Abstract

This PhD project focuses on the development and characterisation of a hyperspectral thermal imaging system. The imaging system is based on a commercial microbolometer sensor, with a sensitivity in the long wave infrared (LWIR) range between 8 and 14 µm, followed by a scanning Fabry-Pérot interferometer (FPI) in front of the collecting optics. The hyperspectral datacube is therefore plane scanned, which allows the camera to build the hyperspectral datacube while being statically mounted.
The scanning FPI, acting as a wavelength filter, operates in the first order. The most essential components in the FPI are the thermal mirrors which constitute the focus of the first part of this thesis. Initial physical vapour deposition (PVD) experiments provided thermal mirrors that lead to hyperspectral thermal images which documented the concept of the imager. A mirror was produced by using a recipe which consisted of three-layer-structure including an absentee layer at the design wavelength of 10.5 µm. The thermal mirror recipe comprised of an antireflective coated ZnSe substrate upon which a Ge/BaF_2/Ge-coating was deposited. The two mirrors used in the FPI showed average absorption values of 10.5 % and 6.8 % measured by standard Fourier transform infrared spectroscopy (FTIR) measurements combined with a reflection-configured FTIR measurement. The mirrors were incorporated into an FPI and used to acquire hyperspectral thermal images. It was shown that the difference in the emission spectrum of five samples of polyimide tape, a carbon nanotube coated aluminium surface, borosilicate glass, black painted aluminium, and bare aluminium was measurable at 100 °C as opposed to the measurements of the emitted thermal radiation at room temperature (RT). The RT measurements were very inefficient using the high absorption homegrown mirrors, and at the final part of this project, commercially coated thermal mirrors were purchased and incorporated into the FPI. These mirrors consist of an antireflective coated ZnSe substrate coated with a Ge/ThF_4/Ge coating with absorption values of <2 % within the sensor sensitivity range measured by a combination of FTIR and FTIRR measurements. These mirrors were incorporated into the FPI and used to acquire hyperspectral thermal images. A logistic regression model was used to differentiate between polyimide tape, Al_2O_3,

borosilicate glass, fused silica, and Al_2O_3 ceramic at temperatures as low as 34 °C. Each material was recognised with true positive rates above 94 %, calculated from the individual pixel spectrum. The surface temperature of the samples was subsequently predicted using pre-fitted partial least squares (PLS) models, which predicted all surface temperature values with a common root mean square error (RMSE) of 1.10 °C whereby it outperformed conventional thermography.
The last chapter concerns applications of the hyperspectral thermal imaging system developed in this thesis. Two separate images are analysed and documents a strong segregation of organic gasses based on transmission spectra, and a promising segregation of polymers based on emission spectra at 100 °C compound temperature.
In summary, it is concluded that an FPI based hyperspectral thermal imager is a viable instrument for hyperspectral acquisition of light emitted within the LWIR range.