MXene composite with gold nanoparticles on microfiber for enhanced sensitivity

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Abstract

Optical microfibers are finding new applications in various industries requiring high sensitivity and selectivity. However, in some cases microfibers are not sensitive enough and physical and chemical modifications of microfibers need to be utilized for increasing the sensitivity. Here we report surface modification of SMF-28 single-mode optical fiber with a composite of gold nanoparticles and MXene.

Methods

Our methodology is based on transmission measurements at the distal end of the microfibers. For this, first, single-mode silica fibers were tapered.

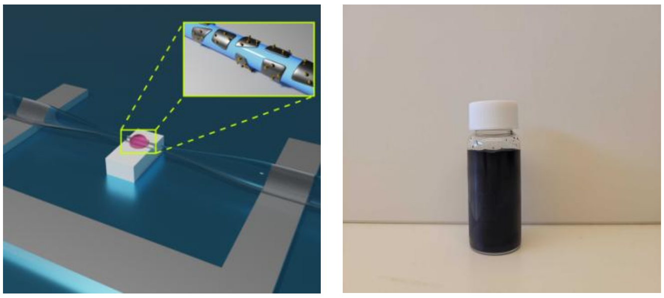

Figure 1. (left) Illustration of the MXene on the surface of an optical fiber. (right) Titanium carbide MXene in solution.

The surface, homogeneity, presence of inclusions and elemental composition of MXene samples were studied. MXene samples were examined using a transmission electron microscope (TEM). We observed films with large areas but of minor oxidation.

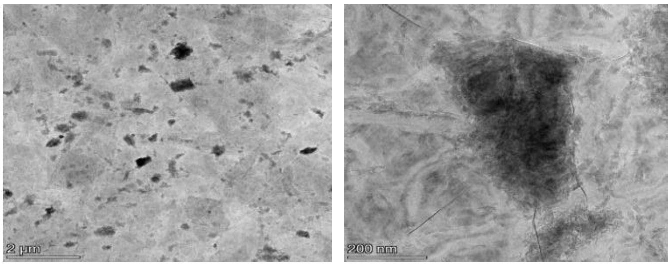

Figure 2. TEM image of MXene samples at magnification (left) x3400 and (right) x73000.

Next, we studied the samples of MXene via X-Ray photoelectron spectrometry for determining composition of the samples and characterized the percentage. The data is presented in Table 1.

Table 1. Elements composition and quantitative evaluation of MXene.

Name	Peak BE	FWHM eV	Area (P) CPS.eV	Atomic %
C S1	282.59	0.72	8235.44	45.07
O1S	530.69	2.04	18787.90	36.14
Ti 2P3	456.11	1.93	3098.99	18.79

We note a presence of large percentage of oxygen, which is a signature of oxidation process. This observation is confirmed by TEM images.

Results

To study various samples with different ratios of gold nanoparticles and MXene, an experimental setup was built. the microfiber region of a tapered fiber acts as a sensing device. A commercial single-mode fiber was tapered to a diameter of 2.5 μm with a length of 2 mm. The fiber was glued to a metal fork for robustness and stability.

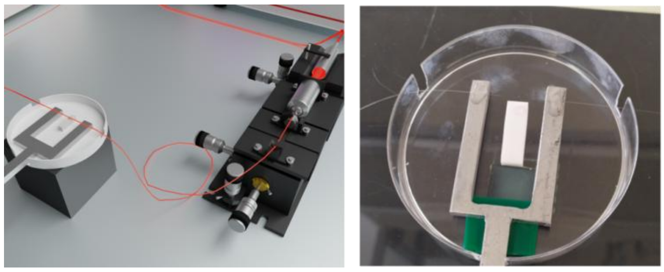

Figure 3. (left) Illustration of the experimental setup. (right) The photograph of tapered fiber on a metal fork above the Teflon spacer.

A volume of 6 μL was dripped on a Teflon spacer and the microfiber was immersed in that volume. The fiber transmission at visible and near-infrared was collected directly by spectrometer. Figure 4 shows the measured spectra.

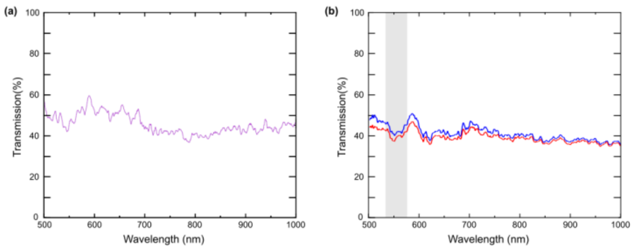

Figure 4. Measured spectra of a) reference tapered fiber and b) MXene with gold overlayers on tapered fibers.

Conclusions

1. We observed large-area MXene films but of minor oxidation.
2. We note a presence of large percentage of oxygen, which is a signature of oxidation process. This observation is confirmed by TEM images.
3. The localized surface plasmon resonance of gold nanospheres with a diameter of 30 nm, was observed at 560 nm as expected.
4. 10% improvement in microfiber transmission over reference microfiber.

Acknowledgement

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References

1. Novikova, A., Katiyi, A., Halstuch, A., & Karabchevsky, A. Green-Graphene Protective Overlayer on Optical Microfibers: Prolongs the Device Lifetime. *Nanomaterials*, 12(17), 2915 (2022).
2. Miller, S. Optical Fiber Telecommunications; Elsevier: Amsterdam, The Netherlands, 2012.