Fraunhofer
CSP

FRAUNHOFER CENTER FOR SILICON PHOTOVOLTAICS CSP

MACHINE LEARNING IN POLYMER CLASSIFICATION FROM HYPERSPECTRAL IMAGING AND RAMAN SPECTROSCOPY

Marko Turek*, Roman Worschech, Jan Bauer, Christian Hagendorf

Fraunhofer Center for Silicon Photovoltaics CSP, Otto-Eißfeld-Straße 12, 06120 Halle (Saale), Germany

* Corresponding author: Tel. +49 (0) 345/5589-5121, marko.turek@csp.fraunhofer.de

INTRODUCTION AND MOTIVATION

High-throughput classification of plastic types

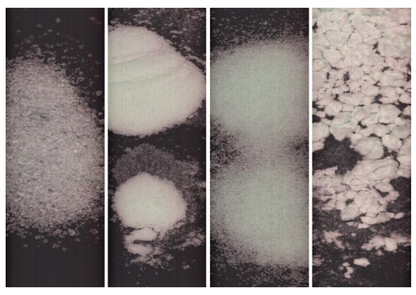
1. **Example: Microplastic** detection and classification:
   Increasing contamination of water and air requires fast analytic routines
2. **Example: Recycling** of compound materials (e.g. photovoltaic modules):
   Separation of materials requires separation of materials

Challenge: Automated and universal data analysis approaches for spectral imaging techniques (e.g. Raman spectroscopy, FTIR, hyperspectral imaging)

TEST SAMPLES AND IMAGING METHODS

Typical sample setup:

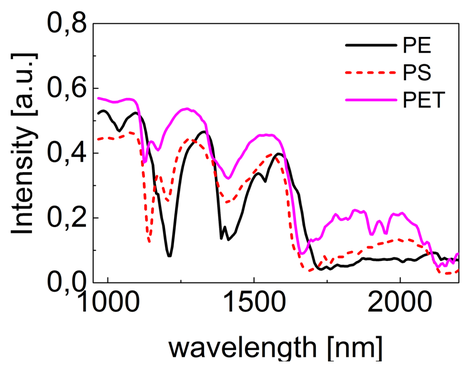
1. Six types of plastics analyzed
   (PP, PS, PVC, PET, PA, PE)
2. Large samples, powder and micro-particles
3. Environment: air or water



Example: plastic powder

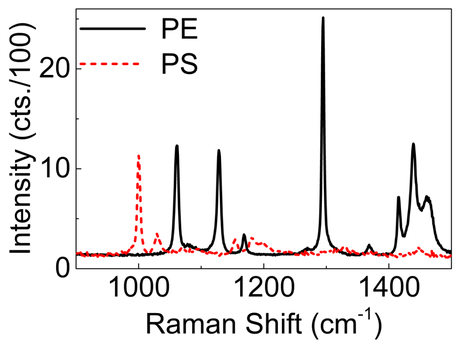
Hyperspectral imaging (HSI):

1. Measurement of spatially resolved reflection spectra in visible and infra-red wavelengths
2. Large data set of high-dimensional data:
   each pixel with entire spectral information



Raman spectroscopy:

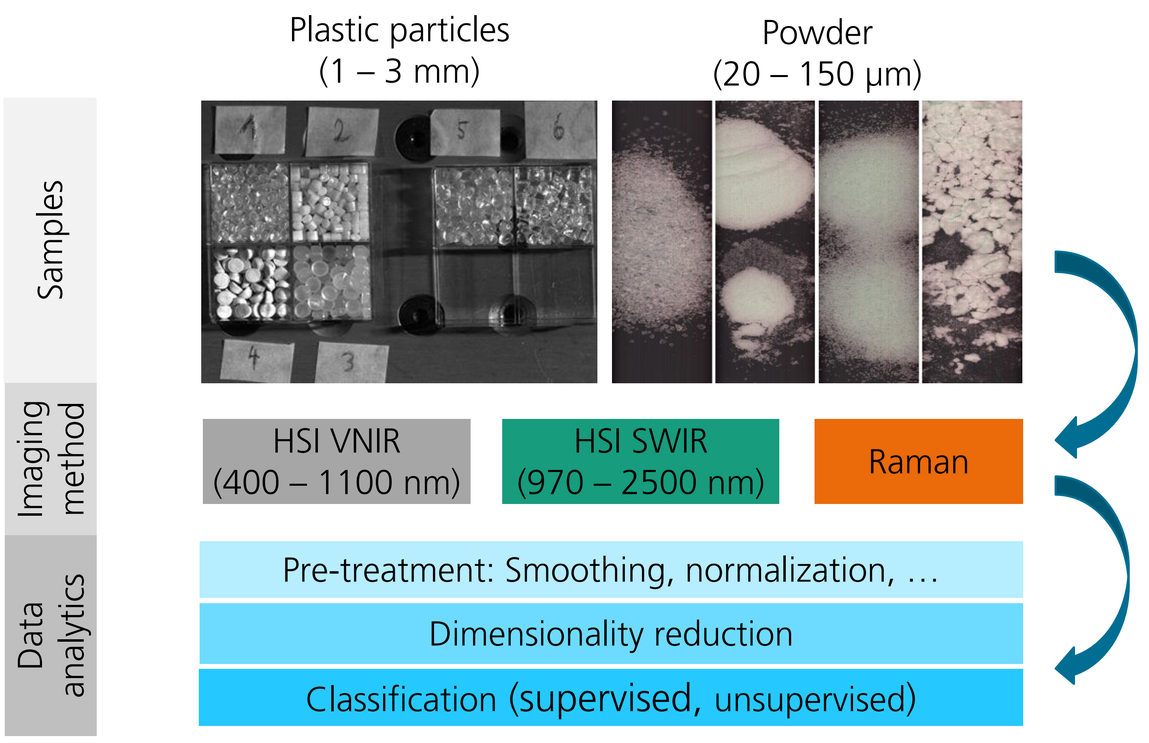
1. Measurement of material properties by inelastic scattering of light
2. Large data set of high-dimensional data:
   each pixel with entire spectral information



Spectroscopic material analytics:

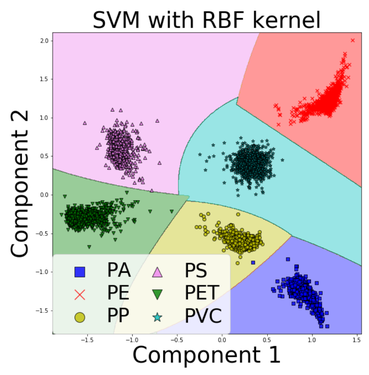
- Measurements yields **large data sets** (one spectrum for each pixel)
- Efficient, **automated and universal** data **algorithms** required
- **Machine learning approach** and artificial neural nets

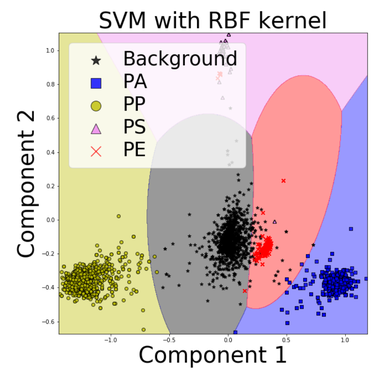
DATA ACQUISITION AND ANALYTICS APPROACH



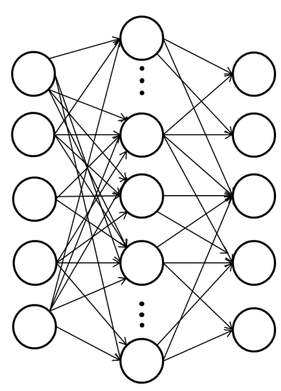
RESULTS: VERY HIGH CLASSIFICATION RATES ACHIEVABLE

Classification models: Support vector machine





Artificial neural net



2dim LDA for HSI

actual class \ predicted class	PA	PE	PP	PS	PET	PVC
PA	1084	0	1	0	0	0
PE	0	1032	0	0	0	0
PP	0	0	1133	0	0	0
PS	0	0	0	1077	0	0
PET	0	0	0	0	1008	0
PVC	0	0	0	0	0	1091

Confusion matrix HIS – SVM

2dim LDA for Raman

ANN structure

actual class \ predicted class	PA	PE	PP	PS	PET	PVC
PA	1085	0	0	0	0	0
PE	0	1032	0	0	0	0
PP	0	0	1133	0	0	0
PS	0	0	0	1077	0	0
PET	0	0	0	0	1008	0
PVC	0	2	2	0	0	1087

Confusion matrix HSI – ANN

Machine learning and artificial neural nets:

- Almost perfect classification achievable on test system
- Raman and Hyperspectral imaging as data basis possible
- Both methods reliable (support vector machines or neural nets)

ACKNOWLEDGEMENTS

Financial support by the BMBF within the "RUSEKU" project (FKZ 02WPL1442D) as well as support and HSI-data by Fraunhofer IFF Magdeburg is gratefully acknowledged.