Effect of the bromination method of PAN carbon fibers on their interaction with ultrahigh-frequency electromagnetic radiation

Dovgan O.M.[1], Moiseienko V.A.[1], Trachevskyi V.V.[2], Mischanchuk O.V.[3], Diyuk V.E.[1], Lisnyak V.V.[1], Grishchenko L.M.[1]

[1]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine;
[2]Institute of Macromolecular Chemistry of NAS of Ukraine, Kyiv, Ukraine;
[3]Chuiko Institute of Surface Chemistry, the National Adademy of Science of Ukraine, Kyiv, Ukraine.
CONTACT: Dr. Liudmyla M. Grishchenko ✉ liudmyla.grishchenko@gmail.com at Faculty of Radiophysics, Electronics and Computer Systems, Taras Shevchenko National University of Kyiv, 64/13, Volodymyrska Str., Kyiv 01601, Ukraine

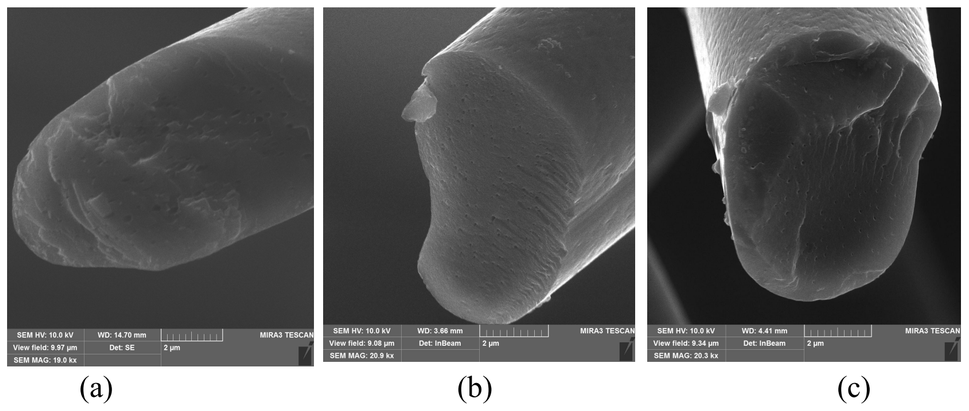
In recent years, carbon materials (CMs) with different microstructures have been reported for which outstanding EMR shielding characteristics have been achieved. Such materials include hollow carbon nanospheres, reduced graphene oxide, and carbon aerogels. Also, CMs have great potential as protective materials due to numerous features including low density, natural origin, low cost, excellent conductivity, and excellent mechanical properties [1]. Despite the widespread use of CMs and their composites as shielding and protective materials in the literature, there are virtually no studies aimed at elucidating the effect of chemical surface modification on their shielding properties [2].

This work aimed to study the effect of chemical surface modification, namely bromination of PAN carbon fibers (CFs) in a low-temperature gas discharge and liquid-phase method.

Table. Bromine concentration (c(Br)), total weight loss (Δm_{tot}) temperature range (Δ_t), and temperature at the peak of desorption of HBr (t_{m1}, t_{m2}) found by TPD MS and TGA.

Sample	*c*(Br), mmol g^{-1}	TPD MS		TGA		
		Δt, °C	*Tm₁, Tm₂, °C*	*Δm_tot, g/g*	*[a]Δt, °C*	*[a]Tm₁, Tm₂, °C*
PAN CFs/Br_2/5	0.11	155–720	325, 540	0.19	190-330	260, 58
PAN CFs/Br_2/10	0.58	155–750	325, 560	0.22	230-370	290, 620
PAN CFs/Br_2/15	0.90	210–725	370,530	0.26	220-390	285, 660
PAN Cfs/Br_2/0,30	0,30	70-650	165, 340	0,20	190-350	220, 530
PAN Cfs/Br_2/1,37	1,37	80-600	160, 330	0,24	170-340	215, 520

[a]*Temperature range for low-temperature HBr desorption*



(a) (b) (c)

FIGURE 1. SEM microphotographs of the initial carbon fiber (a), brominated in a low-temperature gas discharge (b) and brominated in brominated in the liquid phase (c).

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)

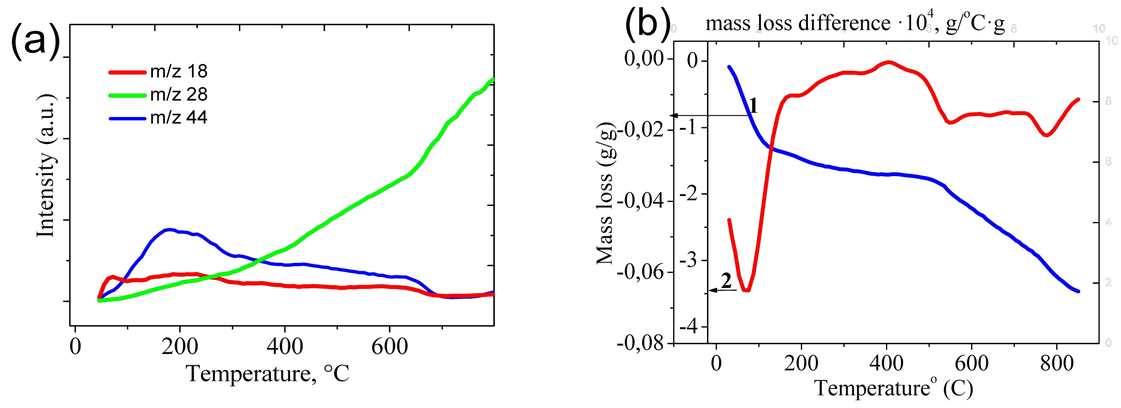


FIGURE 2. TPD MS (a) and TGA (b) profiles of initial carbon fiber.

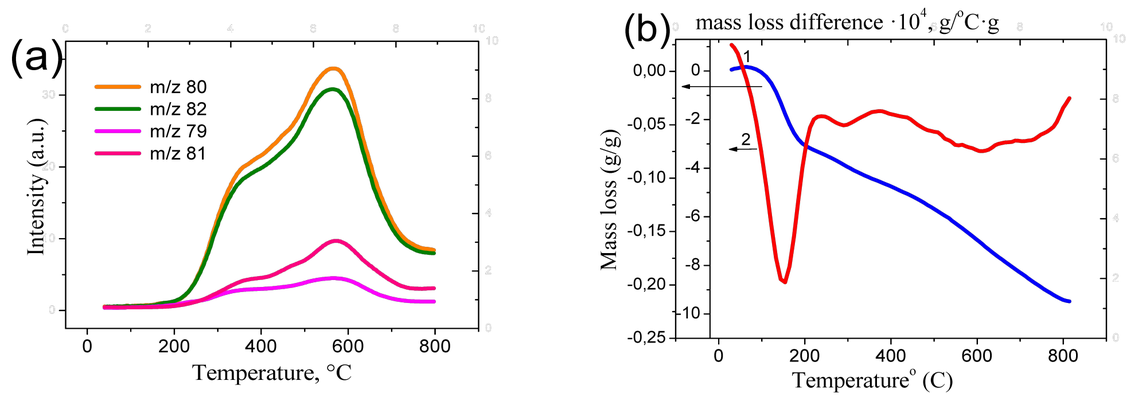


FIGURE 3. TPD MS (a) and TGA (b) profiles of carbon fiber, brominated in a low-temperature gas discharge.

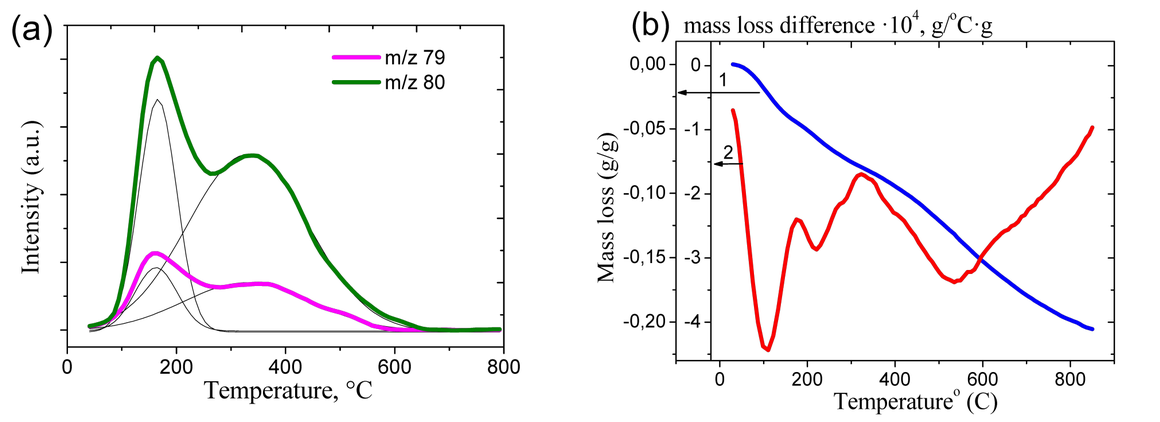


FIGURE 4. TPD MS (a) and TGA (b) profiles of carbon fiber, brominated in the liquid phase.

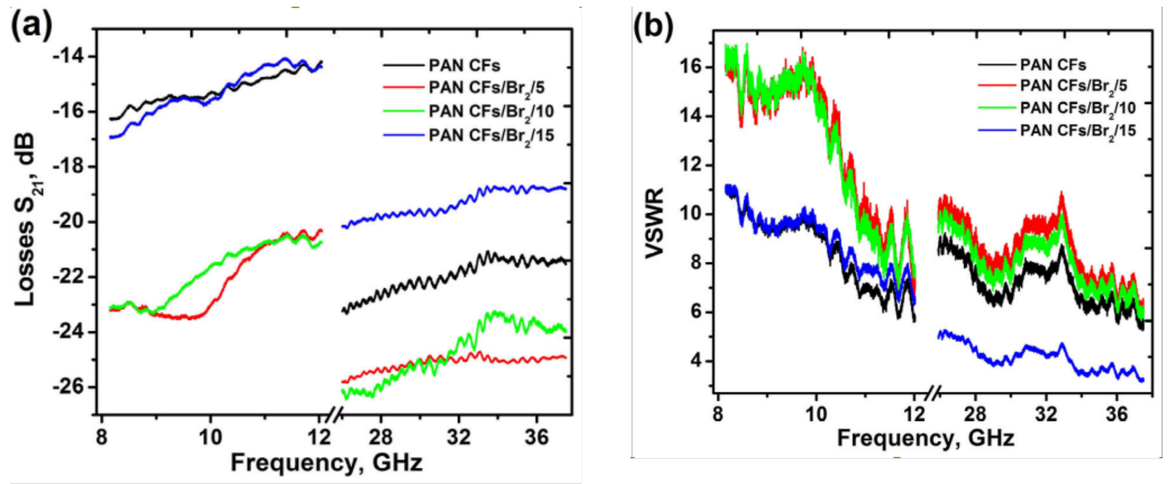


FIGURE 5. (a) S_{21} and (b) VSWR for the brominated and pristine PAN CFs.

Conclusions

1. Carbon fiber samples were brominated in gas and liquid phases and samples with a bromine concentration of 0.11-1.37 mmol/g were obtained.

2. The thermal stability of modified samples was investigated. It is shown that the desorption of bromine-containing groups from the surface of the samples occurs in the temperature range of 80-800°C.

3. Typically, the magnitude of losses for the samples of PAN CFs treated with bromine in a low-temperature gas discharge at a duration of 5 and 10 minutes increased 3 to 6 times (in different bands) relative to the amount of loss for the pristine PAN CFs.

4. The S_{21} losses for the sample with 0.31 mmol g^{-1} of Br increased 2.5 times in the X-range and decreased by 10% in the Ka-band relative to the reference PAN CFs. For the bromine amount of 1.37 mmol g^{-1}, the shielding studies were registered the opposite effect. The VSWR analysis showed a positive effect of added bromine at a concentration greater than 1.37 mmol of bromine per g of PAN CFs. This positive effect is observed in a wide range of frequencies of EMR.

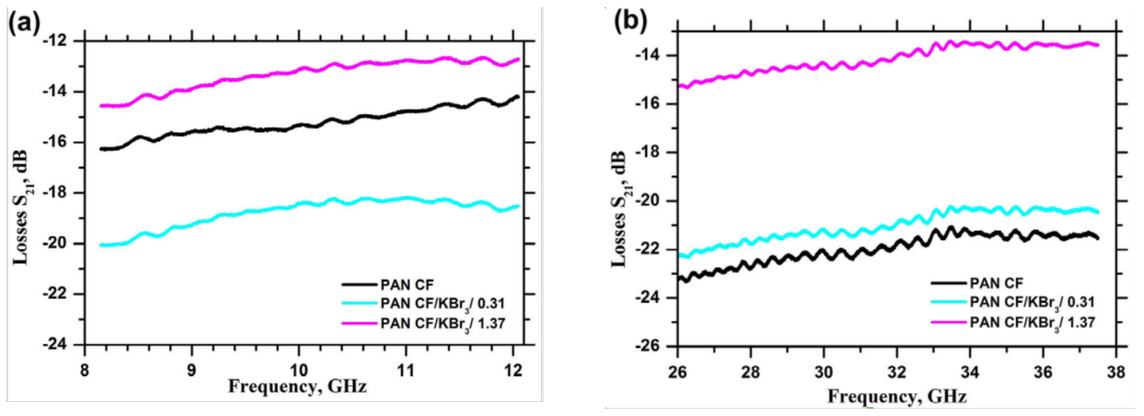


FIGURE 6. Losses S_{21} against frequency.

References

1. P. Yang et al., *ES Mater. Manuf.,* 2020, 7, 34-39.
2. Z.-H. Zhou et al., *ACS Appl. Mater. Interfaces*, 2020, 12 (16), 18840-18849.