MEMS Narrow Band IR Emitters

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With nanophotonics, we play with light on the wavelength scale. With MEMS, we can fabricate silicon machines to manipulate light. The two meet at infrared wavelengths where the wavelength scale structuring matches with MEMS fabrication technology. We show that the combination of plasmonics and MEMS leads to novel thermal infrared emitters with a controllable linewidth. We contrast these emitters with other thermal emitters currently on the market and discuss the reasons for the improvements seen as well as the challenges in further improving thermal emitters.

LEDs are efficient and cheap light sources with good spectral purity. Over the last ten years they have slowly replaced tungsten light bulbs, which have dominated interior lighting since the days of Edison. The problem with light bulbs is that they are thermal sources, and only some of the radiation is emitted at visible wavelengths, with the rest being lost as heat.

At infrared wavelengths, the equivalent of a light bulb remains the source of choice for cost-sensitive applications. All of the drawbacks that light bulbs have in the visible also exist in the infrared. LEDs in the infrared are very inefficient due to leakage currents and the lack of direct band gap materials.

The goal of this work is to use techniques from nanophotonics to create MEMS thermal emitters that are wavelength selective. Thermal emission is given be the temperature and emissivity of the hot object. The emission spectrum is normally the product of the blackbody radiation spectrum (broad) times the material emissivity (flat). The only parameter that can be engineered is the emissivity. From Kirchoff's law, the emissivity is proportional to the absorption of the material.

Our approach is to take a weakly absorbing material and make it selectively absorbing at a given wavelength. There are two classes of weakly absorbing materials: transparent materials and highly reflective materials. In the infrared, most highly conducting metals are also highly reflective and have a very low emissivity. We can change this dynamic by texturing the metal.

The famous enhanced optical transmission of light through sub-wavelength metal holes relies on surface waves travelling a long distance over the metal. If this distance is sufficiently long, the wave is absorbed rather than transmitted. This resonance effect can be tailored by varying the periodicity of the holes, the size and shape of the hole, and also the thickness of the metal layer.

Following these principles, we manufactured a MEMS emitter according to specific design parameters. The emitter is based on a SiN membrane that is a few hundred nanometers thin and a thin metal (Pt) film on its sides. The metal layers play the role of a heating element, but it also allows for the surface plasmon propagation. The emitting area is scalable, and in the chosen design, 1 mm x 1 mm. The devices were processed in clean rooms and characterized with respect to state of the art emitters.

The MEMS emitter indeed shows emissions that are much narrower than a thermal source. In addition, the device can be modulated at 20 Hz with rise times in the order of several milliseconds.

Figure 1 shows an image of a functioning device. Some light emission is visible in the image. The spectral response was measured using a Fourier Transform Infrared Spectrometer (Bruker Vertex 70) and compared with a commercial blackbody source. From this, we can derive the emissivity as a function of wavelength. As seen in Figure 2 the emissivity shows a narrow peak at the design wavelength (7.8 microns) and a very flat, low emissivity at shorter wavelength. We have designed similar devices that operate at 4.3 and 6.1 microns.

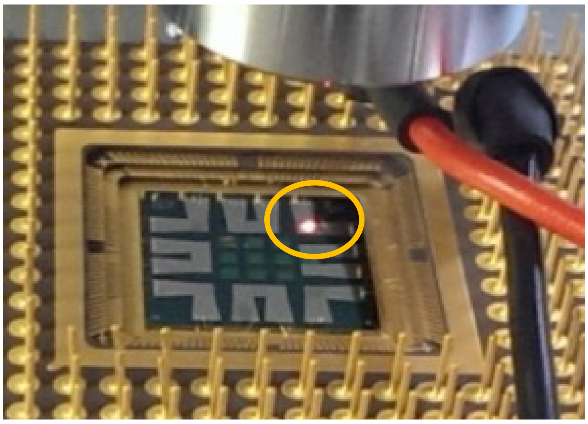

Figure 1: An image showing a working MEMS emitter. The white spot is visible light emission from the hot emitter. The MEMS emitter is housed in a large test package and is under an infrared Fourier transform microscope.

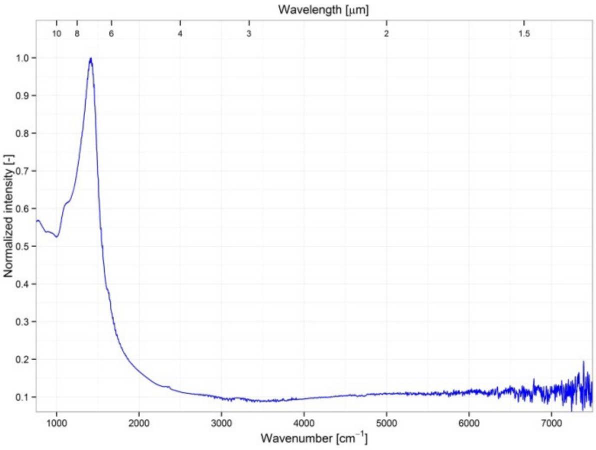

Figure 2: The emissivity of an MEMS thermal emitter using CSEM's hole array technology. The figure shows the emission as a function of wavelength (µm, top axis), and wavenumber (cm^{-1}, bottom axis). Note the low emissivity (0.1) across a wide range of wavelengths in comparison to the high emissivity peaked at 7 µm (1300 cm^{-1}).

In conclusion, we show that an inexpensive MEMS membrane can be designed and microfabricated to have a narrow spectral emission. Not only is the technology cost effective, but it enables the development of low power sources for gas detectors.

CSEM has filed a patent on the technology.