INTEGRATION OF STRETCHABLE OPTICAL WAVEGUIDES WITH SOURCES AND DETECTORS

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Why stretchable/flexible? (for sensing)
Why optical (waveguides)?

Why integrating sources?
Dedicated integration process for precision optical components

SOME RELATED APPLICATIONS
WHY FLEXIBLE / STRETCHABLE (SENSING) SYSTEMS?

- Making “ultra-thin” (sensing) systems
- Unobtrusive systems → wearable, “on body” applications
- Examples: artificial skin

www.Tekscan.com
www.OttoBock.com
www.Tekscan.com
“Domo Robot”, Edsinger, MIT
(www.shadowrobot.com)
WHY FLEXIBLE / STRETCHABLE OPTICAL SYSTEMS?

- Stretchable electronics well-known technology
- Optical systems increasingly important
- Number of advantages (e.g. optical sensors vs. electrical)
- Therefore

Stretchable optical interconnections (=waveguides)
What is an optical waveguide?

How do we make it?
STRETCHABLE OPTICAL WAVEGUIDES: CONCEPT

“Only” flexible waveguide, but meandering

(B. Van Hoe)

Straight waveguide channels, but from stretchable material
STRETCHABLE OPTICAL WAVEGUIDES: FABRICATION

Transparent, rubber-like, “PDMS” materials

(a)

(b)

(c)
STRETCHABLE OPTICAL WAVEGUIDES: FABRICATION

Sylgard®184 (Dow Corning)

$\eta_{\text{core}} \approx 1.57$

$\eta_{\text{clad}} \approx 1.41$

$NA \triangleq \sqrt{n_{\text{core}}^2 - n_{\text{clad}}^2} = 0.69$

→ allows small bending radii
STRETCHABLE OPTICAL WAVEGUIDES: FABRICATION

The microstructures clearly guide light

Bendability + stretchability of the final waveguide sample
WHY INTEGRATING SOURCES AND DETECTORS?

» Waveguide without sources, detectors = useless
» Integration = needed for operation under deformation

» Micrometer waveguide dimensions
  » Requires integration on the micrometer level
  » Bulky, packaged components cannot be used
  » We propose: ultra-thin, flexible OE package

» Additional advantage: the complete system becomes deformable, wearable, portable.
INTEGRATING SOURCES AND DETECTORS: ULTRA-THIN OE PACKAGE

1\textsuperscript{st} step: use of bare die chips + thinning
\begin{itemize}
  \item Final (bare die) thickness \approx 20\mu m
  \item Lapping & polishing steps
  \item (re-)apply back contact if needed (single mode VCSELs)
\end{itemize}

2\textsuperscript{nd} step: embedding of thinned bare dies
EMBEDDING OF BARE DIES

2nd step: embedding in polymer layers

(a) Applying a polyimide and SU-8 layer

(b) Defining a cavity (via laser ablation or lithography)

(c) Placing the thinned chip in the cavity using a glue

(d) Leveling of the chip in the cavity
EMBEDDING OF BARE DIES

2\textsuperscript{nd} step: embedding in polymer layers

(e) Covering with SU-8 and creating vias to the contacts

(f) Metalizing the vias

(g) Applying a covering SU-8 and polyimide layer
EMBEDDING OF BARE DIES

2\textsuperscript{nd} step: embedding in polymer layers: results

Human hair

Laser / detector chip

~40µm thin foil

80 µm
2\textsuperscript{nd} step: embedding in polymer layers: results cross-section images

Back contacted single-mode laser chip

(results B. Van Hoe)
INTEGRATING SOURCES AND DETECTORS

Placement of a 45° mirror-plug on the optoelectronic package
INTEGRATING SOURCES AND DETECTORS

Aligning + bonding with the waveguide array
INTEGRATING SOURCES AND DETECTORS

Resulting waveguides + sources / detectors
INTEGRATING SOURCES AND DETECTORS

Resulting waveguides + sources / detectors

- waveguide array
- mirror plug
- 1x4 VCSEL array
- 1x4 VCSEL array
- 1mm
- 0.5mm
INTEGRATING SOURCES AND DETECTORS

Resulting waveguides + sources / detectors
OPTICAL LINK: LOSSES?

Light in → waveguide → light out?
OPTICAL LINK: BENDING LOSSES?

Light in ➔ bended waveguide ➔ light out?
OPTICAL LINK: STRETCH LOSSES?

Light in ➔ stretched waveguide ➔ light out?

Up to 30% elongation tested
OPTICAL LINK: STRETCH LOSSES?

Light in ➜ stretched waveguide ➜ light out?

30% elongation

Very limited stretching induced loss!
OPTICAL LINK: RELIABILITY?

Light in $\rightarrow \infty$ stretched waveguide $\rightarrow$ light out?

(10% elongation)

Very limited variation over time!
ALTERNATIVE APPLICATIONS

applications: ultra-thin (sensing) systems
THANK YOU