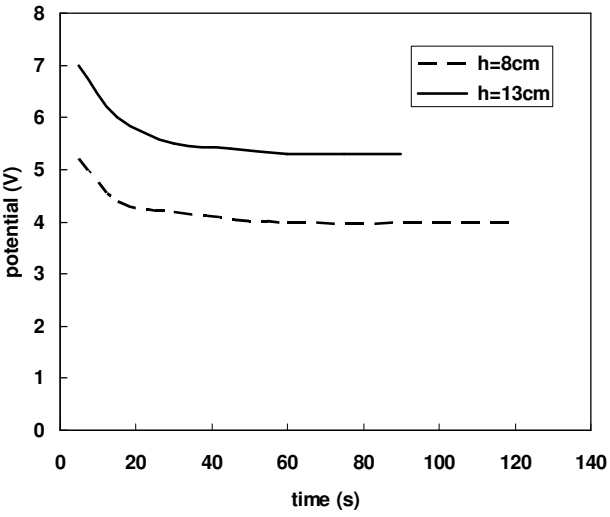

Fig. 7. Dependence of potential at constant current of 1A on time and distance (h) between the electric contact and electrolyte level

It is quite important to keep the voltage corresponding to required current within certain ranges to avoid the extreme overheating of fibre, entering as well as exiting the electrolyte. The overheating could lead to burn out the fibres or the electrolyte could boil at the fibre surface. On the other hand higher current is required for deposition of higher Ni amounts in galvanic unit and this can be achieved only at higher voltage for given electric resistance.

It appears that the Ni coating is preferentially formed close below the electrolyte level. This leads to the decrease of electric resistance of the fibre tow what makes the deposition of Ni even in deeper locations possible.

Dependence of potential on time for defined distance of electric contact from the electrolyte level is presented in Fig. 7. It can be seen that the most intense potential decrease takes place right at the beginning of deposition (below 15 sec). This is due to the fact that the deposited Ni coating lowers the electric resistance of the fibre tow in the solution. Higher initial potentials were measured for larger distance between the electrical contact and the solution level. If the fibre passing time through the solution is too short the potential might remain too high. In this case not enough current might be available for Ni deposition. This could yield too thin or even not continuous Ni coating. Therefore the deposition rate cannot be increased over certain limits without additional measures leading to the decrease of electric resistance of fibres.

4. Conclusions

The most important factors influencing the formation of continuous layer on carbon fibres are time of galvanic process and depth of immersion of carbon fibres in bath. No continuous coating is formed just below the electrolyte level after 15 seconds of exposure in electrolyte and current 1 A. Only isolated islands of nickel can be found on the fibre surfaces in higher depth.

The continuous coatings on individual fibres are formed just below the electrolyte level after 90 seconds of coating with 1 A current, but continuous nickel coating can be found even 155 mm below the electrolyte level. The isolated Ni islands were even found 190 mm below the electrolyte level.

Acknowledgements

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References

[1] V. K. Sachdev, K. Patel, S. Bhattacharya, R. P. Tandon: J. Appl. Polym. Sci. *120* (2011) 1100-1105.

[2] http://www.hexcel.com/Resources/SelectorGuides/CarbonFiber_SelectorGuide_us.pdf [available 03.12.2011]

[3] S.S. Platenev: In: Galvaničeskie pokritija v mašinostrojenii Vol.1, Ed. M.A.Šlugera, Mašinostroenie Moskva 1985, pp.105-118. (*in Russian*).

[4] F. Simančík, P. Šebo: Kovove mater. *29* (1991) 358-365.