MULTIFUNCTIONAL TITANIUM-CALCIUM PHOSPHATE GRAPHENE IMPLANT ELECTRONICS FOR BONE TISSUE ENGINEERING

E.M. DOGADINA, R.D. RODRIGUEZ, S.I. TVERDOHLEBOV, E.S. SHEREMET
National Research Tomsk Polytechnic University, Research School of Chemistry and Applied Biomedical Sciences
E-mail: elizavetadogadina@gmail.com

Titanium implants are the most common implants for bone restoration. To improve their integration, various coatings, such as calcium phosphate, are used. However, in order to accelerate bone regeneration, patients should already put a load on the damaged bone in the first days [1]. Therefore, during postoperative recovery, it is important to choose the right load on the damaged limb. Built-in deformation sensors will help in determining the degree of bone recovery to determine the permissible load on it.

Moreover, titanium has a modulus of elasticity about 10 times greater than bone tissue [2], which is the main cause of deformation or failure of the implant. In this case, the deformation sensor will help to find out about the overload on the implant promptly.

In this work we perform laser processing of modified graphene (mod-G) on titanium substrates coating with calcium phosphate (CaP) for the fabrication of conductive implants with deformation sensor.

Titanium plates were coated with calcium phosphate by micro-arc oxidation method. Graphene was functionalized with diazonium salts during the oxidative electrochemical exfoliation of a graphite electrode in sulfuric acid. The resulting powder was diluted with ethanol with concentration of 4 mg/mL. Dispersion was deposited on top of titanium/CaP samples and dried in a hood. Further the samples were treated with a blue 3W laser (figure a).

As a result, a robust conductive structure was obtained which was stable after 5 minutes of ultrasound exposure. Calcium phosphate has a highly porous structure. Therefore, one of the reasons for the composite formation is the filling and covering of these pores with graphene. This hypothesis is confirmed by SEM and AFM images (figure b and g). Figures c-e present raman spectrums and raman map of titanium dioxide and G-band of graphene on the L-ModG/ModG interface after ultrasound exposure, which also confirm that graphene fills the pores.

The bending test confirmed that the L-modG/CaP/Ti structure can be used as a deformation sensor. The plot of resistance as a function of bends number is presented on figure h. The change in resistivity during cyclic load applying confirms the concept to use such composite as deformation sensor.

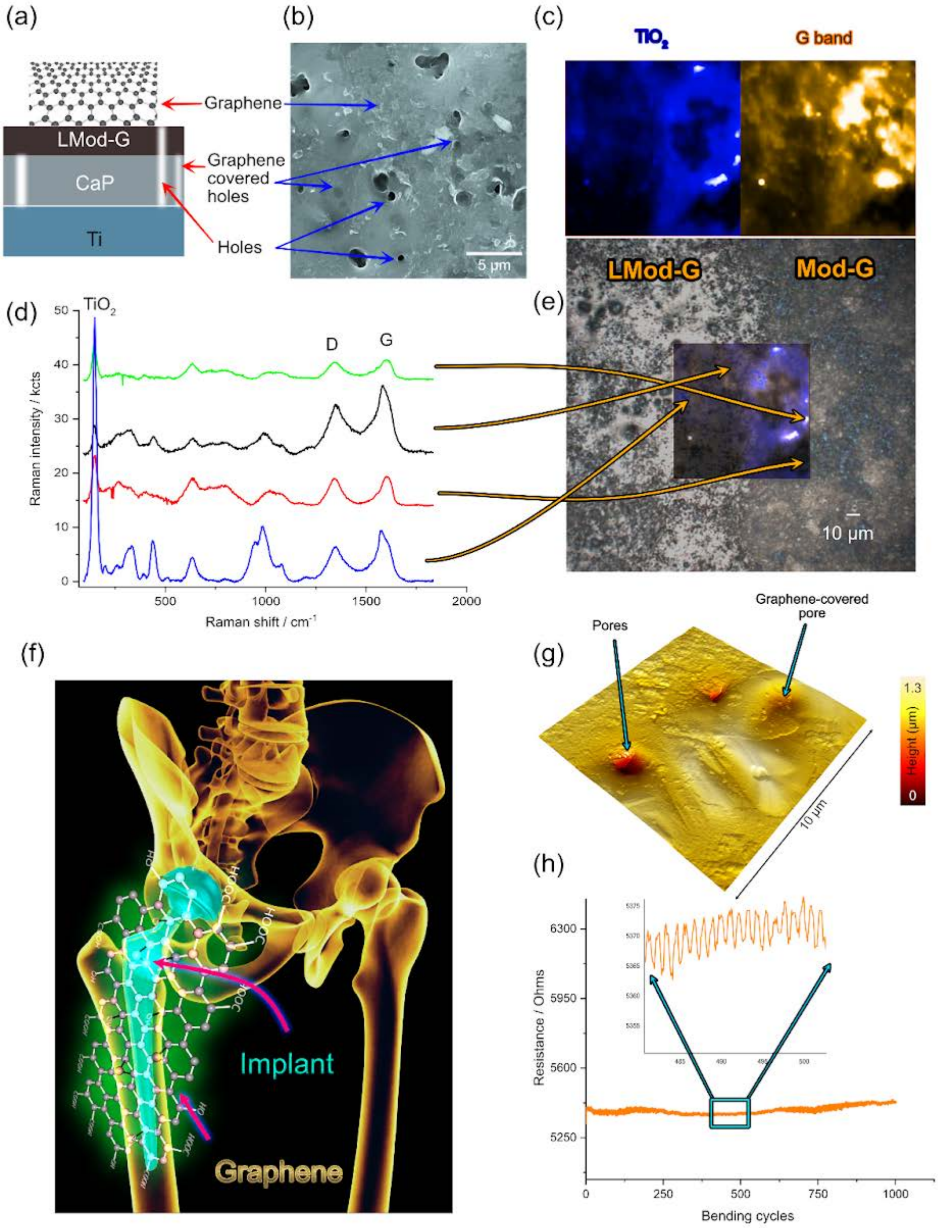

Figure 1 – (a) Samples structure; (b) SEM image; (c) Raman maps of TiO_2 and G-band; (d) Raman spectrums of the region of interest; (e) Overlap of TiO_2 and G-band raman maps on optical image; (f) Sketch of titanium-graphene implants application; (g) AFM topography covering the region of interest; (h) Bending test result shows the dependency between bends and resistivity

References

1. Goodship A.E, Lawes T.J, Rubin C.T. Low-magnitude high-frequency mechanical signals accelerate and augment endochondral bone repair: preliminary evidence of efficacy // J Orthop Res. – 2009. – № 27. – С. 922–930.
2. Garot C., Bettega G., Picart C. Additive Manufacturing of Material Scaffolds for Bone Regeneration: Toward Application in the Clinics // Adv Funct Mater. – 2021. – №31.
3. Colilla M., Manzano M., Vallet-Regí M. Recent advances in ceramic implants as drug delivery systems for biomedical applications // Int J Nanomedicine. – 2008. – №3. – С. 403–414.