

LOW-TEMPERATURE MICROMECHANICAL PROPERTIES OF EPOXY RESIN/GRAPHENE OXIDE NANOCOMPOSITES

H. V. Rusakova, L. S. Fomenko, S. V. Lubenets, A. V. Dolbin, N. A. Vinnikov,
R. M. Basnukaeva, S. V. Cherednichenko

B. Verkin Institute for Low Temperature Physics and Engineering of NAS of Ukraine,
47 Nauky Ave., Kharkiv, 61103, Ukraine
e-mail: rusakova@ilt.kharkov.ua

1. INTRODUCTION

The response of neat epoxy resin (ER) and ER/reduced graphene oxide (rGO) nanocomposites to the action of a localized load at temperatures $T = 77-300$ K was studied. It has been established that during indentation in the range of $77 \text{ K} < T < T_{\text{he}}$, where the threshold temperature of high-elasticity $T_{\text{he}} \approx 210-240$ K, the indenter impressions on the surface of the studied samples are completely restored when the load is removed and the samples are heated to room temperature. At the same time, at higher indentation

temperatures $T_{\text{he}} < T < 300$ K, the impressions are preserved and can be measured to determine the Vickers microhardness H_V . The phenomenon of low-temperature elasticity was previously observed by us during indentation of a number of polymers and nanocomposites; it was associated with the formation of fibrillar-porous nanostructures with reduced glass transition temperatures during low-temperature local deformation [1].

2. THE DEPENDENCE OF MICROHARDNESS OF NANOCOMPOSITES ON rGO CONTENT AT ROOM TEMPERATURE

At room temperature, the dependence of microhardness of nanocomposites on rGO content were obtained (Fig. 1). It can be seen from the figure that the introduction of graphene oxide into the epoxy matrix leads to a significant increase in microhardness. The maximum effect was observed for ER-0.83 wt% rGO nanocomposite, the microhardness of which exceeds H_V of neat ER by 40%. Reduction of microhardness for ER-2.3 wt% rGO nanocomposite is associated with the formation of rGO agglomerates.

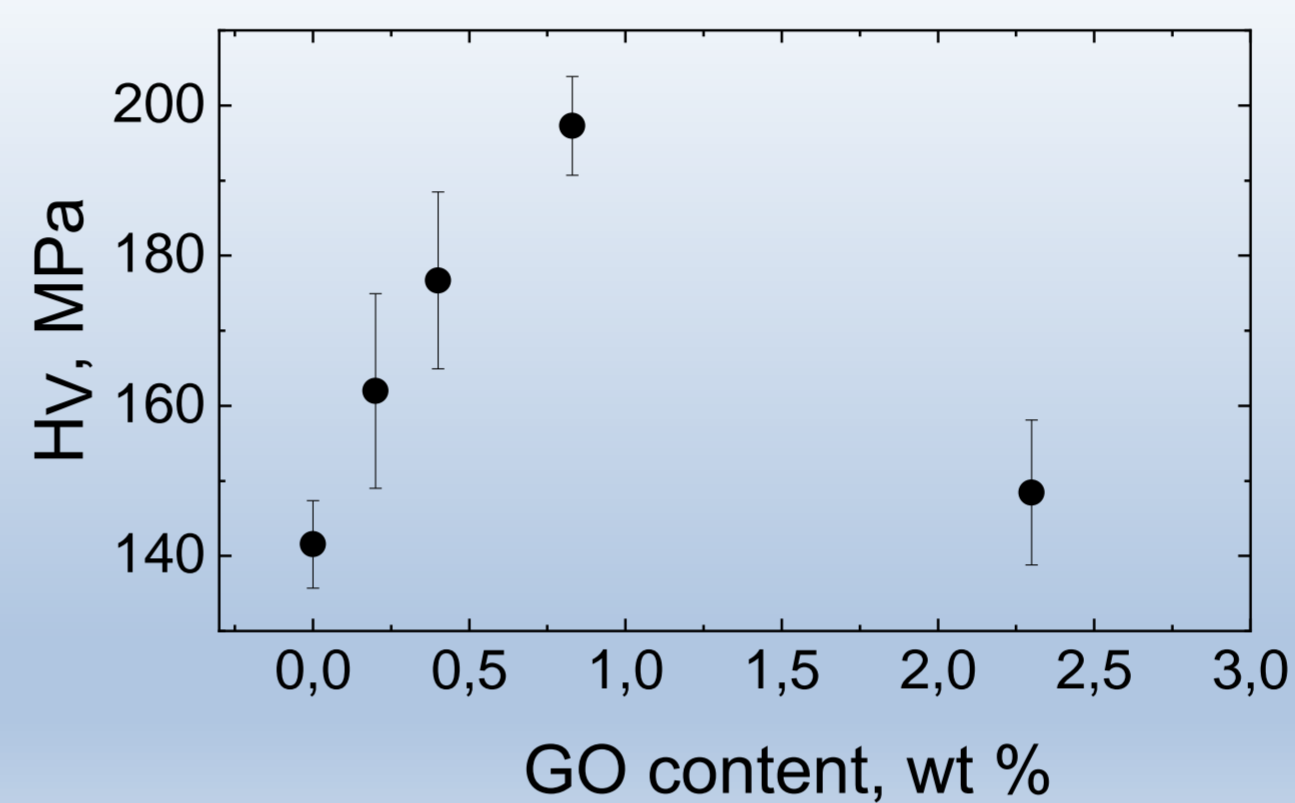


Fig. 1. The dependence of microhardness of ER/reduced graphene oxide nanocomposites on rGO content at room temperature.

3. THE INFLUENCE OF TEMPERATURE ON THE MICROHARDNESS OF NANOCOMPOSITES

The effect of temperature on the microhardness of neat ER and ER/rGO nanocomposites was studied in the temperature range from 300 K to $T_{\text{he}} \approx 210-240$ K (depending on the rGO content). The temperature dependences of microhardness for three nanocomposites ER/rGO are shown in Fig. 2. It can be seen from the figure that lowering the temperature from 300 K to $T_{\text{he}} \approx 210-240$ K is accompanied by an approximately two-fold increase in microhardness, which indicates the thermally activated nature of the deformation process in the region of the indenter impression.

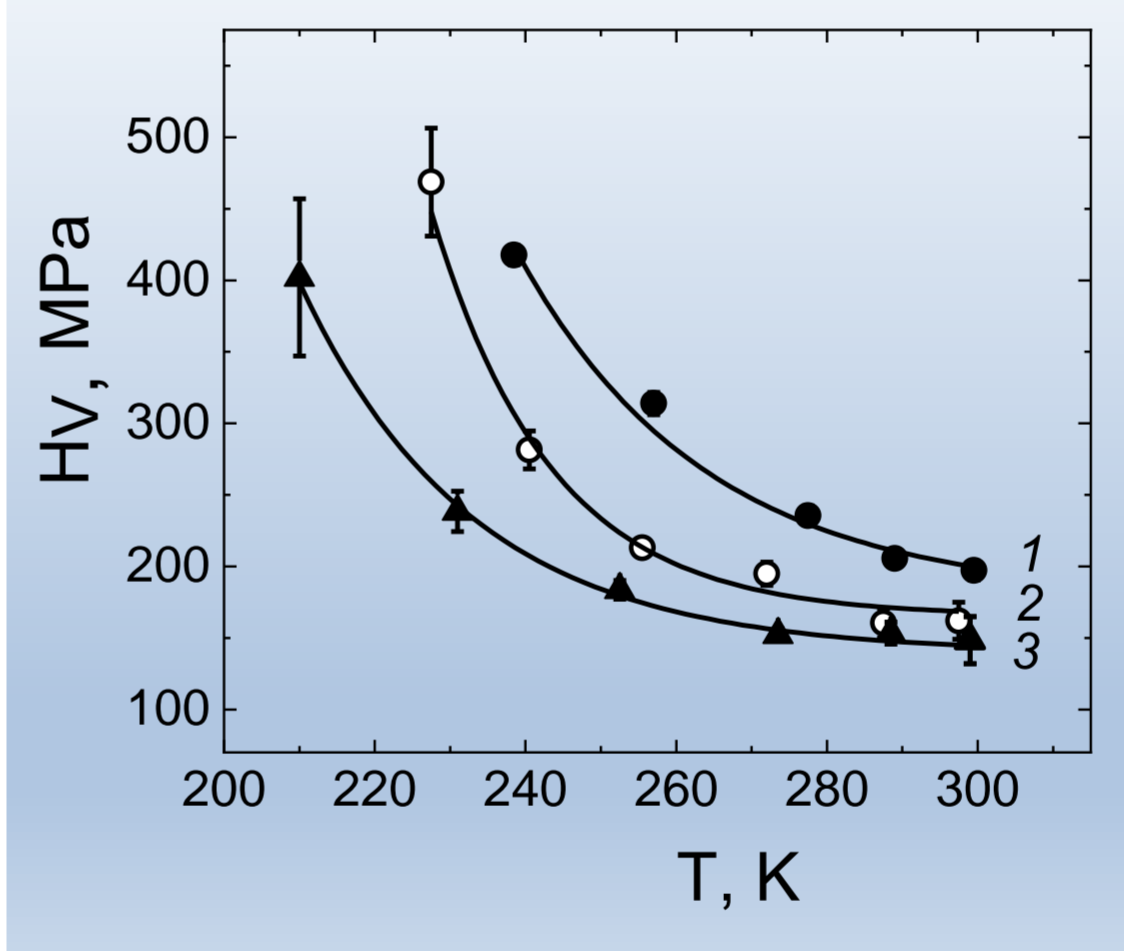


Fig. 2. The temperature dependences of microhardness for three nanocomposites:
1 – ER-0.83 wt% rGO,
2 – ER-0.2 wt% rGO,
3 – ER-2.3 wt% rGO.

4. THE NATURE OF LOW-TEMPERATURE ELASTICITY OF POLYMERS

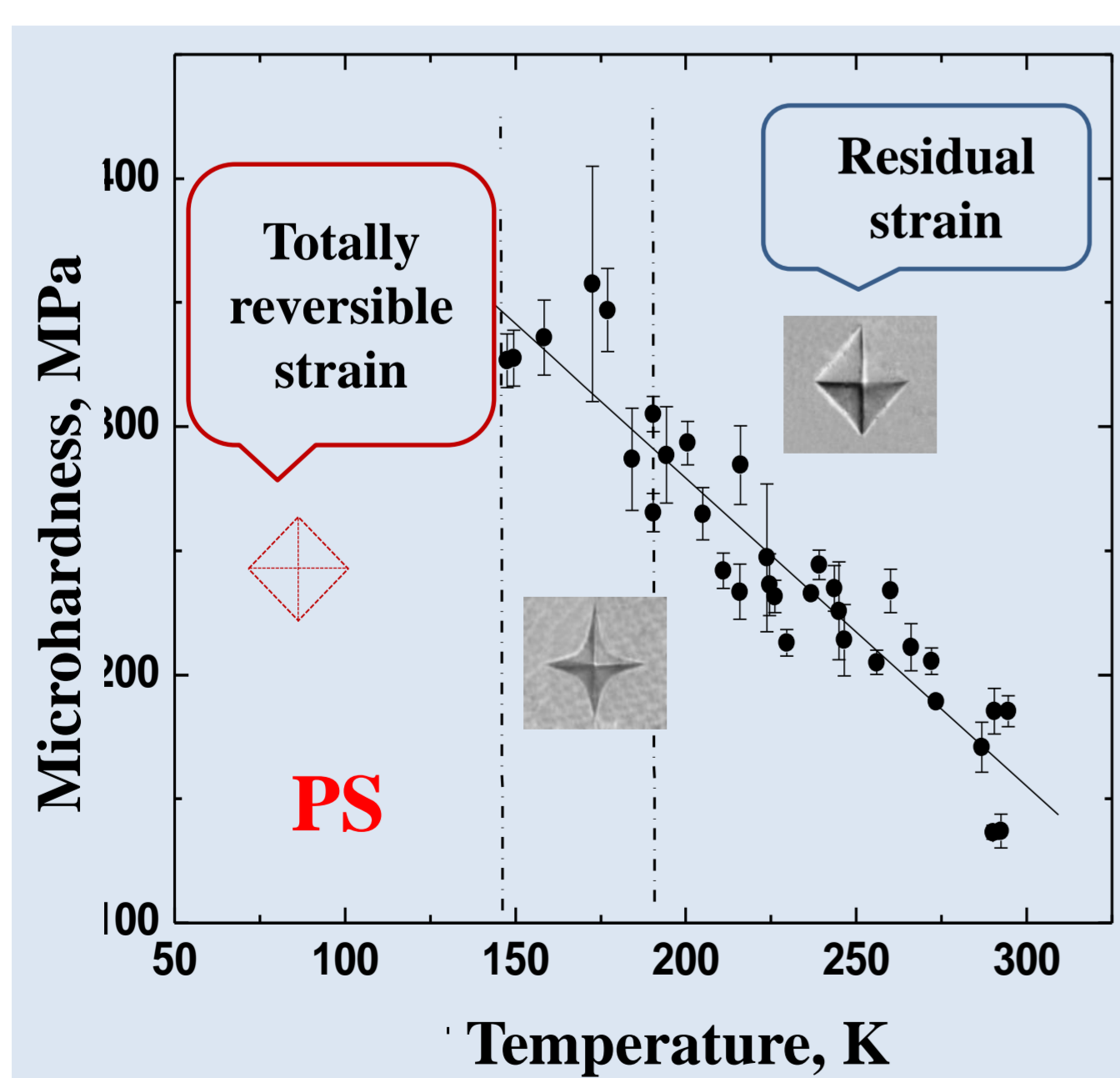


Fig. 3. The temperature dependence of microhardness of polystyrene.

For the first time, complete or partial reversibility of plastic deformation during indentation at low temperatures was observed by us on polystyrene, a thermoplastic polymer with a glass transition temperature of $T_g = 373$ K. The reversibility of the deformation in the microzone under the indenter impression was revealed, when the impressions made at low temperatures were not fixed on samples warmed to room temperature. Subsequently, we observed the effect of low-temperature high-elasticity on a number of pure polymers, as well as on nanocomposites based on graphene oxide [1]. The effect of reversibility of deformation in microindentation experiments in liquid nitrogen at a temperature of 77 K and in low-temperature gaseous nitrogen is obviously caused by the course of local deformation when the indenter is depressed by crazing and the effect of the adsorption-active medium on the formation of crazes.

Nature of the effect: when exposed to nitrogen adsorption activity, local zones of fibrillar-porous nanostructures (crazes) are formed, which have thermodynamic and mechanical characteristics that are different from the characteristics of the block polymer. This results in high-elasticity.