Formation of Optical Coupling Structure between Silica Glass Waveguides and Molten Tellurite Glass Droplet

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\[ l \sim 0.6 \text{ mm} \rightarrow v \sim 0.007 \text{ mm}^3 = 7 \text{ nl} \]
Optical Coupling Structure btw Silica Fibers & Tellurite Glass.

**Fabrication method**

*How did we make it? What is the advantage?*

**Optical performance**

*How much is the loss? Is it adequate?*

**Possible application**

*What can it be used for?*
Fabrication method

Property gap btw the two

<table>
<thead>
<tr>
<th>Thermal expansion coefficient ($\times 10^{-7}/^\circ C$)</th>
<th>Refractive index</th>
</tr>
</thead>
<tbody>
<tr>
<td>170</td>
<td>80TeO₂-20ZnO glass 2.08</td>
</tr>
<tr>
<td>~6</td>
<td>Silica glass 1.46</td>
</tr>
<tr>
<td>26.3</td>
<td>Silicon —</td>
</tr>
</tbody>
</table>

\[\uparrow \text{OK!} \]

- **PLC**: SiO₂ layer $\sim 30\mu m$ over Si substrate

Fresnel refraction $\sim 0.1\text{dB} \times 2$
**Fabrication method**

- **Spot heating**: 10mm, upto 500°C
- **Micro sampling**: automatic chopsticks:-)
- **glass**: $80\text{TeO}_2-20\text{ZnO}$
  - $100\text{TeO}_2$  
  - $(in\ mol\%)$
- **fibers are cut by** a commercial cleaver
  - $(\angle = 90 \pm 0.6^\circ)$

**Equipment**

- Pt plate + Heater
- Fiber Holders
- CCD Cameras
- (1) (2) (3)
Fabrication method

Temperature control is critical

- too high

- too low
Measuring internal reflection

- Valid for Single-mode fibers
- resolution: 20µm
Optical performance

Internal reflection distribution

No reflection due to precipitates!
Optical performance

Insertion loss: air vs. glass

Insertion Loss, $\ell$/dB

Distance btw fibers, $d$/mm

$\lambda=1.31\mu m$

with air

with glass

Pull length

80TeO$_2$-20ZnO
Optical performance

Ins. loss: value & variation

- Large loss value
  - Lack of waveguide structure

Variation
- in Loss (●●) : Disalignment
- in Distance (↔) : Solidification during pulling

Emmision of Er$^{3+}$, EX: 800nm
Fabrication method

100TeO₂ is precipite-free?

Not yet checked by XRD, but...

- ✔ No light reflection from inside
- ✔ Insertion loss: same as 80TeO₂–20ZnO
- ✔ Can survive the bending test

⇒ No harmful precipitates for optical applications
Quenching rate is very high!

TeO$_2$—ZnO by Marinov et al. ('72)

This work

Glass forming region by Burger et al. ('92)

Twin—roller

Copper mold

Carbon mold

TeO$_2$ 100%

Cooling rate (K/s)

10$^3$ 10$^2$ 10$^1$ 1

10$^{-1}$ 10$^{-2}$

Assuming precipitate-free,

Quenched at

$\sim 10^3$ K/s.

TeO$_2$ (mol%)

Zn$_2$Te$_3$O$_8$

Temperature (°C)

400 600 800

60 70 80 90 100

$\triangleright$ Quenched at

$\sim 10^3$ K/s.
Fabrication method

Heat history

Merit: Can suppress precipitation

☞ Wider choice in Composition
"Nature chose ones to be fiber, but the others can join fibers."

S. Todoroki (2002)
Possible application

No waveguide, No use.

Demerit: Lack of waveguide structure

To be improved:

- Insertion loss \(\downarrow\)
- Var. of Insertion loss \(\downarrow\)
Possible application for reducing insertion loss

- Make a waveguide structure afterwards
  - by fs-laser pulse irradiation
- Use TEC fibers
Possible application for reducing variation in loss

- More rigid void is needed.

☞ How about "Melt on chip" like soldering?

Planar Lightwave Circuit vs. Electric Circuit
Possible application

Stress tolerance test

• Tellurite glass melt is inserted into Silica glass ferule (ID : $126^{+3}_{-0} \mu m$) at $800^\circ C$

☞ No fracture if $\ell \leq 2$mm

• Can insert melt into sub-mm void
Possible application

How about microcavity?

Spillane et al.,

- Silica glass microsphere
- Ultra-low threshold (∼ 60 μW) for Raman lasing

- Existing microspheres are to be improved.
  - Small Q-value due to small refractive index
  - Ununiformity of reheated glass powder
  - Fast deterioration of the dye

☞ Tellurite glass microcavity?
SUMMARY

Optical Coupling Structure btw Silica Fibers & Tellurite Glass.

Fabrication method

Even TeO$_2$ melt is quenched without precipitation.

Optical performance

$\sim 10$dB loss can be improved by n-modulation.

Possible application

Hybrid device where soft glass meets a-silica device.