Developing a fluorescence immunosensor for detection of HER2-positive breast cancer based on graphene and magnetic nanoparticles

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Abstract
Breast cancer is regarded as the most common cause of death after lung cancer among women. Using graphene quantum nanoparticles (GQNPs) to construct a biosensor increases the sensitivity, rapidness, and flexibility of biological tests to detect cancer cells. In this study, we developed a fluorescence immunosensor based on GQNPs and magnetic nanoparticles (MNPs) for selective detection of HER2-positive breast cancer. The GQNPs and MNPs were conjugated with Herceptin individually which was confirmed by physicochemical studies. Then, the conjugates were exposed to the SK-BR3 breast cancer cells to form a sandwich structure of MNP-Herceptin-SK-BR3 cell-Herceptin-GQNP. Then, an inverted fluorescence microscope was used to detect breast cancer cells after isolating them using a magnet. The results showed a high sensitivity (even one cell ml^{-1}) and specificity of the designed biosensor for the detection of SK-BR3 cells within 30 min.

References

[1] Sibbering, M., Courtney, C-A., (2016). Surgery (Oxford) 34(1), 25-31.

[2] Maria, A.M., El-Shebiney, M., El-Saka, A.M., Zamzam, Y., (2018). Journal of the Egyptian National Cancer Institute 30(2), 49-55.

[3] Blackwell, K., Gligorov, J., Jacobs, I., Twelves, Ch., (2018). Clinical breast cancer 18(2), 95-113.

[4] Dehdashti, F., Wu, N., Bose, R., Naughton, M.J., X.Ma, C., Marquez-Nostra, B.V., Diebolder, Ph., Mpoy, Rogers, B,E., Lapi, S.E., Laforest, R., Siegel, B.A., (2018). Breast Cancer Research and Treatment 169, 523-530.

[5] Bray, F., Ferlay, J., Soerjomataram, I., Siegel, R.L., Torre, L.A., Jemel, A., (2018). CA: A Cancer Journal for Clinicians 68(6), 394-424.

[6] Marcuzzo, Th., Giudici, F., Ober, E., Rizzardi, C., Bottin, C., Zanconati, C., (2016). Pathology-Research and Practice 212(10), 911-8.

[7] Rodriguez, C., Suciu, V., Poterie, A., Lacroix, L., Miran, I., Biochard, A., Delaloge, S., Deneuve, J., Azoulay, S., Mathieu, M.C., Valent, A., Michiels, S., Arnedos, M., Vielh, Ph., (2016). Molecular Oncology 10(9), 1430-1436.

[8] Hou, Y., Nitta, H., Parwani, A.L., Li, Z., (2020). Diagnostic Histopathology 26(2), 61-68.

[9] Liu, Ch-P., T, T-I., Ch, T., Sh, V.S., Wu, Ch-Y., Wong, Ch-H., (2018). Proceedings of the National Academy of Sciences 115(4), 720-725.

[10] Yuan, P., Gao, S-L., (2017). Chronic Diseases and Translational Medicine 3(1), 21-32.

[11] Lowes, S., Leaver, A., Redman, A., (2019). Surgery (Oxford) 3, 140-150.

[12] Pacheco, JG., Rebelo, P., Freitas, M., Nouws, H.P.A., Delerue-Matos, C., (2018). Sensors and Actuators B: Chemical 273, 1008-1014.

[13] Gohring, J.T., Dale, P.S., Fan, X., (2010). Sensors and Actuators B: Chemical 146, 226-30.

[14] Gruhl, F.J., Rapp, M., Lange, K., (2010). Procedia Engineering 5, 914-917.

[15] Tabasi, A., Noorbakhsh, A., Sharifi, E., (2017). Biosensors and Bioelectronics 95, 117-123.

[16] Salahandish, R., Ghaffarinejad, A., Naghib, S.M., Majidzadeh-A, K., Zargartalebi, H., Sanati-Nezhad, A., (2018). Biosensors and Bioelectronics 117, 104-111.

[17] Fan, H.Y., Yu, X-H., Wang, K., Yin, Y.J., Tang, Y.J., Tang, Y.l., Liang, X.H., (2019) European Journal of Medicinal Chemistry 182 11620.

[18] Sharma, L., Som, N.N., Pillai, Sh.B., Jha, P.K., (2019). Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 224 117352.

[19] Krishnam, S.k., Singh, E., Singh, P., Meyyappan, M., Singh Nalwa, H., (2019). ROYAL SOCIETY of CHEMISTRY 9, 8778-8881.

[20] Yang, X., Fan, Sh., Li, Y., Guo, Y., Li, Y., Ruan, K., Zhang, Sh., Zhang, J., Kong, J., Gu, J., (2020) Composites Part A: Applied Science and Manufacturing 128 105670

[21] Dolatkhah, M., Hazhemzadeh, N., Bara, J., Adibkia, Kh., Aghanejad, A., Barzegar-Jalali, M., Omidi, Y., (2020) Colloids and Surfaces B: Biointerfaces 193 111104.

[22] Huang, H., Wang, B., Chen, M., Liu, M., Leng, Y., Liu, X., Li, Y., Liu, Zh., (2016). Sensors and Actuators B: Chemical. 235, 356-61.

[23] Mittal, S., Kaur, H., Gautam, N., Mantha, A.K., (2017). Biosensors and Bioelectronics 88, 217-31.

[24] Wu, J-B., Lin, M-L., Cong, X., Liu, H-N., Tan, P-H., (2018). ROYAL SCIETY OF CHEMISTRY 47, 1822-1873.

[25] Taheri, H., Amini, B., Kamali, M., Asadi, M., Naderlou, E., (2020). spectrochemical Acta - Part A: Molecular and Biomolecular Spectroscopy, 229, 117891.

[26] Naderlou, E., Salouti, M., Amini, B., Shahbazi, R., Zabihian, S., (2020). Artificial Cells, Nanomedicine and Biotechnology, 48(1), 810–817.

[27] Shahriary, L., Athawale, A.A., (2014). International Journal of Renewable Energy and Environmental Engineering 2(01), 58-63.

[28] Wang, Sh., Niu, R., Yang, Y., Zhou, X., Luo, Sh., Zhang, Ch., Wang, Y., (2020). International Journal of Biological Macromolecules 153, 583-590.

[29] Parsamehr, P-S., Zahed, M., Ahmadzadeh-Tofighy, M., Mohammadi, T., Rezakazemi, M., (2019). Deselination 468, 114079.

[30] Pena-Bahmonde, J., N.Nguyen, H., K.Fanourakis, S., F.Rodrigus, D., (2018). Joutnal of Nanobiotechnology 16(1), 1-17.

[31] Ignatiadis, M., Rothe, F., Chaboteaux, C., Darbecq, V., Rouas, Gh., Criscitiello., Metallo, J., Kheddoumi, N., Singhal, S.K., Michiels, S., Veys, I., Rossari, J., Larsimont, D., (2011). PloS ONE 6(1), e15624.

Figures

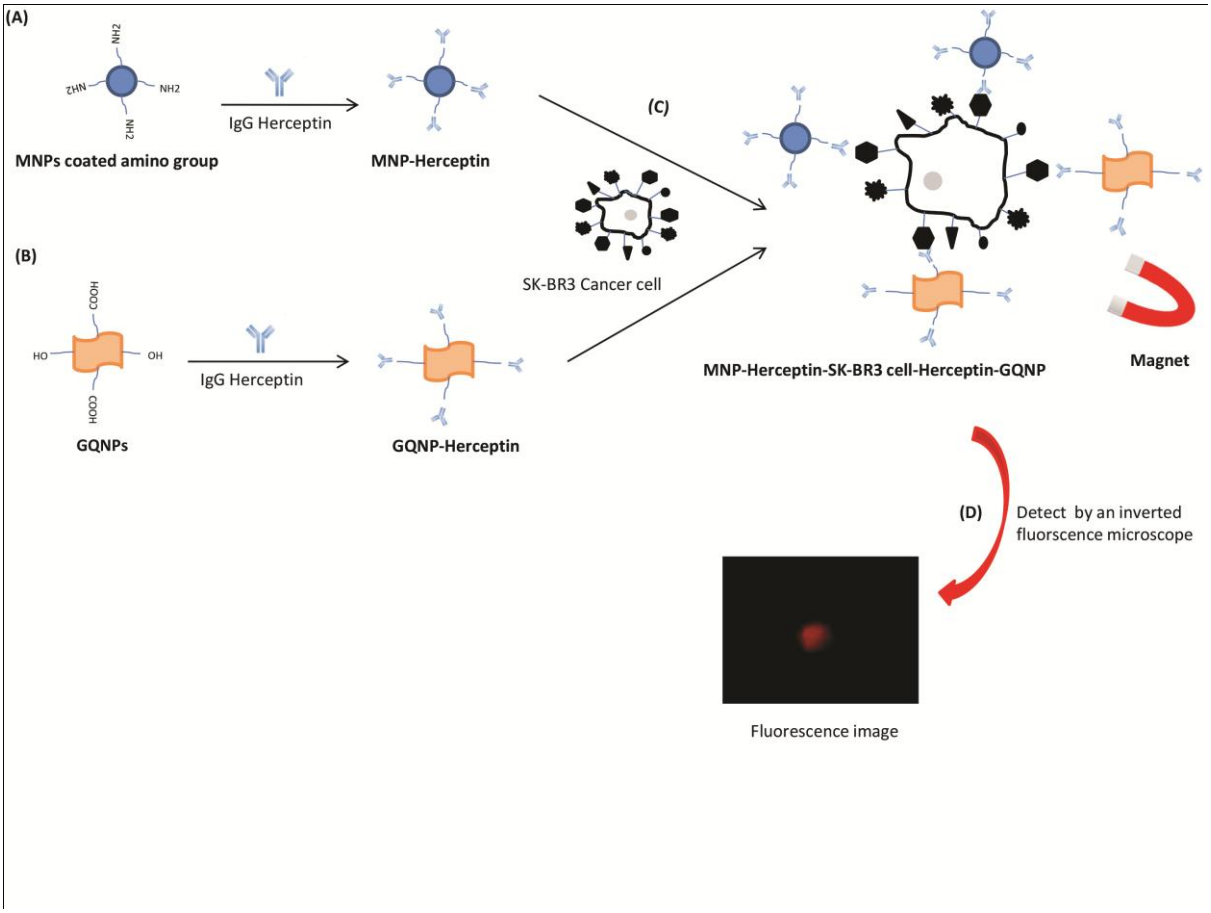

Figure 1: Fig. 1. schematic detection of SK-BR3 breast cancer cell, (A) synthesis and conjugation of MNP-Herceptin, (B) synthesis and conjugation of GQNP-Herceptin, (C) MNP-Herceptin and GQNP-Herceptin were added to SK-BR3 breast cancer cell, (D) detection of SK-BR3 cancer breast cell by an inverted fluorescence microscope.

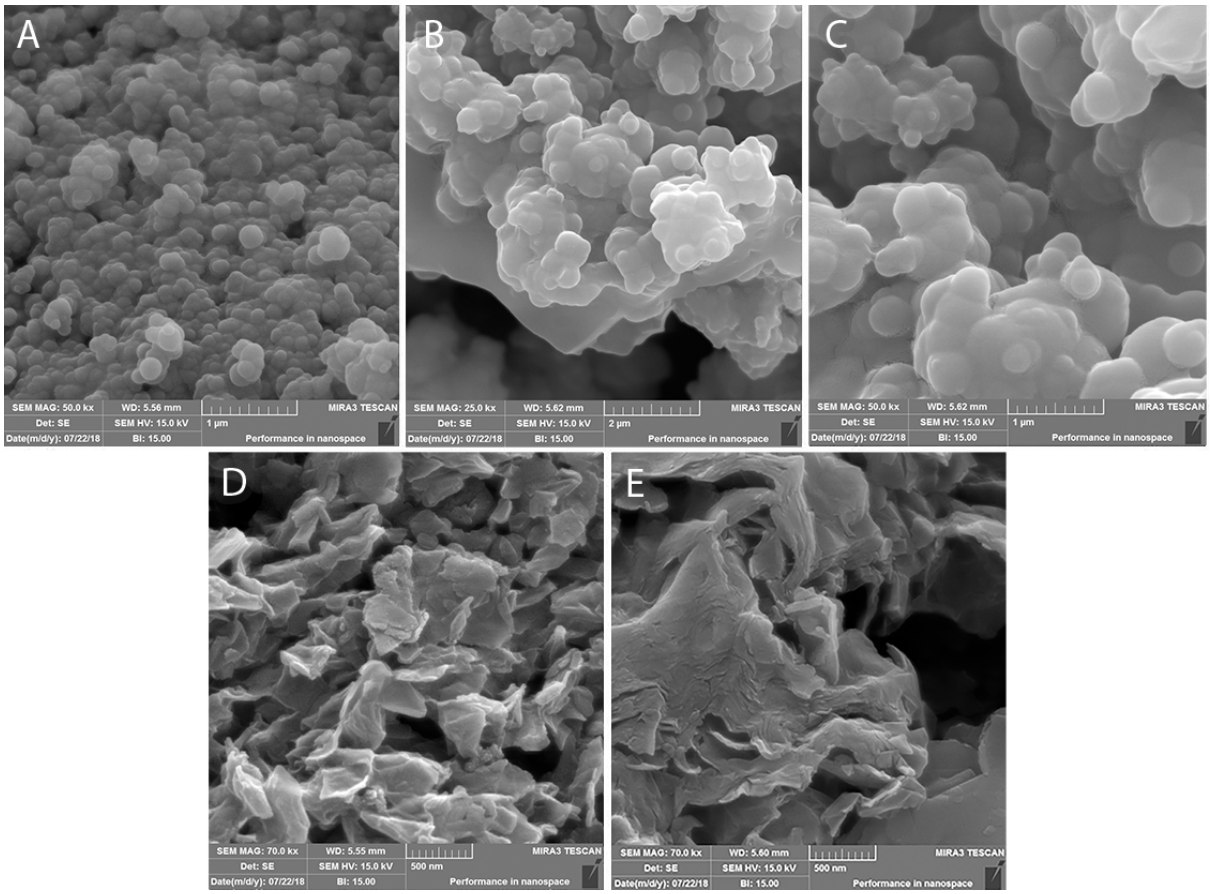

Figure 2: SEM images of synthesized GQNPs and MNPs; (A) MNPs; (B) amino group coated MNPs; (C) MNP-Herceptin; (D) GQNPs and (E) GQNP-Herceptin.

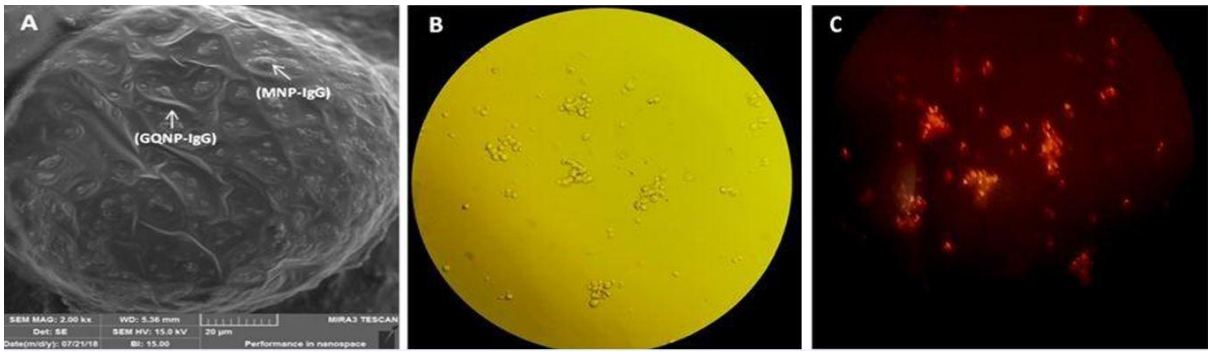

Figure 3: (A) SEM of sandwich structure; MNP-Herceptin-SK-BR-3 cell-Herceptin-GQNP; (B) Visible image of sandwich structure; MNP-Herceptin-SK-BR-3 cell-Herceptin-GQNP (magnification ×10); (C) Fluorescence image of sandwich structure; MNP-Herceptin-SK-BR-3 cell-Herceptin-GQNP (magnification ×10).

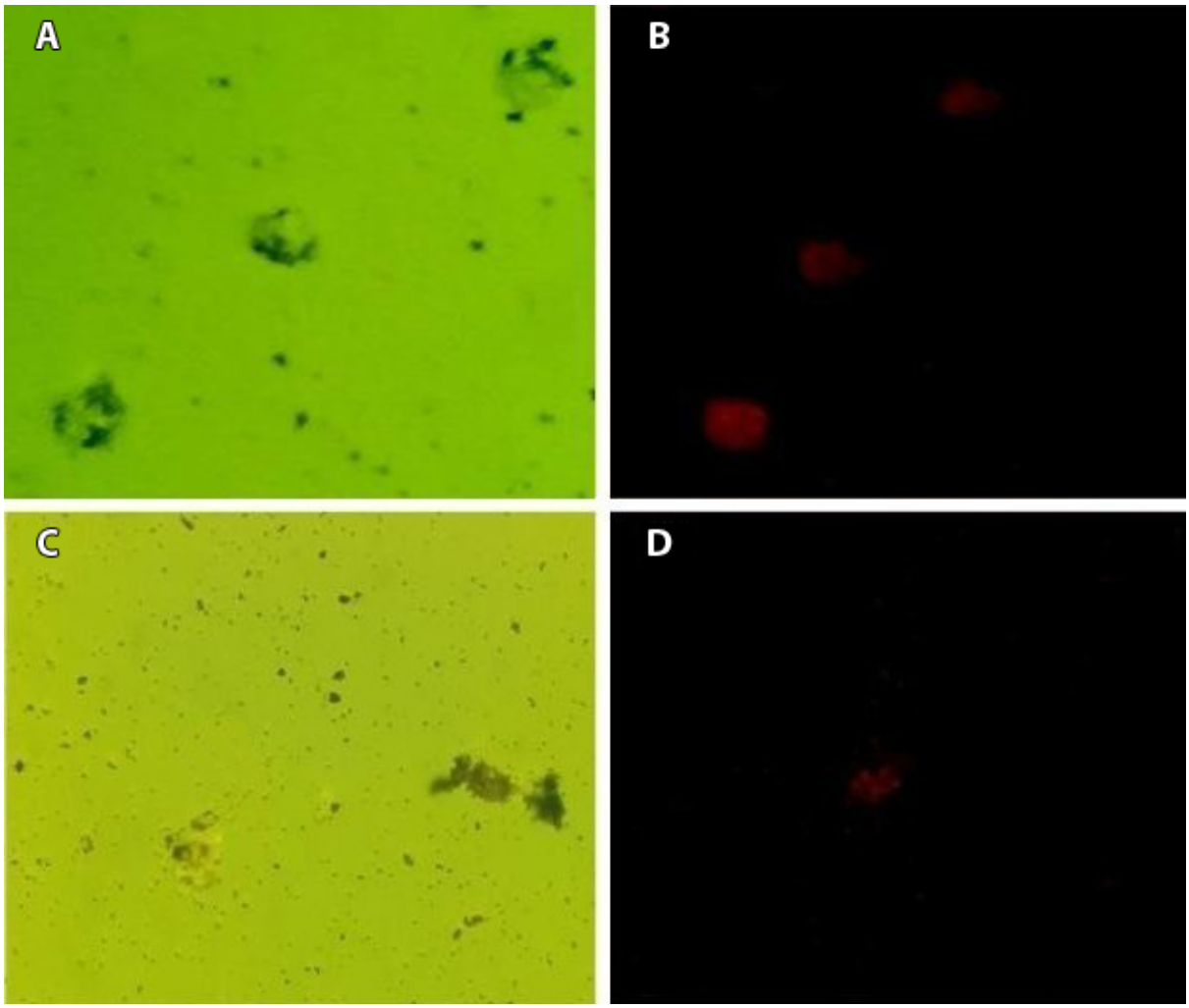

Figure 4: (A) visible image of sandwich structure; MNP-Herceptin-SK-BR-3 cell-Herceptin-GQNP (magnification ×40); (B) Fluorescence image of sandwich structure; MNP-Herceptin-SK-BR-3 cell-Herceptin-GQNP (magnification ×40); (C) Visible image of sandwich structure; MNP-Herceptin-MCF-7 cell-Herceptin-GQNP (magnification ×40); (D) Fluorescence image of sandwich structure; MNP-Herceptin-MCF-7 cell-Herceptin-GQNP (magnification ×40).

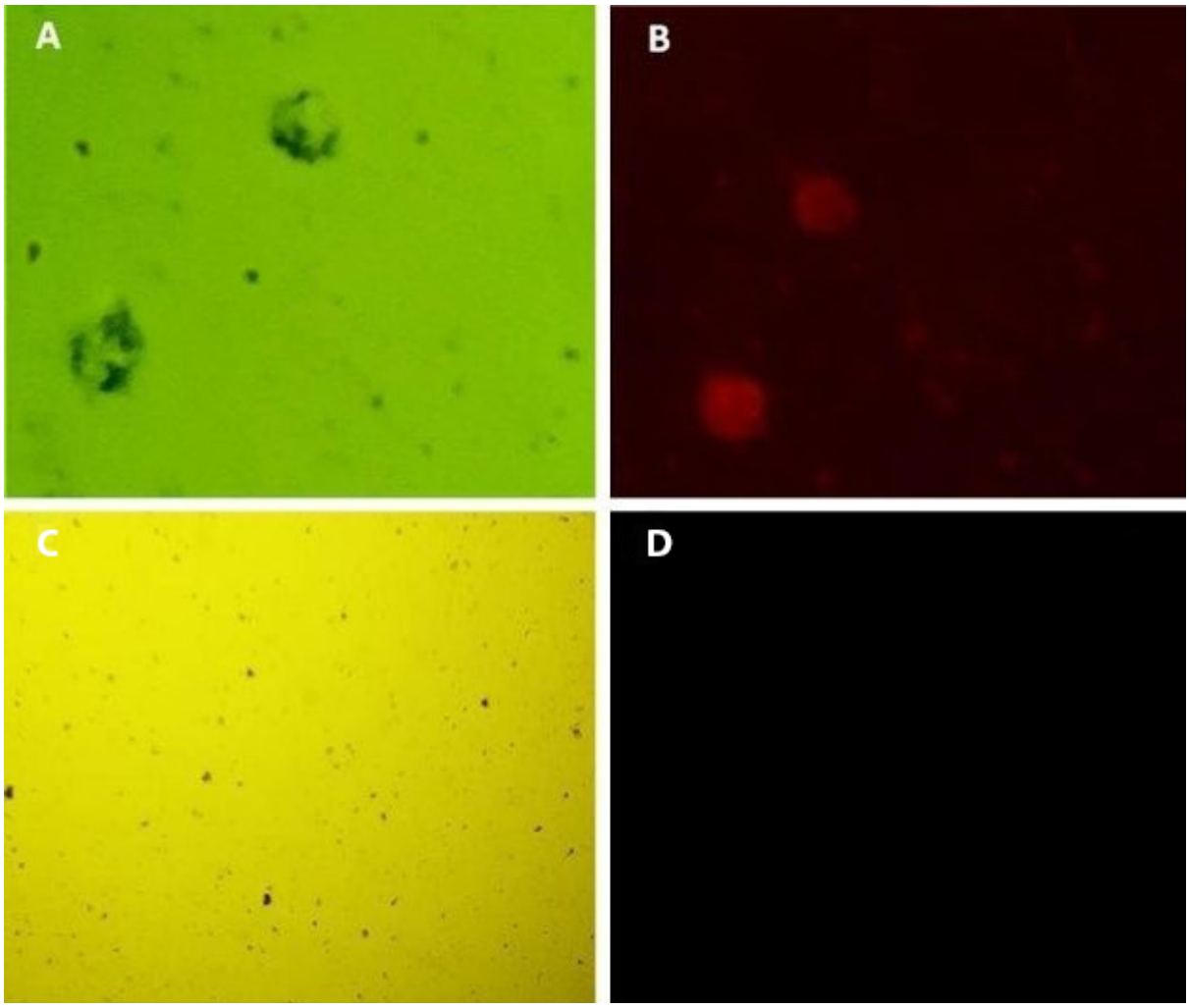

Figure 3: Visible and Fluorescence images (magnification ×40); (A) Visible image of sandwich structure; MNP-Herceptin-SK-BR3 cell-Herceptin-GQNP (magnification ×40); (B) Fluorescence image of sandwich structure; MNP-Herceptin-SK-BR3 cell-Herceptin-GQNP (magnification ×40); (C) Visible image of MDA-MB-453 cells (magnification ×40); (D) Fluorescence image of MDA-MB-453 cells (magnification ×40).