PIEZOELECTRIC RESPONSE IN HYBRID MICROPILLAR ARRAYS OF POLY(VINYLIDENE FLUORIDE) AND REDUCED GRAPHENE OXIDE

I.O. PARIY[1], *V.V. SHVARTSMAN*[2], *D. C. LUPASCU*[2], *G. B. SUKHORUKOV*[3], *T. LUDWIG*[4], *S. MATHUR*[4], *M.A. SURMENEVA*[1], *R.A. SURMENEV*[1,4]

[1]Physical Materials Science and Composite Materials Centre, National Research Tomsk Polytechnic University, 634050 Tomsk, Russia

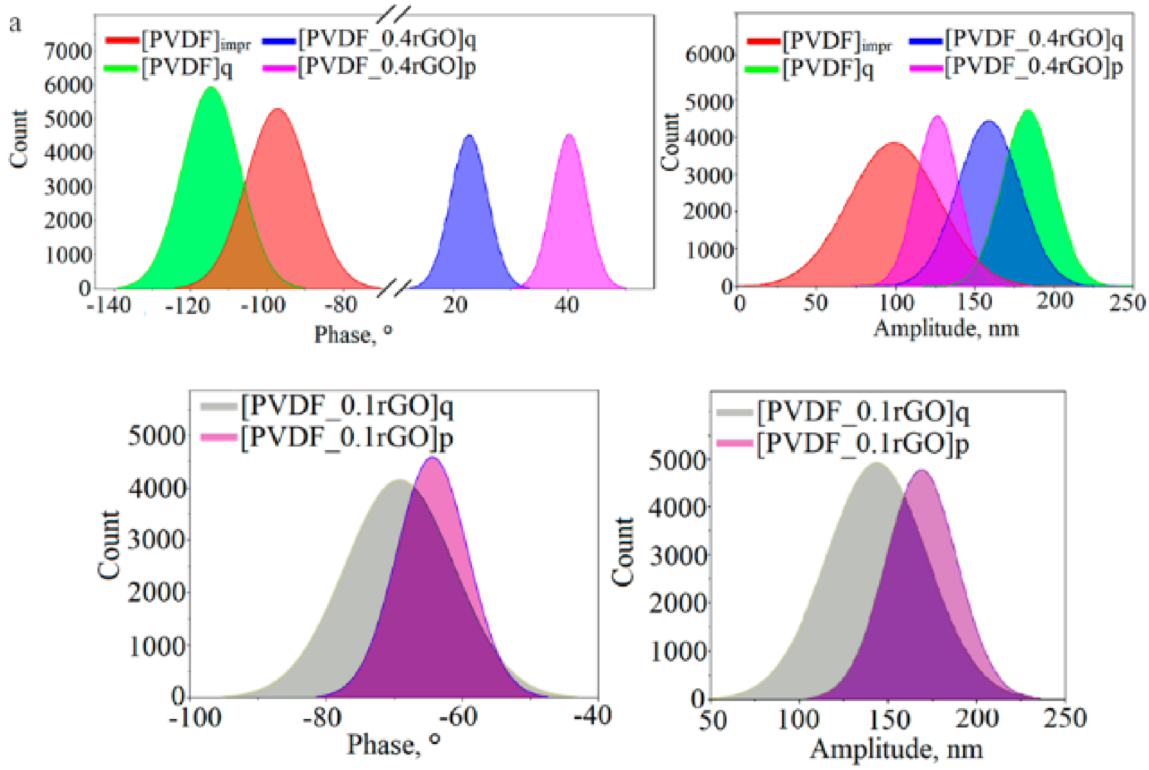
[2] Institute for Materials Science and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 45141 Essen, Germany

[3] School of Engineering and Materials Science, Queen Mary University of London, London E1 4NS, UK

[4] University of Cologne, 50923 Cologne, Germany

E-mail: rsurmenev@mail.ru

This work was dedicated to study poly(vinylidene fluoride) (PVDF) micropillar arrays obtained by soft lithographyË followed by phase inversion at a low temperature. Reduced graphene oxide (rGO) nanoflakes were incorporated into PVDF thin films as a nucleating filler. The effect of the treatment conditions on the crystallization behaviour and the piezoelectric properties of the patterned PVDF films was investigated by differential scanning calorimetry (DSC), Fourier transform infrared spectroscopy (FTIR) and piezoresponse force microscopy (PFM). Figure 1 shows the statistical distribution of the PFM phase and amplitude values for the PVDF micropillar arrays and the piezoelectric characterization of the PVDF micropillar arrays.



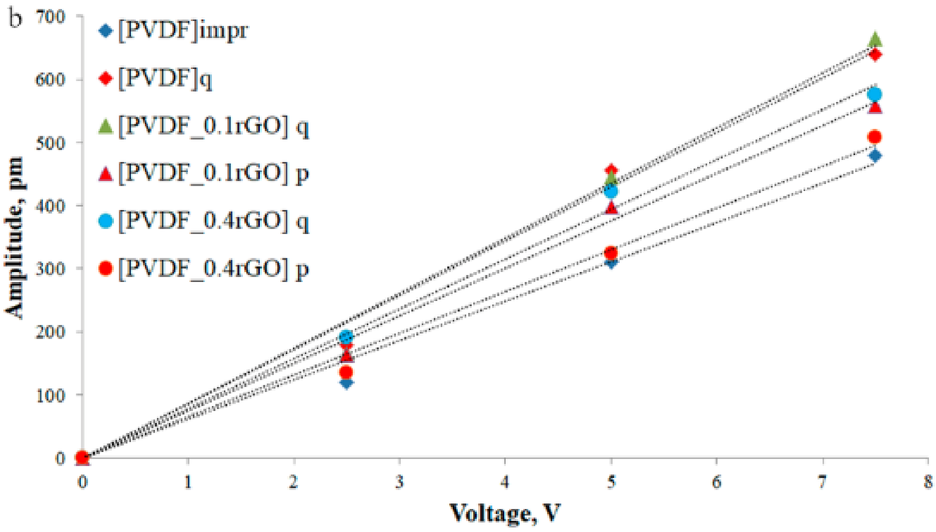


Figure 1 – The statistical distribution of the PFM phase and amplitude values of the imprinted and quenched PVDF micropillars, micropillars with 0.4 wt % rGO and micropillars with 0.1 wt % rGO (a) and the measured piezoelectric signal versus the amplitude of the applied ac voltage (b)

The results of this study provided a qualitative indication of the enhancement of the piezoelectric response of PVDF micropillar arrays loaded with rGO and quenched at −20°C. The obtained PFM data displayed that the maximum piezoelectricity of the developed PVDF-patterned films was 86 and 87 pm/V for the quenched neat PVDF sample and that loaded with 0.1 wt % of rGO respectively, which is substantially higher than a $|d_{33}^{eff}|$ of 64 pm/V for the imprinted PVDF. The presence of 0.1 wt % of rGO increased the degree of crystallinity by 15 % and decreased the α-phase content compared with neat PVDF. The addition of rGO into the PVDF matrix resulted in a change in the preferred polarization direction, and the piezo-response phase angle changed from −120° to 20°–40°. Piezoelectricity was induced by the domain orientation alignment, which was induced in the PVDF micropillars without the application of a strain or an electric field during the synthesis. The samples with 0.1 wt % of rGO has the highest degree of crystallinity, the largest amount of electroactive phase, and the highest piezoelectric coefficient $|d_{33}^{eff}|$ among all of the studied samples. The approach used in this work enables one-step printing of ferroelectric patterns without any harsh post-processing steps, which could degrade the functional properties of PVDF. Thus, the fabricated piezoelectric PVDF micropillars can be used in different applications, including tissue engineering scaffolds, vital sign transducers, biomedical energy harvesters, and dynamic sensors at the cellular and subcellular levels.

Acknowledgments. The present study was supported by Russian Science Foundation (№18-73-10050) and Tomsk Polytechnic University Competitiveness Enhancement Program grant. The support from Humboldt foundation is acknowledged.

References:

1. Song J., Lu H., Foreman K., Li S., Tan L., Adenwalla S., Gruverman A., Ducharme S. // J. Mater. Chem. – 2016. – № 4. – С. 5914-5921.
2. Yang S.M., Mazet L., Okatan M.B., Jesse S., Niu G., Schroeder T., Schamm-Chardon S., Dubourdieu C., Baddorf A.P., Kalinin S. V. // Appl. Phys. Lett. – 2016. – № 108. – С. 252902.
3. Zubko P., Catalan G., Tagantsev A.K. // Annu. Rev. Mater. Res. – 2013. – № 43. – С. 387-421.