Examination of metallic surfaces for IR gray body sources.

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1. Gray bodies

Testing and calibration of IR devices require the standard IR sources with precisely defined emissivity. In such case the black bodies with emissivity $\varepsilon = 1$ are usually used. With recent development of two- and multi-spectral techniques the gray bodies are also applied [1]. Their emissivity is usually from the $0.5 < \varepsilon < 1$ range. The use of gray bodies make it possible to test the data processing algorithms, namely, in multi-band pyrometry, the ability to measure correct temperature value regardless of actual emissivity of an object. In testing of IR cameras, the efficiency of NUC procedures can be verified.

Sources with known, stable emissivity value $\varepsilon < 1$ can be constructed using cavity emitters. Practical realization of such source was presented in [1]. The multi-cavity emitter is described there, with cone-shaped emitters. Different emissivity values are obtained through different shapes of the cones, defined by a configuration coefficient Fc:

$$Fc(H,D) = 1 - \frac{1}{\sqrt{4\frac{H^2}{D^2} - 1}} \qquad (1)$$

where: H – height, D- base diameter of the cone.

Relation between material emissivity ε and cone effective emissivity ε_{eff} is given by:

$$\varepsilon_{eff} = \frac{\varepsilon}{1 - (1 - \varepsilon)F_c} \qquad (2)$$

By changing the configuration coefficient it is possible to achieve the desired emisivity value ε_{eff}. The relation between effective emissivity and configuration coefficient can be approximated by the following function:

$$\varepsilon_{eff} \cong \varepsilon + (1 - \varepsilon) \cdot \varepsilon \cdot F_c \qquad (3)$$

It means, that it is possible to achieve effective emissivity equal or greater than the material emissivity ε. The emissivities are equal for a flat surface (Fc=0). With low material emissivity it is possible to obtain wide range of effective emissivity values by adjusting the configuration coefficient. Low emissivity is characteristic for metallic surfaces. Additionally certain metals, like gold or nickel, are resistant to environmental conditions thus assuring long-term stability of parameters over time.

The source described in [1] was designed to test a multi-band pyrometer, so outer cone diameters were rather small – around 25 mm. In case of universal device, suitable also for IR camera testing, this diameter should be considerably larger – around 100 mm. Low emissivity of smooth metallic surface poses a serious problem with achieving larger (close to 1) effective emissivity values and retaining rather compact size of the device. Increase of material emissivity value was an obvious choice, but achieved without the change of material. The solution was to apply appropriate mechanical treatment to the metallic surface in order to increase its roughness..

There is no analytic relation between emissivity and surface properties, there are too many factors involved. As a result, the choice of parameters of material processing was performed experimentally. Furthermore, the resulting surface finish should have anizotropic properties, which also limits the choice of available technologies. Finally, the sand-blasting with corundum abrasive was chosen, and the material properties depended on the abrasive grain size used in the process.

2. Measurement of surface roughness

After the initial analysis, the gold-coated aluminum was chosen as a cone material. The aluminum was sand-blasted prior to vacuum plating process, so the surface propertied were determined by the parameters of mechanical treatment. Three samples were prepared and the mean roughness Ra was increased twice with each consecutive sample.

The measurements were performed with optical profilometer Wyko NT1100, mainly to avoid damaging of gold layer. Comparative measurements were also performed using mechanical profilometer PGM-1C. additionally, the SEM microscope was used both in standard and in BaseScatter Electron mode. Sample surface scans from SEM microscope are presented in Fig.1.

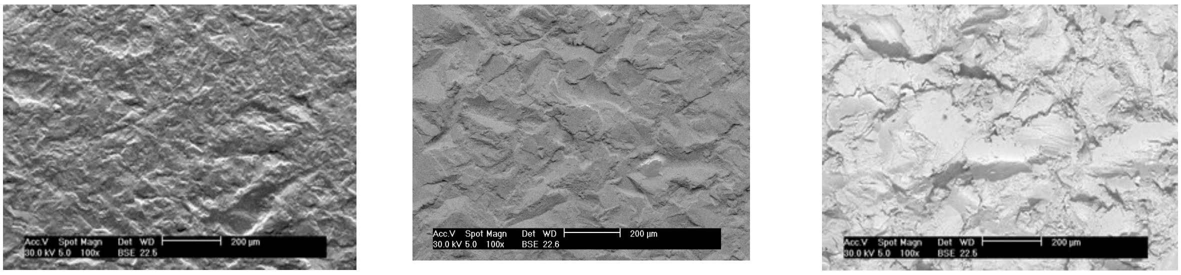

Fig. 1 *Surface images from SEM microscope*

Basic surface parameters are presented in Table 1 as well as the parameters of abrasive grains used to process the sample.

3. Evaluation of radiative properties

The thermographic emissivity measurements were performed using ThermaCAM P640 camera. It was necessary to apply close-up lens to assure adequate, small field of view required for the measurements of micro-scale effects. The angular emissivity characteristics (emissivity dependence on the angle of observation) was also measured.. Table 1 shows the measured emissivity value in normal direction for all tested samples.

Table 1. *Surface roughness and emissivity*

Sample		Au1	Au2	Au3
Grain size (Al_2O_3)		24/850/710	22/1000/850	16/1400/1180
Roughness	SR_a	5,27	8,98	11,63
	SR_z	53,99	95,04	110,93
	SR_q	6,71	11,37	14,72
Emissivity		0.18	0.23	0.28

4. Conclusions

Sand-blasting finish significantly changes the emissivity properties of tested samples. The gold-plated aluminum material processed as Au1 sample seems to be most suitable for manufacturing cavity emitters. Initial emissivity is low enough and light-scattering properties are sufficient to eliminate the influence of ambient thermal radiation.

REFERENCES

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