Optical properties and photothermal applications of TiN nanomaterials

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Titanium nitride (TiN) has emerged as an alternative plasmonic material compared to gold (Au) by virtue of its similar optical response but additional compatibility with the semiconductor industry technology and refractory nature. Furthermore, the optical and, therefore, plasmonic properties of TiN nanomaterials offer an additional tunability degree compared to Au by varying the stoichiometry in TiN_x or even TiO_xN_y (i.e., titanium oxynitrides), thus tuning the material response from metallic-like to oxide-like.

In this contribution, first the basic optical properties of TiN_x compact films prepared by magnetron sputtering are discussed in terms of spectroscopic ellipsometry. The latter was exploited as a powerful tool not only to retrieve the complex permittivity, but also to estimate the film stoichiometry and resistivity by means of Drude-Lorentz modelling, finding a good agreement with the results of four-point probe method. [1]

Incomplete oxidation of the films, thus leading to TiO_xN_y, is further considered as a strategy to obtain the so-called double-epsilon-near-zero (2ENZ) behavior. As an example, we discuss how the 2ENZ effect can be promoted by ion-assisted pulsed laser deposition (PLD), leading to compact TiO_xN_y with enhanced absorptance.

A further optical tunability of TiN-based nanomaterials can be achieved by synthesizing vertically aligned nanostructured films, thus leading to nearly unitary broadband absorption. Two different approaches are presented, i.e., TiN nanotube arrays prepared by electrochemical anodization and nitridation of the so-obtained TiO_2 nanotubes, and PLD deposition of porous TiO_xN_y films from a TiN target. Both approaches allowed obtaining scalable photothermal materials featuring broadband solar absorption. Such potentialities were experimentally investigated in terms of temperature generation under moderate solar light concentration and solar-steam generation. [2,3]

Finally, plasmonic properties of nanostructured TiN materials are promising for photothermal catalysis applications. This was demonstrated in the model gas-phase CO oxidation reaction to CO_2 by employing TiN nanotubes decorated by Rh nanoparticles as catalyst under moderate light concentration (~ 10 Suns). [4] These results open the way to further studies, such as the production of value-added chemicals by CO_2 reduction.

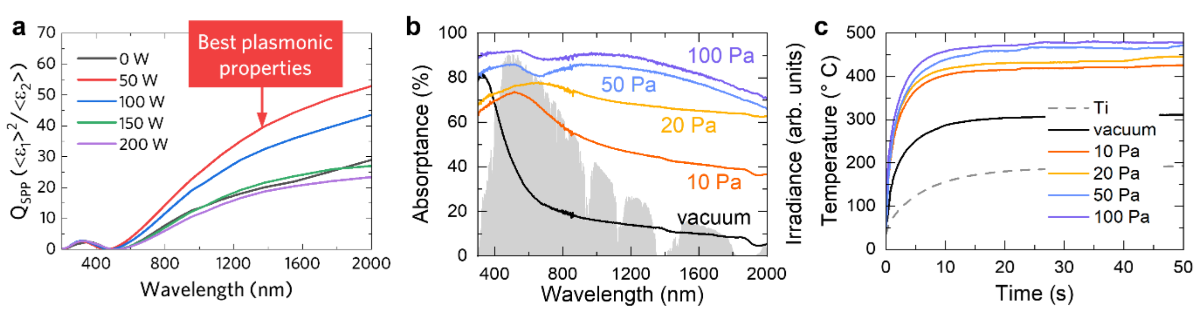

Fig. 1 (a) Quality factor for surface plasmon polaritons (QSPP) for TiN_x films deposited by radiofrequency (RF) magnetron sputtering by varying the substrate RF bias from 0 to 200 W. Reproduced from ref. [1]. (b) Optical absorption of TiN_x and TiO_xN_y films prepared by pulsed laser deposition (PLD) by varying the background gas pressure (N_2/H_2 95/5%) and (c) temperature profiles of the same films under concentrated solar-simulated light (17 Suns = 1.7 W cm^{-2}) in argon atmosphere. Reproduced from ref. [2].

References

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