**Designing hybrid nanocomposites of molybdenum disulphide/carbon nanomaterials**

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**Highlights**

* Method of the producing MoS2 nanoparticles on carbon nanomaterials has been developed.
* Effect of carbon materials on properties of the obtained composite was investigated.

**1. Introduction**

In recent years, remarkable interest has been focused on the 2D nanomaterials and their applications, due to their unique properties. Designing and manufacturing new nanostructures with improved properties using modern techniques is a tempting prospect for nanotechnology. One of the most famous 2D nanomaterials is graphene. It is an amazing material, which has a large theoretical specific surface area (2630 m2g−1), high intrinsic mobility (200 000 cm2v−1s−1), high Young’s modulus (∼1.0 TPa) and thermal conductivity (∼5000 Wm− 1K−1). It also has very high optical transmittance (∼ 97.7%) and good electrical conductivity. Graphene and its derivatives such as graphene oxide (GO) or reduced graphene oxide (rGO) are new nanomaterials that have recently found numerous applications, such as graphene-based electronic devices, catalysts, transparent conductive electrodes and others [1]. Similarly, molybdenum disulphide (MoS2) is a widely used 2D nanomaterial. Molybdenum disulphide has a crystal structure consisting of layers of S–Mo–S where a layer of molybdenum atom is sandwiched by two layers of sulphur atoms. Individual layers of
S–Mo–S are coupled together by weak van der Waals forces, which could move relatively easily against each other. Furthermore, MoS2 is a widely studied semiconductor, with a large band gap of around 1.8 eV. Thanks to the above-mentioned properties MoS2 found numerous applications such as a dry lubricant, in hydrogen evolution reaction catalysis, hydrogen storage and others [2]. In addition, MoS2 can be an excellent candidate for being combined with carbon nanomaterials to obtain new hybrid nanocomposites with outstanding properties including higher photocatalytic activity, increase of the adsorption of pollutants, and improved rheological properties [3].

**2. Methods**

The aim of the conducted research was the preparation of hybrid nanocomposites formed from molybdenum disulphide and carbon nanomaterials such as graphene oxide (GO), reduced graphene oxide (rGO), graphene oxide modified with ammonia (GO-NH3), and reduced graphene oxide modified with ammonia (rGO-NH3). Graphene oxide was synthesized from graphite powder, following modified Hummer’s method [4]. Reduced graphene oxide was prepared by the chemical reduction method using a 50% hydrazine solution. Furthermore, GO and rGO materials were modified with ammonia solution, which led to the addition of nitrogen-containing groups in the structure. Molybdenum disulphide nanoparticles were synthesized in the turbulent micromixer with coaxial geometry, using ammonium molybdate tetrahydrate, citric acid and ammonium sulfide as the substrates for the reaction. Physicochemical analysis of obtained carbon nanomaterials and molybdenum disulphide was carried out, using various analytical techniques: Fourier-transform infrared spectroscopy, thermogravimetric analysis, X-ray Diffraction, elemental analysis, particle sizing analysis, and electron microscopy. Molybdenum disulphide/carbon materials hybrid nanocomposites were obtained by: a) mixing both materials in an ultrasonic bath, followed by
an ultrasonic homogenizer, b) a precipitation process in the turbulent micromixer. The full analysis of the samples was carried out. In addition, the optical properties of the obtained nanocomposites were evaluated by UV-vis spectroscopy, following the degradation of methylene blue (MB) under solar-like irradiation and under UV irradiation.

**3. Results and discussion**

Reduction of GO leads to partial removal of oxygen groups from GO (the content of oxygen in GO was 43.71 wt.%, and in rGO was 17.51 wt.%). Modification of GO with ammonia resulted in
an enrichment of the GO structure with nitrogen (from 0.58 wt.% to 3.67 wt.%). Modification of rGO with ammonia solution resulted in an enrichment of the rGO structure with nitrogen (from 0.00 wt.% to 0.53 wt.%). The dispersion using an ultrasonic bath, followed by an ultrasonic homogenizer is a good method to obtain hybrid MoS2/carbon nanomaterials, which was confirmed by XRF and TGA method. The precipitation method that allows controlled heterogeneous nucleation of primary nanoparticles of MoS2 on graphene particles still needs improvement, due to the excess of sulphur present in the final product. The conducted research has shown the hybrid nanocomposites have better photocatalytic activity toward the photodegradation of methylene blue compared to pure MoS2.

**4. Conclusions**

The aim of the presented research was the preparation process of hybrid MoS2/carbon nanomaterials. Carbon nanomaterials including graphene oxide, reduced graphene oxide, graphene oxide modified with ammonia, and reduced graphene oxide modified with ammonia have been tested for this purpose. The obtained hybrid nanomaterials possess both favorable features and disadvantages and still needs further research. Although, the degradation of MB tests allowed to state that the presence of the carbon nanomaterials in the hybrid materials improve photocatalytic activity.

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