Topics

- Introduction
- Axsun Technologies
- ID Needs
- Anavo Analyzer - Carpet Identifier
- Application – Carpet ID
- Lessons Learned
- Other applications
  - Plastics
  - Quant
  - On-line possibilities
- Conclusion
Axsun Technologies is a leader in the design and manufacture of products based on micro-scale optoelectronics.

- Founded in 1998
- Locations
  - Billerica, MA
  - Livermore, CA
- About 100 employees
Axsun Technologies designs and manufactures “spectral engines” and analyzer systems for a wide range of customers.

These engines enable the transformation of sophisticated laboratory instruments to embedded systems and sensors for outside-the-lab...anytime, anywhere measurements.
Spectral Engine Foundation Technology

- Axsun manufactures
  - Optical devices
  - Dedicated complete solution products
- Proven, high-yield manufacturing process
  - Over 10,000 spectral engines shipped and in use
  - Over 100 Million device hours
“Powered by Axsun” Products Today…

Pharmaceutical Manufacturing
(Pfizer, GSK, Wyeth, Merck, etc.)

Telecommunications
(Siemens, Lucent, Huawei, etc.)

Food/Petrochemical

Recycling/Chemical

Semiconductors

Pharmaceutical Process
(Thermo Electron)

Pharmaceutical & Petrochemical Development
(GE Sensing, Pfizer, GSK, BP, etc.)

Food/Petrochemical
Carpet Recycling challenges

Issues / Challenges / Concerns

- Focus
- Speed
- **ID Technology**
- Geographical coverage
- WtE vs. Reuse & Recycle
- Funding
- **Volume**

Bob Peoples
Fiber ID Units
Technical Requirements

- Fast reading time (< 1 sec)
- Accurate and repeatable
- No “false positive” readings
- Not affected by fiber color
- Not affected by carpet texture
- Not affected by moisture
- Not affected by dirt
- Not affected by topical add-ons
- Available, updatable ID library

Bob Peoples
2005

Manual tests

Large/Expensive fixed in-place / rolling solution

Unreliable solution
2006

- New rapid id system introduced
  - Developed in partnership with carpet recycling leaders
  - < 1 second analysis time
  - Battery operated
  - High identification fidelity
• Anavo™ Analyzer carpet Identifier
  – Rugged .....more later
  – Ergonomic
  – CARE LED color scheme
  – Internal, automated reference
  – Audio response
  – Shoot out or down
  – Audio
  – < 1 second analysis

• Anavo™ Analyzer Material Analyzer
  – For sorting larger # of material types
  – For quantitative testing

• Competitive products
  – Phazir
Anavo™ Analyzer Design

• Uses Axsun core mini-spectrometer
  – Existing / Production unit made in some volume
• CARE key feature list
• Product design considerations
  – Survivability
  – Ergonomics
  – Size / weight
  – Flexibility
• Developed closely with carpet recycling industry leaders
• Extensive interaction between our design engineers and the end users
  – Site visits
  – Design reviews through the process
  – Work-flow studies
Got our engineers out of the clean room
Real-world input

Prototype Testing

Real-time software modifications
**Anavo™ Analyzer**

- **Environmental Protection**
  - Sealed/Gasketed assembly to prevent internal damage from
    - Dust
    - Moisture
    - Grit

- **Ruggedness**
  - Integral shock bumpers
  - Survives 3 foot drop to concrete

- **Power**
  - Quick swap battery for portable operation
    - Up to 8 hour battery life
    - Commercially available battery
Drop testing performed
• 3 Feet to concrete
• All angles

Drop Testing
Dropuse.mpg

More drop testing
droptest2.mpg
Survival test
An Anavo™ Analyzer carpet identifier recently went through a baler
- Anavo™ Analyzer still powered up!
- Internal cable disconnected
- Reconnected cable → system correctly identifies final test carpet sample set!
Data Entry/Logging software

Wireless or wired
Data saved to Excel files
Anavo™ Analyzer Carpet Identifier Specifications

- Measurement time
  - < 1 second
- Temperature Range
  - 40° – 115°C
- Audio
  - On-board system or ear-piece
- Protection
  - IP 52 (dust etc.)
  - 3 Foot drop to concrete
- Power
  - Battery (quick-swap)
  - Line-cord
- Calibration
  - Internal, automated
- Libraries
  - Updatable using off-the shelf software

Standard unit identifies:
- Nylon 6
- Nylon 66
- PET
- Polypropylene
- Wool
- Unknown
What does Anavo™ mean?

Company Lawyer:
I did a trademark search on all of the excellent product names you suggested.

Every One of Them is Taken.

So I did a search on the names that weren't so great.

Those are taken too.

Then I checked on the names i crud, i puke, eatdirt, and defective product.

All taken.

So our new product name will be a combination of grunts and shrieks.

Like this?

Grrrr-eeey-aaa?

That one is taken. Ours sounds more like a monkey passing a kidney stone.
Carpet Identification Application
Modeling (Chemometrics)

- Building a mathematical equation that relates a spectrum collected from a sample to some information of interest
  - Concentration (Quantitative)
  - Identification (Qualitative)
Model Development Software Flow

1. Collect Calibration Set
2. Develop Library/Calibration
3. Save Model
4. Download Model to firmware
5. Initiate Scan → Spectrum
6. Apply Processing
7. Apply Model → Result
8. Report Result

- Standard chemometrics package
- Utility program
- SNV, First/Second derivative, combination, others
- KNN, SIMCA, PLS, others
- Display result
System Calibration Test Samples

Test Samples Supplied by customer
Models / Libraries

• Ability to update is essential
  – Add known samples miss-identified to library
  – Add new materials
    • PTT/Sorona
    • PVC

• Need to include appropriate rejection criterion / limits
  – “Unknown” is far better than wrong!

• Calibration set includes variations in
  – Colors
  – Texture
    • Cut Pile
    • Cut and Loop pile
    • Level loop pile
    • Etc.
Carpet Application

- Over 500 carpet samples supplied by customers for initial model development
- Additional samples collected over time, calibration data base currently > 1,000 samples
- Extensive field testing at multiple sites performed to validate the accuracy of the system
  - Millions of samples tested
  - System accuracy and speed passed all aspects of validation and wider deployment initiated
Infometrix Pirouette is an industry standard modeling package
- Documented, tested, training programs etc.

Pirouette transforms supported:
- SNV, derivative, baseline correction

Pirouette Algorithms supported:
- Qualitative analysis (ID) algorithms. (SIMCA + KNN)
- Quantitative analysis algorithms. (PLS)

Customers, Axsun or consultants can develop models and download them to the analyzer
- Allows for improvements and reconfiguration
Axsun’s system can accurately identify wet samples.

Mathematical correction applied to minimize distortions due to water in samples.
“Dirty” Samples

• Extensive testing has been successfully performed on “real-world” used carpet samples

• Operators are trained to perform the analysis on a piece of the carpet sample that doesn’t have obviously large grease/oil contamination
Blended Carpets

- Blended Carpets contain more than one material
  - Example: Nylon 6 / Polypropylene Blends
- The spectra for the blended samples will contain features of both blended materials
- Blended carpets that aren’t predominantly one material will be classified as “Unknown”
**Dark Carpets**

- Very dark samples “Absorb” much more light than lighter samples.
- Data processing normalizes this intensity effect for most samples.
- Samples that are too absorbing will be classified as “Unknown.”
- This is a very small percentage of carpet materials.

![Graph showing absorbance and absorbance-SNV for light brown and dark brown samples.](image)
Things we’ve learned

• Buttons
• Seals

• Training / Sampling
  – Ex. contact vs stray

• Support
  – Updates and support over internet
  – Hot swaps
  – Quick turn around
  – Model enhancements to improve performance or change application
• Feedback from customers that have evaluated prototype systems has been extremely positive
  
  – “It’s really really fast!”

  – “They love it. Great job.”


  – “You mean it doesn’t need a cooling jacket above 75 degrees and a tea cozy below 50?”

  – “The most exciting development since the conference took place is the field trials of a new Axsun identification unit.” – CARE Newsletter, Feb 2006
Other Applications in Recycling
Plastics/Polymers

- Nylon 6
- Nylon 66
- Polyester
- Polybutylene terephthalate (PBT)
- Polycarbonate
- ABS
- Blends of PC/ABS (in increments of at least 5%)
- High Impact Polystyrene (HIPS)
- Polystyrene (PS)
- Polysulfone (PSO)
- Polypropylene (PP)
- High Density Polyethylene (HDPE)
- Low Density Polyethylene (LDPE)
- Polyphenylene Sulphide (PPS)
- PVC
- Ethyl vinyl alcohol (EVA) – barrier film for bottles
- Polylactic acid (PLA)
Library currently contains
> 500 scans of > 30
different materials

- Solid pieces pre shredding
- Shredder output
- Pellets
- Flake
Other applications

• Plastics
  – Identification
  – Quality for incoming/outgoing material

• Quantitative analysis
  – Ex. Composition of mixed polymers or blended fibers
    • Requires training set with known concentrations

• On-line analysis
  – Measuring stream of fiber on conveyor before adding to the process
CARE Needs – Axsun Anavo™ Analyzer

- Fast Reading time (< 1 sec.)
  - < 1 second readings
- Accurate and repeatable
  - Validated with millions of samples
- No “false positive” readings
  - Extremely rare, if so update library
- Not affected by fiber color
  - Validated in the field, exception is dark black
- Not affected by fiber texture
  - Validated in the field
- Not affected by moisture
  - Moisture removal processing
- Not affected by dirt
  - Validated in the field
- Not affected by topical add-ons
  - No effect reported
- Available, updatable ID library
  - Yes using commercial model development software
Anavo™ Analyzer

- Available for lease through Shaw/Infiltrator Systems
- Available from Axsun
- Direct lease option available based on your input
Thank You
Any Questions?

AXSUN Technologies Inc.
Tel: 978-262-0049
Email us at info@axsun.com
www.axsun.com