Static Tensile Test of rGO-PDMS Composite

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Abstract

Presented paper shows results of the tensile strength of the rGO-PDMS composite (pure PDMS doped with reduced graphene oxide (rGO). As a result, the relative elongation of the rGO-PDMS was obtained reaching 600% as compared to control samples before breaking of the composite.
Microfractographic measurements of fracture in static tensile test showed delamination in places where rGO flakes were present, what favored the initiation of breaking process.
The decrease of the Young module was observed by 8% when PDMS was doped with reduced graphene oxide.

KEY WORDS: *silocone, rGO-PDMS composite, PDMS, graphene oxide, RGO, tensile strength*

1. Introduction

Polydimethylsiloxane (C2H6OSi)n (Fig. 1) belongs to a group of polymeric organosilicon compounds. PDMS was developed in the middle of twentieth century as a replacement for natural rubber and is the most common elastomer in use today [1]. PDMS is different from other elastomers, it consists of silicon and oxygen in the form of siloxane [2, 3]. PDMS characterize with relatively low prices, softness, transparency, outstanding physical properties, chemical stability, and high gas permeability [4-7].

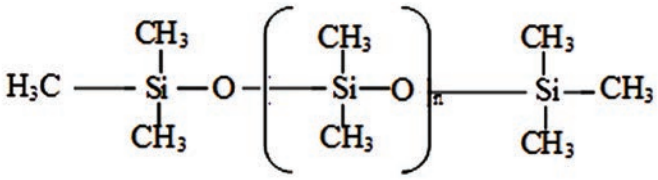

Fig. 1. Chemical structure of polydimethylsiloxane

In paper presented by S. Tazawa, el.al [8] from the results of the tensile testing, it can be found that the stress at break of the PDMS with l-phenylalanine nearly became seven times higher than that of the PDMS without l-phenylalanine. The DMA results revealed that the PDMS could maintain its storage modulus for three heating cycles, while the melting temperature was also kept at □120 °C. Moreover, the mechanical property was analyzed through two remolding cycles, and it was found that the PDMS could almost maintain its mechanical property after the heat remolding. PDMS also possessed some self-healing property, where the Young's modulus of the cut PDMS could maintain at least 70% of its original Young's modulus after contact and self-healing.

Advantageous mechanical and structural properties resulted in PDMS wide range of application in food industry [9], automobile industry [10,11] and medicine as (urology, ohtalmology, dermatology, immunology) [12].

Tino Töpper et. al.[13] showed that implementation of the soft sub-micrometer-thin elastomer membranes will become an essential component of dielectric elastomer transducers with strains comparable to human muscles, operated at the conventional battery voltages for future artificial muscles or skin implants.

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Wei Qian et.al [7] presented application of rGO-PDMS membrane for medical purposes. They showed that the rGO-PDMS composite membrane exhibited bionic performance (ordered pore structure and suitable WVTR), improved mechanical properties, good compatibility and effective antibacterial activity. In vivo experiment indicated that the rGO-PDMS composite membrane could accelerate wound healing via enhancement of the re-epithelialization and granulation tissue formation. These findings suggest that rGO doping PDMS uniquely resulted in a multifunctional material for potential use in wound dressing [7].

The goal of the conducted research in presenter paper was to determine the influence of the content of reduced graphene oxide (rGO) flakes on the structure and static tensile strength.

2. Method of Investigation

The research on functional properties was subjected to rGO-PDMS composite developed in cooperation with the Biomedical Engineering Center, Institute of Optoelectronics, Military University of Technology and Topsil Global company. Structural investigations were performed using the Quanta 3D FEG scanning electron microscope (FEI company). The experiment to determine the chemical composition was made by laser emission induction spectroscopy (LIBS) method. The laser beam was focused on the material samples causing its ablation, followed by heating and ionization of the occurring vapors and plasma generation. Created plasma was a source of strong continuous and discrete radiation, characteristic of atoms occurring in a given sample.

Tensile strength tests were carried out on the Zwick Roell Kappa 500 pulsator (Fig. 2). The maximum of the tensile strength of the vises was ±50 kN and the maximum distance of the relocation of the sample was 1500 mm. The dimensions of the rGO-PDMS samples are presented in Fig. 3.

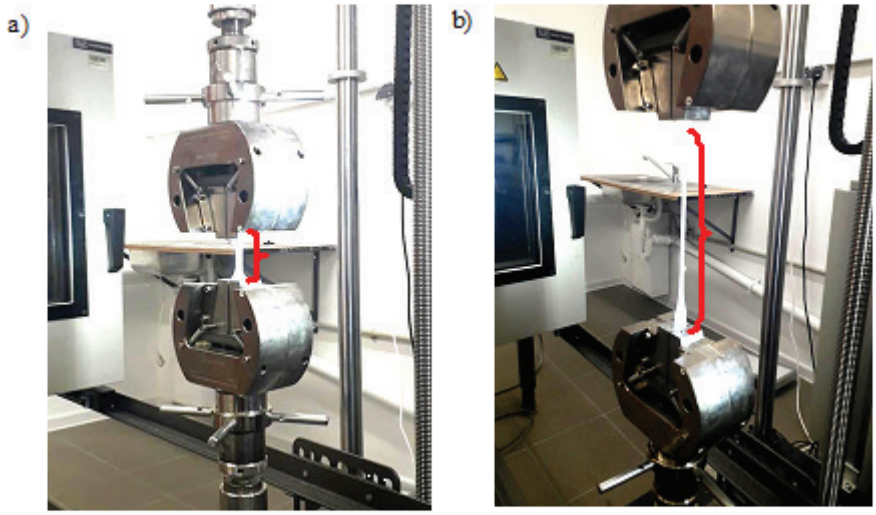

Fig. 2. Zwick Roell testing system with integrated videoextensometer, before (a) and after tests (b)

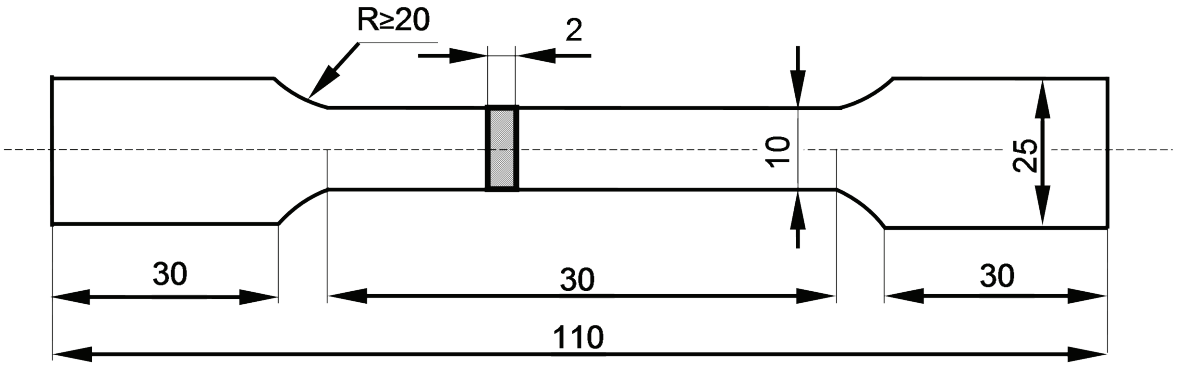

Fig. 3. Dimensions of the rGO-PDMS composite for mechanical tests

In presented experiments the electromechanical navigation of the displacement speed was implemented and was set to 100 mm/min. The test were started form preliminary loads set to 0,5 N with speed of 5 mm/min.

Spectral analysis of Raman spectra was performed on a Nicolet iS50 spectrometer from Thermo Fisher Scientific company. This device is used to measure scattering spectra in the mid-infrared range and qualitative and quantitative analysis (resolution 4cm^{-1}, the range of measurements 4000-400 cm^{-1}).

3. Structural Research

The work presents structural, spectroscopic and strength tests as well as LIBS chemical composition analysis of a rGO-PDMS composite. In the visual assessment, rGO-PDMS composite was characterized by homogeneity, however, microscopic analysis performed using optical and scanning microscope showed numerous flakes of reduced graphene oxide (rGO) (Fig. 4 a, b), also located on its surface (Fig. 4 c, d).

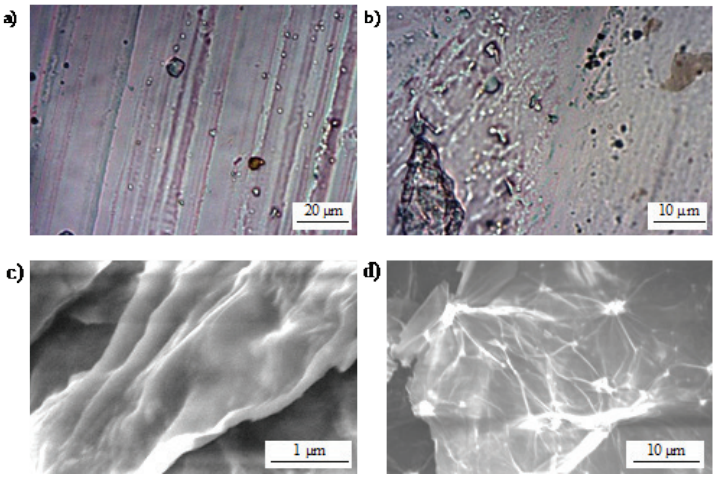

Fig. 4. Morphology of the rGO-PDMS composite surface

All analyzed by Raman spectroscopy samples were characterized by typical spectral bands in the 2900-2970 cm-1 range, derived from the C-H cyclic alkanes stretching vibrations, which are part of the siloxane structure. In the 1590, 1350 cm-1 area, rGO bands were observed what is an conformation of their presence in the polydimethylsiloxane structure (Fig. 5).

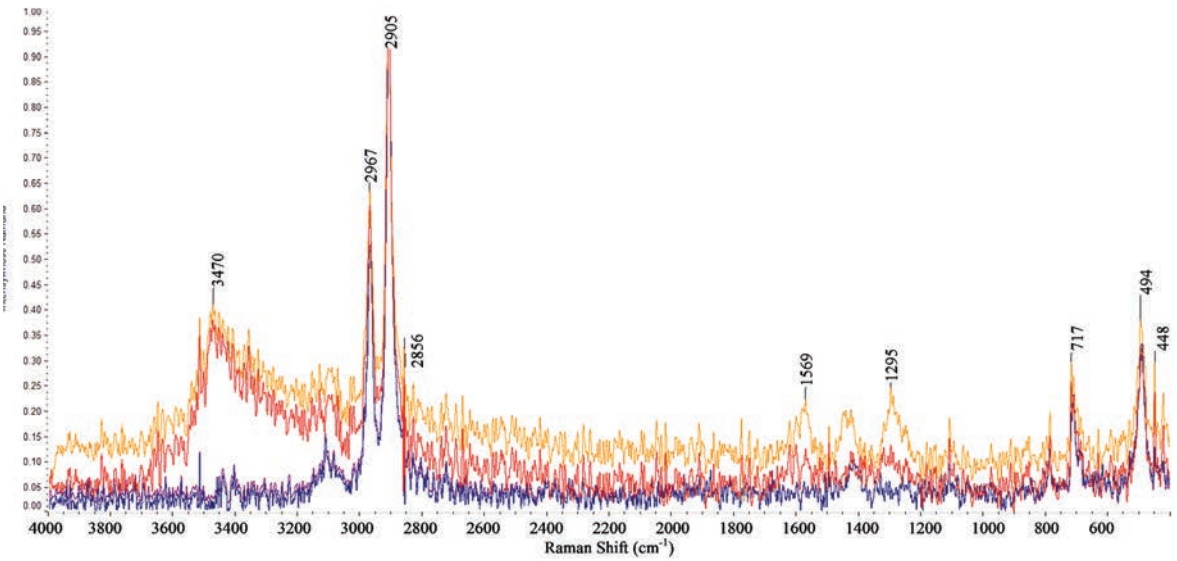

Fig. 5. Raman spectra of the rGO-PDMS composite and PDMS

LIBS spectrum of the rGO-PDMS composite was registered with use of 10 laser shots. The spectrum is dominated with molecular transition of the Si element and minor qualities of Ca, C, Mg, Na, Fe and Ti resulted from the presence of the additives which enhance structural and mechanical properties of the composite and form the storage conditions (Fig.6.).

Analysis of the chemical composition made by LIBS spectroscopy also confirmed the presence trace elements of carbon from rGO bonds.

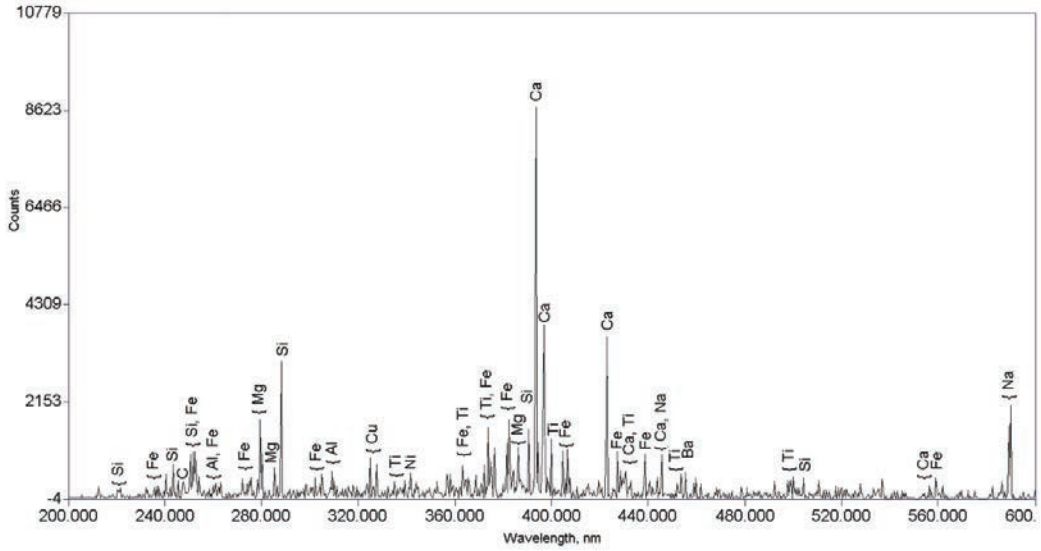

Fig. 6. LIBS spectroscopy of rGO-PDMS composite

4. Static Tensile Test

During static tensile test measurements of the axial force and displacement, which served to designate the strain-stress curve (Fig. 7). The strain was referenced to initial cross section and strain to the parallel length of the sample. The mean value of the static tensile test curve of rGO-PDMS was compared to pure PDMS. The measurements showed that doping PDMS with rGO did not influence significantly on the mechanical properties of the composite. The reduction of the Young module was observed, ranging around 8% ((EPDMS=7,19 MPa, ErGO-PDMS composite = 6,64 MPa).

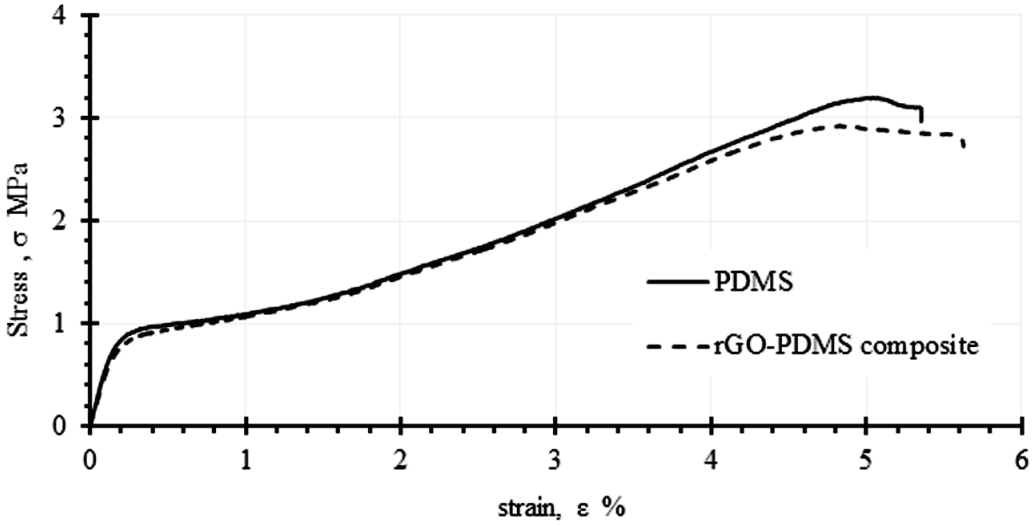

Fig. 7. Stress-strain relationship of rGO-PDMS composite and PDMS

The breaking process in both materials was observed mainly on the edge of the samples tested (Fig. 9 c, d). Topography of the fracture area was smooth in macroscopic scale (Fig. 8a). On the surface of the fracture area of the PDMS sample craters and pits were observed (Fig. 8a). The analysis of the fracture morphology of the rGO-PDMS composite revealed the presence of numerous flakes of reduced graphene oxide.

a) b)

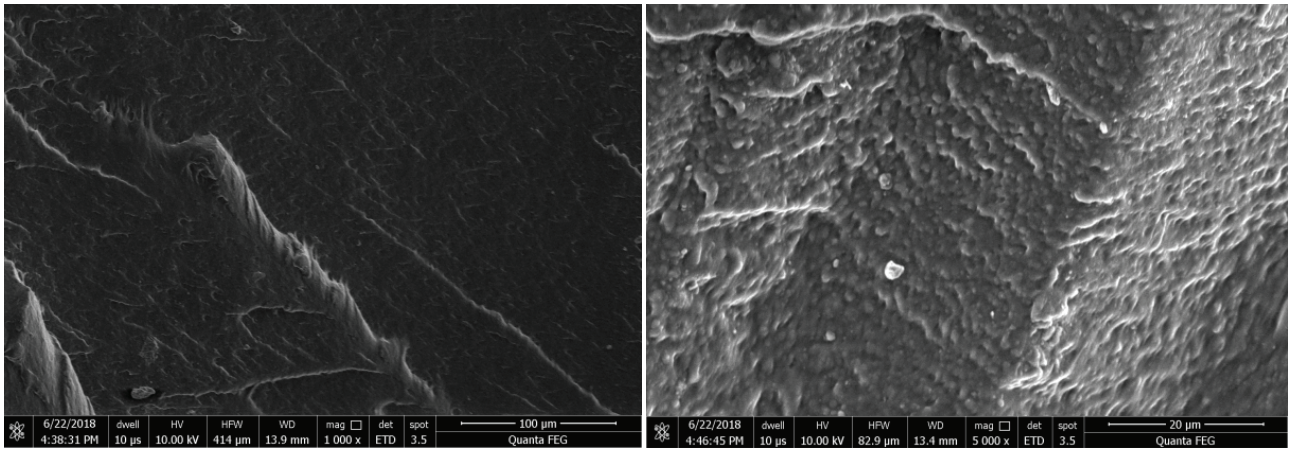

Fig. 8. Microfractography of the PDMS Surface

Despite that flakes of reduced graphene oxide were intentionally incorporated into the PDMS (Fig. 9 a-f) they didn't influence significantly the weakening of the durability of composite. On the fracture area of the composite rGO-PDMS showed week coherence with PDMS, which was shown in Fig. 9 e, f.

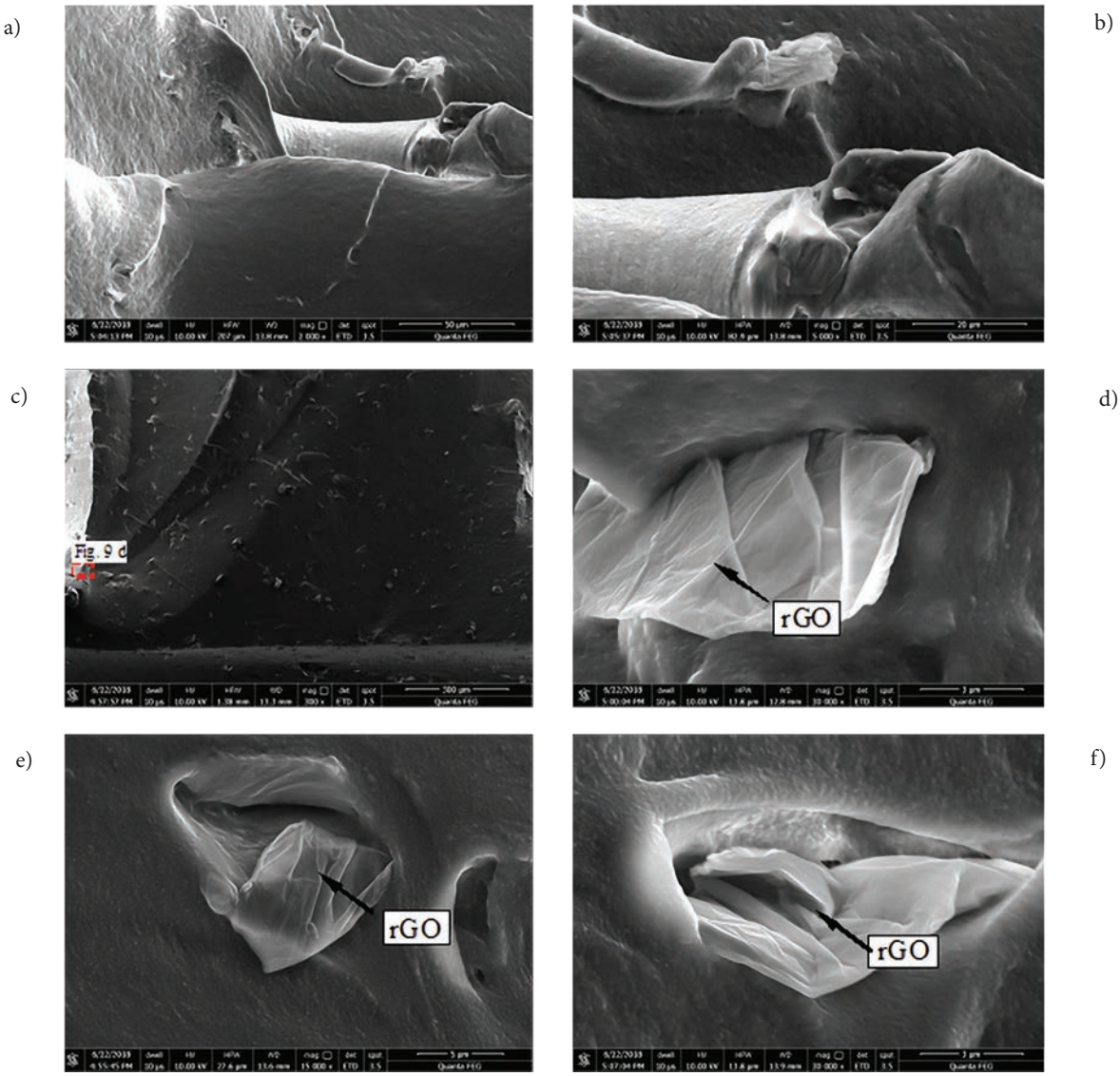

Fig. 9. Microfractography of the rGO-PDMS composite surface

Conclusions

Conducted structural and spectroscopic studies confirmed the presence of RGO in rGO-PDMS composite. The means values of the static tensile strength of PDSM as compared to rGO-PDMS composite shoved Young module decrease for about 8% (E_{PDMS} = 7,19 MPa, $E_{rGO\text{-}PDMS}$ composite = 6,64 MPa). On the fracture surface numerous flakes of reduced graphene oxide were observed. The breaking point for all examined samples was near the edge of the samples and continued the direction of the fracture towards the core of the material.

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