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Commentary

# Diatom-derived Mesoporous Silica Nanoparticles Loaded with Fucoidan for Enhanced Chemo-Photodynamic Therapy

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## ABSTRACT

Conventional cancer treatments face limitations, driving the exploration of combination therapy for enhanced effectiveness. This study introduces a innovative approach by utilizing Diatom-Derived Mesoporous Silica Nanoparticles (dMSN) enriched with lanthanide metal ions, enabling dual-action therapy. These nanoparticles not only exhibit photodynamic therapy capabilities but also offer MRI and fluorescence imaging functions.

Incorporating fucoidan, a potent natural anticancer agent from brown algae, the study achieves remarkable efficacy against drug-resistant cancer cells. The combination of dMSN-EuGd@Fucoidan outperforms standalone photodynamic therapy or chemotherapy, presenting a robust solution for cancer treatment. Leveraging the unique properties of diatoms, the most prevalent group in the ocean, aligns with sustainable healthcare principles.

In summary, this research pioneers a combined chemo-photodynamic therapy system, harnessing the advantages of fucoidan and innovative diatom-derived nanoparticles. It addresses drug resistance and suboptimal drug delivery, moving us closer to more effective and targeted cancer treatments.

**Keywords:** Diatom mesoporous silica nanoparticles, fucoidan, Chemo-photodynamic Therapy



## ABOUT THE STUDY

The impact against cancer has been relentless, and while conventional treatments have played a important role, their limitations necessitate exploration beyond the traditional. This study delves into the domain of combination therapy, a potential avenue where diverse treatment modalities merge to enhance therapeutic efficacy. Recognizing the intricacies posed by cancer's interaction with healthy tissues, and the development of drug resistance over time, innovative therapies have taken center stage. Photodynamic therapy, heat therapy, and immunotherapy represent pioneering approaches, with combination therapy acting as a transformative force.

The adoption of nanoparticles within combination therapy is a promising concept. These nanoparticles, when appropriately customized, provide a platform for the synergy of chemotherapy and Photodynamic Therapy (PDT). PDT leverages photosensitizers to generate Reactive Oxygen Species (ROS) upon light exposure, capable of eradicating drug-resistant cancer cells. This approach offers resistance ignorance, rendering it a promising complement to traditional chemotherapy.

The focus of this study centers on the design of an integrated therapy, blending chemotherapy with PDT. The unique approach here involves the synthesis of Diatomaceous Earth Mesoporous Silica Nanoparticles (dMSN) enriched with lanthanide metal ions, thus endowing them with PDT capabilities. Notably, these nanoparticles possess MRI and fluorescence imaging abilities, adding layers of functionality. This innovation, utilizing diatoms as a source material, marks an eco-friendly and novel approach to combined chemo-photodynamic therapy (Figure 1).

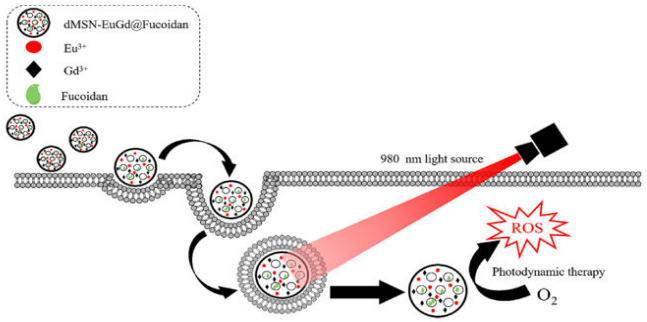


**Figure 1:** When diatom source drug carrier: dMSN-EuGd@Fucoidan penetration into the cancer cell through the endocytosis, the anticancer drug: fucoidan will release. Then, the material was irradiated with 980 nm light and generates the Reactive Oxygen Species (ROS) to enhance cytotoxic effect. Finally, the combination of chemotherapy and photodynamic therapy effectively inhibits cancer cells.

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## Combination of functionality: Lanthanide enriched nanoparticles and fucoidan chemotherapy

The successful synthesis of dMSN embedded with lanthanide metal ions prepare for the convergence of PDT and chemotherapy. The incorporation of lanthanide metals into the MSN structure provides the carrier itself with photodynamic capabilities, ensuring maximal drug-loading capacity. This ingenious approach addresses the historical challenge of insufficient drug delivery common to earlier combination therapies.

Fucoidan, a fucose-rich sulfated polysaccharide extracted from brown algae, emerges as a potential chemotherapy component. The study identifies that fucoidan from Sargassum oligocystum displayed robust anticancer activity, particularly evident through cell viability assays on HCT116 cancer cells shown in Figure 2. The incorporation of fucoidan within dMSN-EuGd creates a formidable combination therapy solution, providing superior anticancer efficacy compared to the use of PDT or chemotherapy in isolation.

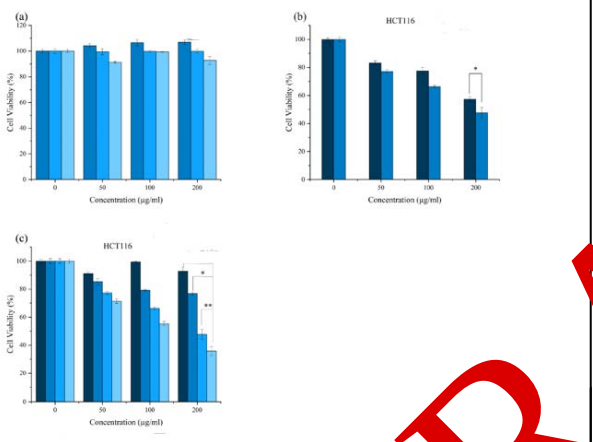


**Figure 2:** The viability of (a) L929 normal cells, A549 cancer cells and HCT116 cancer cells, after co-cultured with dMSN-EuGd. Comparing the cell viability of HCT116 treated with (b) Fucoidan and dMSN-EuGd@fucoidan, and (c) dMSN-EuGd and dMSN-EuGd@fucoidan with and without 980 nm laser irradiation (1 W/cm²). Bars indicate SD, n= 3. (**P < 0.01 and *P < 0.05).

**Note:** (a) ( ▬ ) L929; ( ▬ ) A549; ( ▬ ) HCT116; (b) ( ▬ ) Fucoidan, ( ▬ ) dMSN-EuGd@fucoidan, (c) ( ▬ ) dMSN-EuGd (dark), ( ▬ ) dMSN-EuGd (light), ( ▬ ) dMSN-EuGd@fucoidan (dark), ( ▬ ) dMSN-EuGd@fucoidan (light).

## The advantages of diatom-derived nanoparticles

The study introduces an exciting avenue with Diatom Mesoporous Silica Nanoparticles (dMSN) as the chosen carrier for combination therapy. Diatoms, the most prevalent group in the ocean, are known for their unique silicon dioxide cell walls. After their demise, what remains is the inorganic matter rich in silicon dioxide, which gradually deposits on the seabed, mingling with silt and clay, ultimately forming diatomaceous earth. This environmentally-sourced material boasts specific advantages: low cost, high surface area, easy surface modification, and the ease with which it can be transformed into mesoporous nanoparticle as shown in (Figures 3 and 4). The utilization of dMSN from diatomaceous earth aligns with green chemistry principles (Table 1).

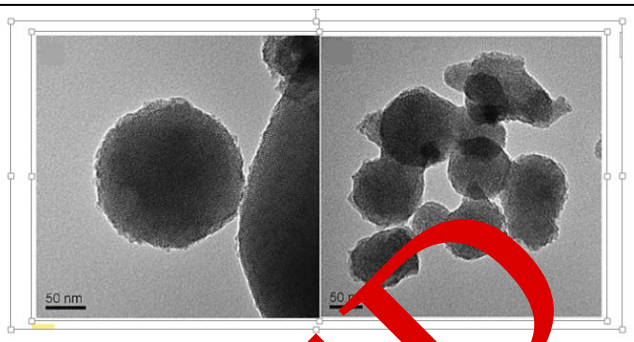


**Figure 3:** TEM images of dMSN.

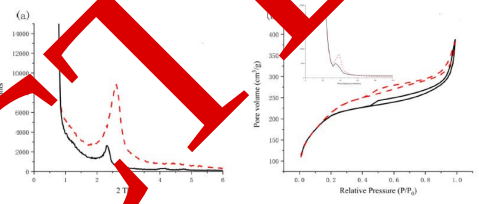


**Figure 4:** (a) Small angle powder X-ray diffraction (pXRD) pattern of dMSN and dMSN-EuGd, (b) Nitrogen adsorption desorption isotherms for dMSN and dMSN-EuGd. **Note:** ( ▬ ) dMSN; ( ▬ ) dMSN-EuGd.

| Physical data | dMSN | dMSN-EuGd |
|---|---|---|
| BET surface area ($m^2/g$) | 748.39 | 684.53 |
| Pore volume ($cm^3/g$) | 0.41 | 0.38 |
| BJH desorption diameter (nm) | 3.73 | 3.71 |
| XRD 2θ (°) | 2.31 | 2.75 |
| d spacing (nm) | 3.22 | 3.17 |
| Wall diameter (nm) | 1.4 | 1.51 |

**Table 1:** BET and PXRD analysis of the properties of dMSN-EuGd.

## CONCLUSION

In conclusion, this study represents a pioneering step towards the creation of a combined chemo-photodynamic therapy system. The incorporation of fucoidan, a naturally sourced and potent anticancer agent, into diatom-derived nanoparticles introduces a novel approach to cancer therapy. By enhancing the anticancer

effects of chemotherapy, this study paves the way for a more effective and targeted therapeutic approach.

The ingenious combination of drug-resistant cancer cell eradication through ROS generation and the potent chemotherapy delivered by these nanoparticles presents a promising strategy. The innovative use of diatomaceous earth as the nanoparticle source highlights the study's eco-conscious approach.

With these innovation, this research holds important potential for future cancer therapies, putting us closer to overcoming the challenges of drug resistance and ineffective drug delivery in the fight against cancer. We eagerly await further developments and applications of this innovative approach.