Plasmonic Field Enhancement on Planar Metal Surfaces

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The power density supplied to deuterium-metal systems is a key to initiate the nuclear reaction. We previously proposed and analyzed the electromagnetic energy focusing effect around metal nanoparticles and nanoshells to significantly increase the reaction probability [1,2]. In the present work, we show that such a plasmonic field enhancement occurs also on planar metal surfaces. Removing the noble-metal approximation in Ref. 3, we have fully calculated the maximum field enhancement for the metals commonly used in the community (Fig. 1). The main formula to represent the field enhancement factor, defined by the ratio of the spatial electromagnetic energy densities with and without the metal object, is summarized as:

$$\eta \equiv \frac{\left|\vec{E}_{SP}\left(0^{+}\right)\right|^{2}}{\left|\vec{E}_{0}\right|^{2}} == \frac{c\left(\left|q_{1}\right|^{2}+\left|k_{SP}\right|^{2}\right)\cos\theta\left(1-R\right)}{\omega\varepsilon_{1}^{1/2}k_{SP}\text{''}\operatorname{Re}\left\{\dfrac{k_{SP}\left(\varepsilon_{1}q_{1}\text{'}+\varepsilon_{2}q_{2}\text{'}\right)}{\varepsilon_{2}q_{1}\text{'}q_{2}\text{'}}\right\}}$$

, where we followed a set of common notations in electrodynamics and the subscripts *1* and *2* denote the surrounding medium and the metal, respectively. Notably, our calculation is only based on the Maxwell equations and involves nothing exotic or physically novel. We have thus found that a certain degree of enhancement is available on the metal-surface regions, implicating that this electromagnetic boosting effect had been unconsciously exerted in the experiments reported so far, particularly for the electrolysis-type ones. Importantly, this plasmonic enhancement occurs for the case of an optical-power incidence as well as an electric-bias application. It is therefore important to design and optimize the experimental systems, including the materials choice, structures, and operation conditions, additionally accounting for the plasmonic energy enhancement effect around the gas (vacuum)/liquid-metal interfaces. This sort of numerical model, incidentally, is simple and flexible to connect to other ones, and may construct a comprehensive model by combining with transport and reaction submodels [4], for instance. Further details of our present work are found in Ref. 5.

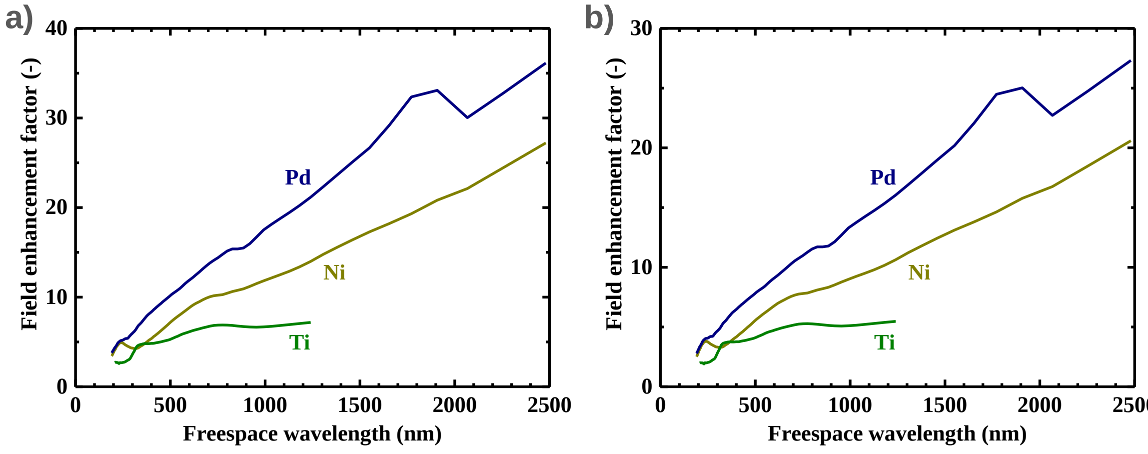

Fig. 1 Field enhancement factors on planar Pd, Ni, and Ti surfaces in (a) D_2/vacuum and (b) D_2O.

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[2] K. Tanabe, "Plasmonic concepts for condensed matter nuclear fusion," J. Cond. Mat. Nucl. Sci., vol. 24, pp. 296-300, 2017.

[3] W. H. Weber, G. W. Ford, "Optical electric-field enhancement at a metal surface arising from surface-plasmon excitation," Opt. Lett., vol. 6, no. 3, pp. 122-124, 1981.

[4] K. Tanabe, "Modeling of hydrogen/deuterium dynamics and heat generation on palladium nanoparticles for hydrogen storage and solid-state nuclear fusion," Heliyon, vol. 2, no. 1, art. no. e00057, 2016.

[5] K. Tanabe, "Plasmonic field enhancement on planar metal surfaces for condensed matter nuclear fusion," J. Cond. Mat. Nucl. Sci., in press.