Comment on “Brighter Light Sources from Black Metal: Significant Increase in Emission Efficiency of Incandescent Light Sources”

In a recent article, Vorobyev *et al.* [1] reported how brighter incandescent light sources could be made using black metal prepared by femtosecond laser ablation. Figures 2 and 3 of that work show how absorptance and emittance of the polished tungsten ribbon increase with the number of laser shots over the spectral range of 250 to 2500 nm. It appears that with irradiance of the tungsten surface, the optical characteristics of the tungsten surface approach that of a blackbody radiator. However, these changes are not sufficient for increasing the efficacy of a tungsten filament lamp as suggested by the authors.

The tungsten filament in an incandescent lamp has a higher luminous efficacy than would a black or gray body at the same temperature because the emissivity of tungsten decreases monotonically as the wavelength increases from the visible into the infrared. At 3000 K, only $\sim$11% of the total thermal emission will be radiated into the spectral regime of 400–750 nm by an ideal blackbody compared to $\sim$13% by a tungsten filament. Increasing the *emission* efficiency of the tungsten filament *per se* is not relevant to increasing the efficacy of the incandescent lamp. Rather, it is the increase of the emissivity differential between the visible region (approximately 400 to 750 nm) and the infrared region of the spectrum that will increase efficacy.

We have used the data on reflectance from Figure 3 of Ref. [1] to plot spectral emissivities normalized at 800 nm, $\varepsilon(\lambda)/\varepsilon(800\ \mathrm{nm})$, as displayed in Fig. 1. The functions for both the nanostructure covered laser induced periodic structure (NC-LIPSS) tungsten and the black tungsten increase with respect to polished tungsten above 800 nm but without appreciable change in the visible spectrum. The general trend is to increase the functions, $\varepsilon(\lambda)/\varepsilon(800\ \mathrm{nm})$ above 800 nm toward unity, i.e., blackbody value, at wavelengths longer than the wavelength of the laser irradiation. Thus, infrared losses increase with respect to visible radiation. Even if the absorptance peak is moved into the visible by suitably choosing the wavelength of laser radiation, the *energy* efficiency of tungsten filament cannot be improved because of the trend just mentioned. This behavior of relative emissivity is exactly opposite of what is desired to improve the efficiency of an incandescent light source.

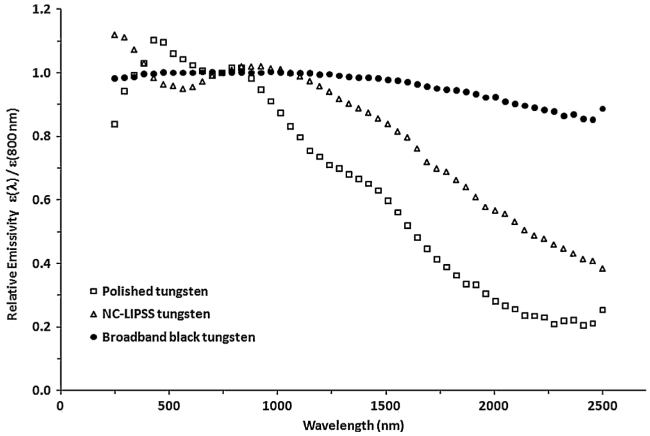

FIG. 1. Relative emissivity, $\varepsilon(\lambda)/\varepsilon(800\ \mathrm{nm})$ of polished tungsten compared to that of NC-LIPPS and black tungsten based on the absorptance calculated from the digitized reflectance data in Figure 3 of Ref. [1].

It is not surprising that the irradiated patch has become brighter relative to the untreated part. The area exposed to laser has higher emissivity, but in the infrared as well as the visible regions of the spectrum. In the absence of any data on power input and spectral power distribution in the article, a quantitative estimate of change in incandescent efficacy cannot be established.

In order to increase the efficacy of an incandescent light source, the filament material has to be made more absorbing (less reflecting) in the 400–750 nm range and less absorbing (more reflecting) at longer wavelengths. This type of change with NC-LIPPS tungsten has not been demonstrated. A 3D photonic band gap material with photonic band gap above 750 nm is more suitable for that purpose [2]. Even then, the stability of such structures at the operating temperature of $\sim$3000 K will remain as a major concern.

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[1] A. Y. Vorobyev, V. S. Makin, and C. Guo, Phys. Rev. Lett. **102**, 234301 (2009).
[2] J. G. Fleming, S. Y. Lin, I. El-Kady, R. Biswas, and K. M. Ho, Nature (London) **417**, 52 (2002).