Effect of chlorination on the interaction of carbon fibers with electromagnetic radiation in the ultrahigh-frequency range

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Today, advanced materials that absorb microwave radiation can capture (absorb) waves incident on the surface of equipment, thus creating hiddenness for radars designed to detect a variety of targets in aviation. Such materials, including carbon materials, are also considered the key to stealth technology in the military [1]. Carbon materials are widely used as adsorbents, catalysts, and catalyst carriers. They are carriers for the support and stabilization of metal nanoparticles and are promising alternatives to polymeric materials.

As a rule, carbon fibers (CFs) are excellent absorbers of EM radiation. They are used in manufacturing protective clothing for soldiers and for the masking of military equipment [2]. The widespread of operating radar and missiles frequencies stimulate the creation of new materials for a defense that should absorb EM radiation in the range of 0.1–40 GHz. For this purpose, we proposed to modify the surface of polyacrylonitrile-based carbon fibers (PAN CFs) by chlorination in order to study the effect of surface modification on the microwave properties of PAN CFs. Chlorination was performed at temperatures of 300, 450 and 600°C. The indicated temperatures were used to denote the samples.

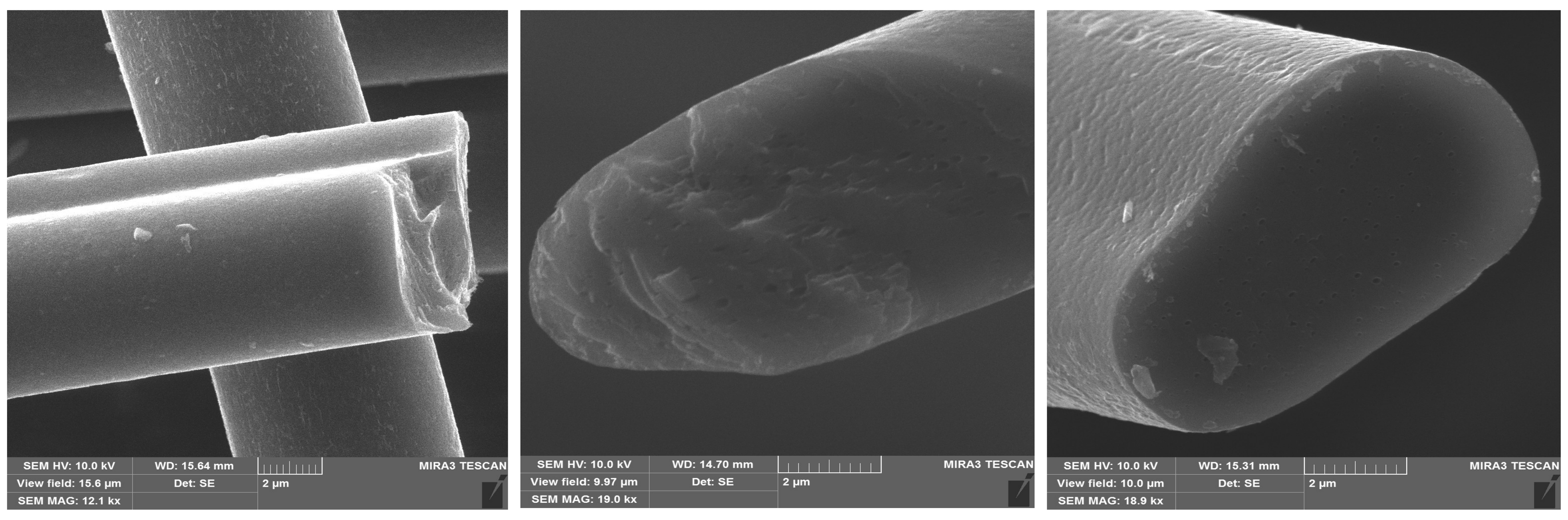

FIGURE 1. SEM microphotographs of the initial carbon fiber.

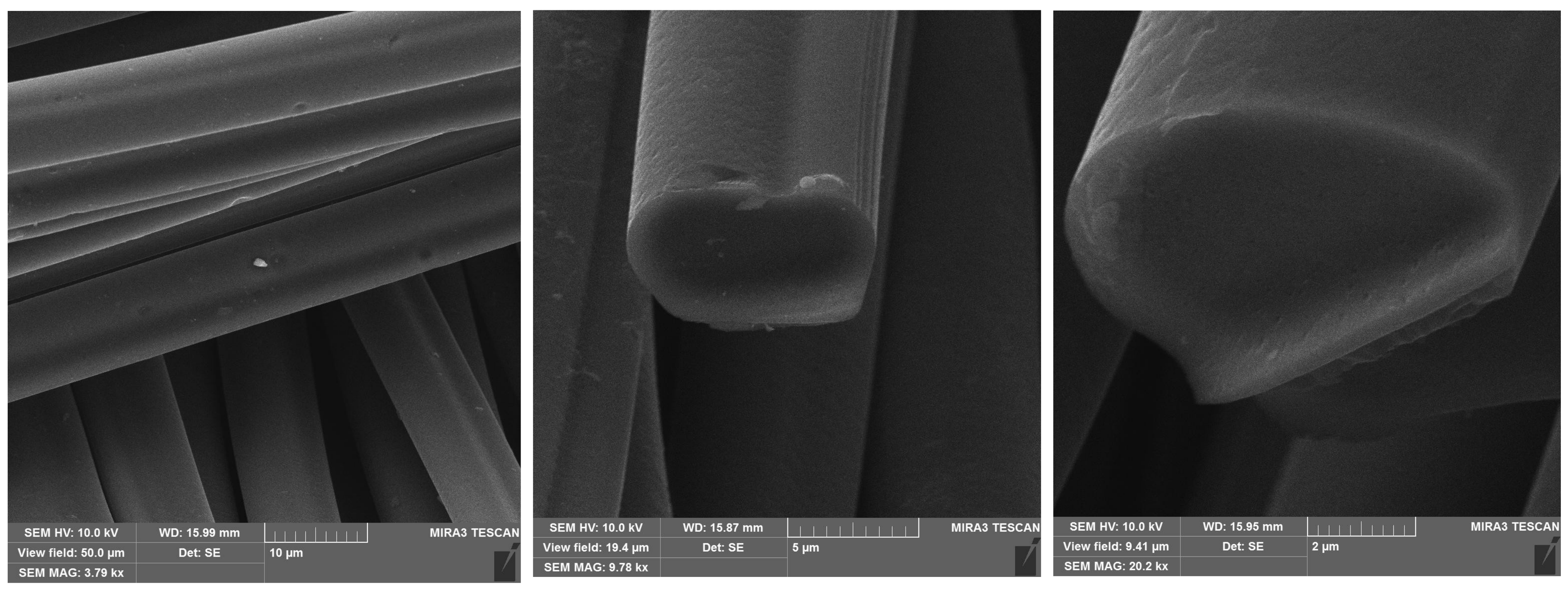

FIGURE 2. SEM microphotographs of chlorinated carbon fiber.

METHODS:

- Scanning electron microscopy (SEM)
- Chemical Analysis (C.A.)
- Thermogravimetric analysis (TGA)
- Thermoprogrammed desorption with IR registration of products (TPD IR)
- Thermoprogrammed desorption mass-spectrometry (TPD MS)
- Vector network analysis method (VNA)

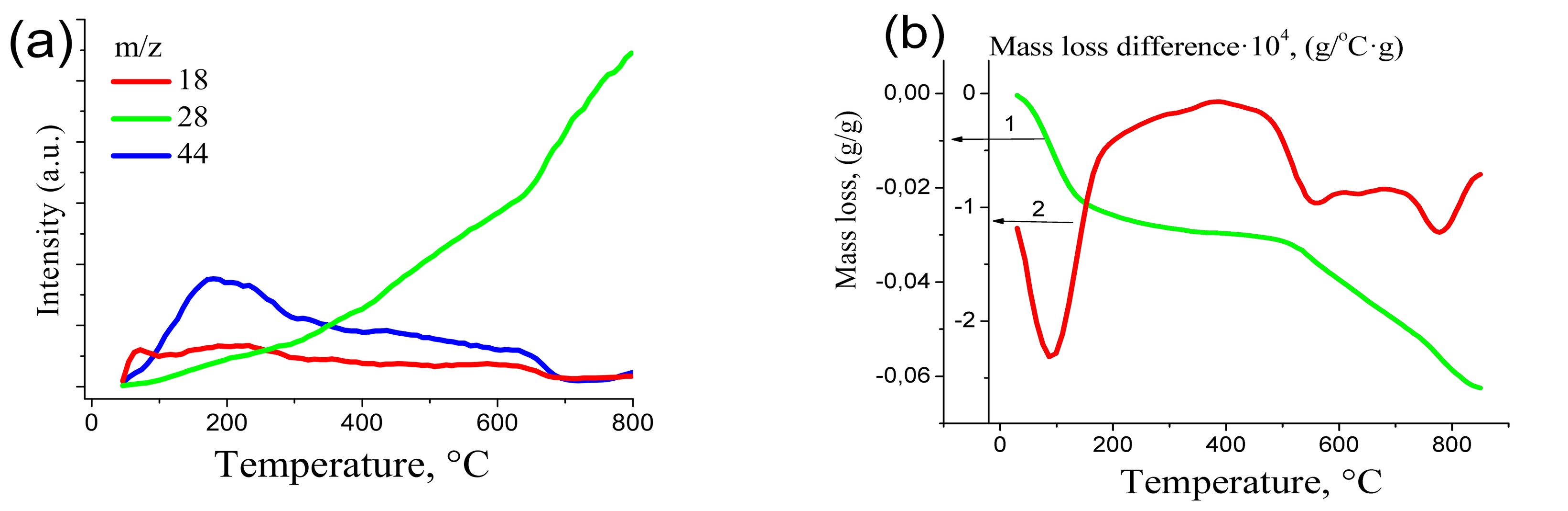

FIGURE 3. TPD MS (a) and TGA (b) profiles of initial carbon fiber.

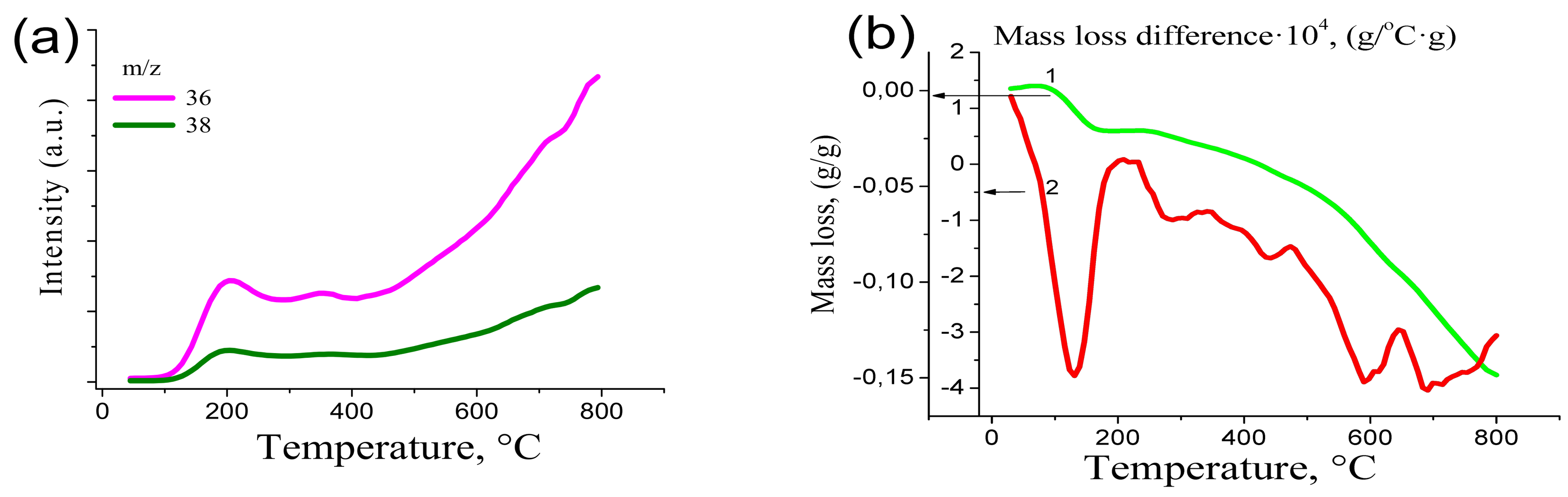

FIGURE 4. TPD MS (a) and TGA (b) profiles of chlorinated carbon fiber.

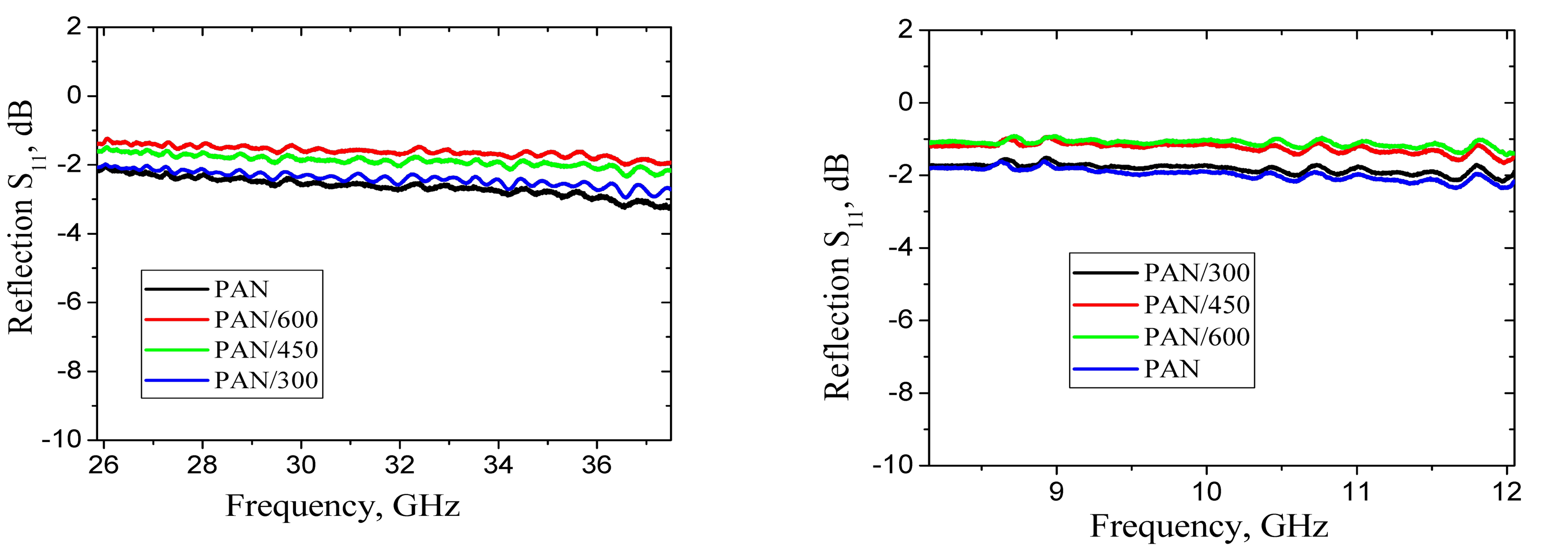

FIGURE 5. Microwave reflection S_{11} of initial and chlorinated carbon fiber.

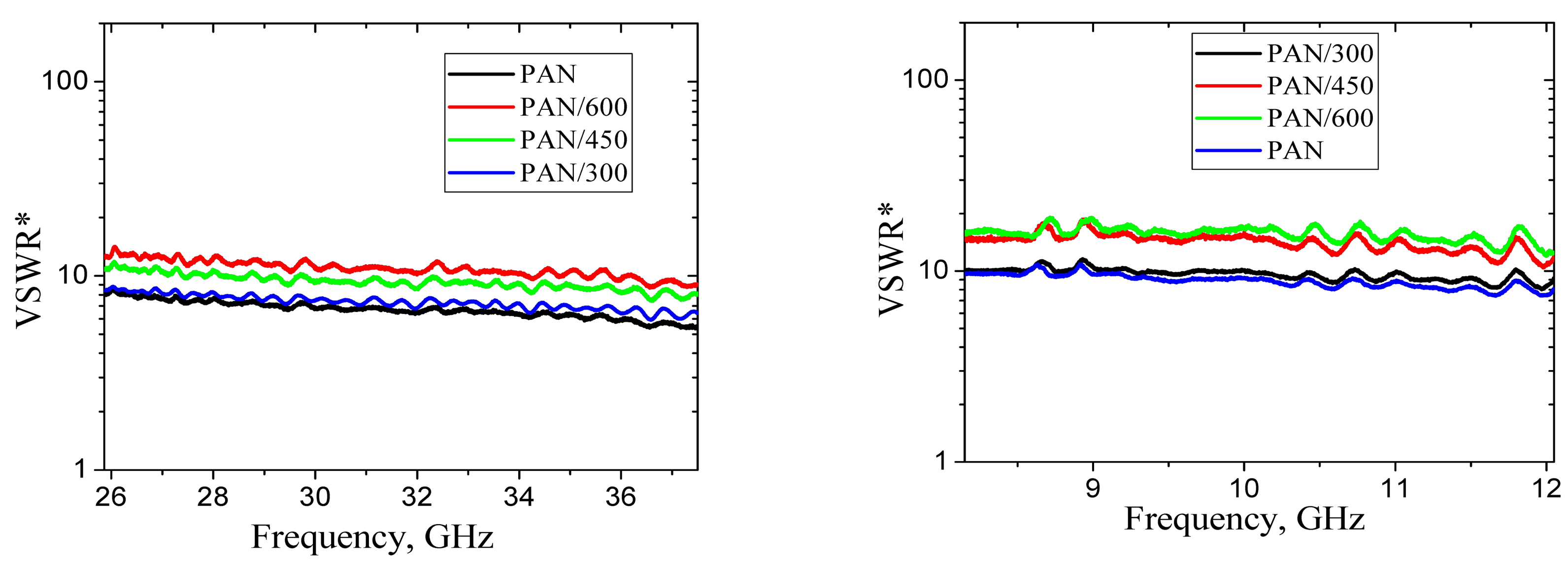

FIGURE 6. VSWR of initial and chlorinated carbon fiber.

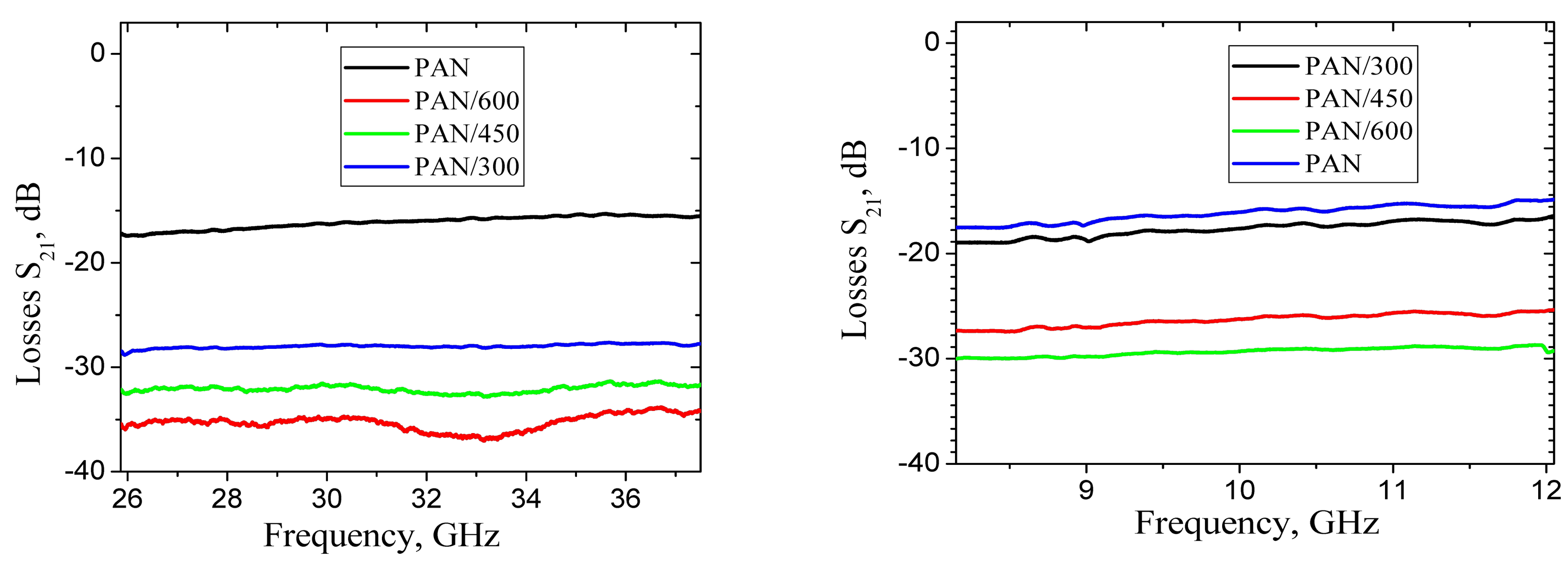

FIGURE 7. Microwave losses S_{21} of initial and chlorinated carbon fiber.

Conclusions

1. Chlorination of carbon fiber at different temperatures was performed and chlorine-containing samples were obtained with a chlorine concentration of 0.2-1.7 mmol/g.
2. The thermal stability of modified samples was investigated. It is shown that the obtained samples have a fairly high thermal stability, the decomposition of chlorine-containing groups occurs in the temperature range up to 800°C.
3. We found that added chlorine has a crucial impact on the attenuation of the power of electromagnetic radiation S_{21} and the reflection coefficient of electromagnetic radiation S_{11} in a wide frequency range for a single layer of the chlorinated PAN CFs.
4. It was shown that the attenuation magnitude and the reflection coefficient are increased with the chlorine concentration, besides their values are constants in a wide range of frequencies that can be used for the construction of the latest generation of microwave attenuators and their attenuation can be programmed once by the injected chlorine concentration in the PAN CFs.

References

1. X. Zhao at al. J. *Mater. Chem. C.,* 2019, **7** (30), 12270 - 12277.
2. L. M. Degenstein at al. *Micromachines,* 2021, **12** (7: 773).

Acknowledgements

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