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Optically tunable catalytic cancer therapy using enzyme-like chiral plasmonic nanoparticles

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Haeun Kang[1,19], Subin Yu[1,2,19], Ryeong Myeong Kim[3,19], Youngbi Kim[4], Sang Chul Shin[5], Dohyub Jang[6], Jeong Hyun Han[3], Sugyeong Hong[7], Eunice EunKyeong Kim[8], Sun Hee Kim[7,9], Dong June Ahn[6,10], Jeong Woo Han[3] ✉, Sehoon Kim[10,11] ✉, Ki Tae Nam[3] ✉, Luke P. Lee[2,12,13,14] ✉ & Dong Ha Kim[1,15,16,17,18] ✉

Cascade enzymatic reactions in living organisms are fundamental reaction mechanisms in coordinating various complex biochemical processes such as metabolism, signal transduction, and gene regulation. Many studies have attempted to mimic cascade reactions using nanoparticles with enzyme-like activity; however, precisely tuning each reaction within complex networks to enhance the catalytic activity remains challenging. Here, we present enzyme-like chiral plasmonic nanoparticles for optically tunable catalytic cancer therapy. We create chiral plasmonic nanoparticles with glucose oxidase (GOD) and peroxidase (POD) activities, followed by introducing circularly polarized light (CPL). By sequentially activating GOD and POD reactions with right-handed CPL (RC) followed by left-handed CPL (LC), we achieve 1.25- and 1.9-fold enhanced catalytic performance (overall 1.3 times enhancement) compared to non-controlled cascade reactions by creating an optimal acidic environment for the subsequent reaction. Moreover, the D-Au nanoparticle shows a 2-fold higher binding selectivity to D-glucose substrates, attributed to chirality matching. In both cell studies and male mouse models, sequentially irradiated groups (RC followed by LC) exhibit the highest radical generation and the most efficient treatment outcomes compared to the other systems under different irradiation conditions. We believe that our system holds strong potential for medical applications, suggesting a promising platform for catalytic therapy.

Living organisms are incredibly complex, comprising countless interconnected biochemical pathways. Cascade reactions play a pivotal role in managing this complexity by organizing reactions into sequential steps, where the product of one reaction becomes the substrate for the next[1,2]. Each step in a cascade reaction is catalytically driven, often by enzymes, to produce the necessary outcomes for cellular function, energy production, and response to environmental stimuli[3–5]. This sequential organization ensures that biological processes proceed in a controlled and orderly manner to conduct complex processes with remarkable precision and efficiency.

Given the critical role of cascade reactions in biological systems, there has been a growing interest in mimicking these processes

A full list of affiliations appears at the end of the paper. ✉e-mail: jwhan98@snu.ac.kr; sehoonkim@kist.re.kr; nkitae@snu.ac.kr; lplee@bwh.harvard.edu; dhkim@ewha.ac.kr