Effects of metallization on TlBr single crystals for detector applications

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PSD-7, Liverpool, GB, 2005

TlBr properties

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- high atomic numbers Z: 81+35 => stopping power
- density (7.56 g/cm3) => compact device
- bandgap (2.68 eV) => room temperature
- inter-pixel resistance ~500 GΩ (gap 100μm, 50V) => 2D-array detector*
- optical transparency: 440nm – 50μm => scintillator?

*Owens *et al.,* Nucl. Instr. and Meth. A 531, 18 (2004)

Material problems

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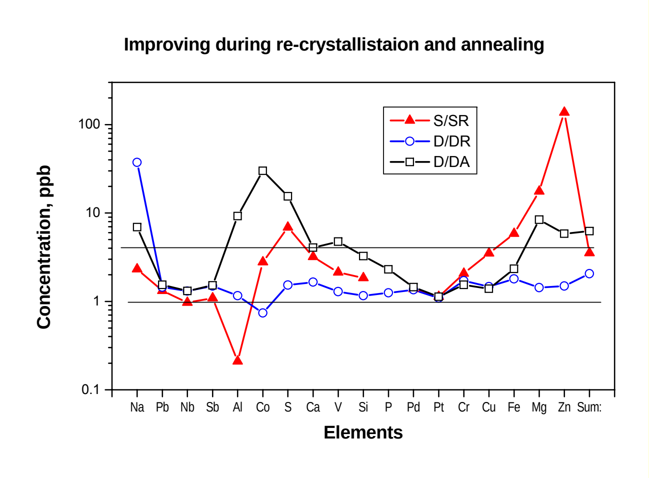
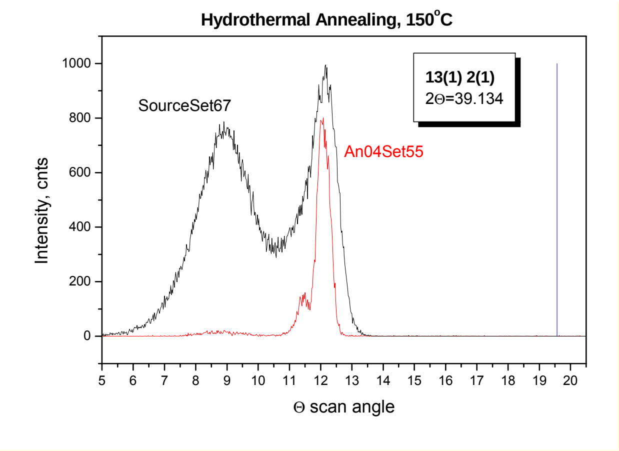
- **Purity**
- **Crystal quality**
- **Manufacturing process**

  (Knoop hardness of 12 kg/mm2)

- **TlBr – toxic compound**





Metallization methods

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Chemical: photographic process, Pd-dielectrics
=> possible **water** inclusion => **X**

Glue: Ag- and graphite-paste
=> crater formation, if poor crystal quality
properly treated samples: 2.5 kV/cm

Physical: vapour (PVD),
electron beam and
sputtering deposition methods =>

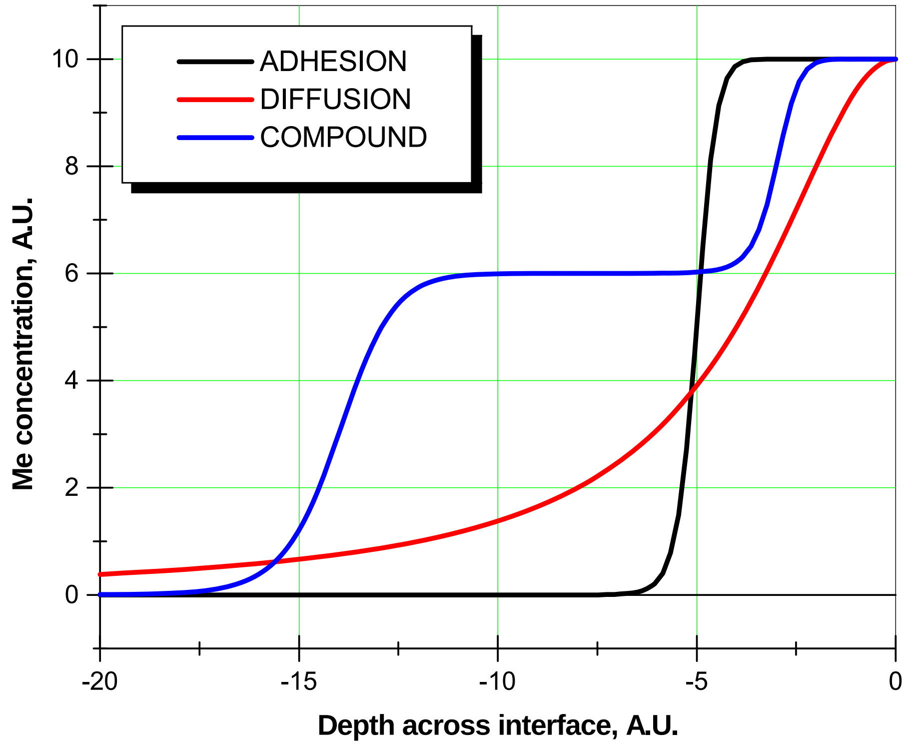
Melt: metal melting on TlBr surface =>

Interaction at the interface

“Adhesion”:
physical deposition

“Diffusion”
physical or melt methods

“Compound”
melt deposition or
physical + annealing



Metal – Tl halide interface parameters

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TlBr (mp = 460°C)

"Adhesion"

"Diffusion"

"Compound"

Metal	mp, °C	Tensile strength*	Stability*	Electro-negativity
Cu	1083	24	Atm	1.9
Ag	962	27	Atm	1.9
Au	1064	27	Atm	2.4
Zn	419	13		1.6
Cd	321	36		1.7
Al	660	Split.	Bad	1.5
In	157	18	Good	1.7
Tl	304			1.8
Sn	232	6		1.8
Ti	1660	18	Good	1.5
Cr	1857	14	Good	1.6
Fe	1535	23	Good Atm	1.8
Co	1495	22	Good	1.8
Ni	1453	22	Atm	1.8
Mn	1244	X	Bad	1.5
Mg	649	X	Bad	1.2

Abr.: Atm. - unstable in atmosphere,
Split. – Splitting
X – Chemical reaction

*Me-thickness – 0.5 μm
units - MN/m^2 [6, 8]

Results: Vacuum deposition

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Electron beam evaporation:

thickness 25 and 40 nm Ti, Cr and Al

⇒ Ti and Cr: good electrical contacts, stable for **~year** in a laboratory environment

⇒ Al: stable during all measurements for **several days**

Fe and Ni – direct contact with **TlBr molten**

=> No reaction, if pure metals and complete degassing of system

=> Ni-boat was used for the melting of TlBr powder

Output:

- Ti, Cr, Fe and Ni elements were inert to TlBr
- Ti and Cr could be used as reliable electrodes
- Al ?

Results: Al/TlBr interface

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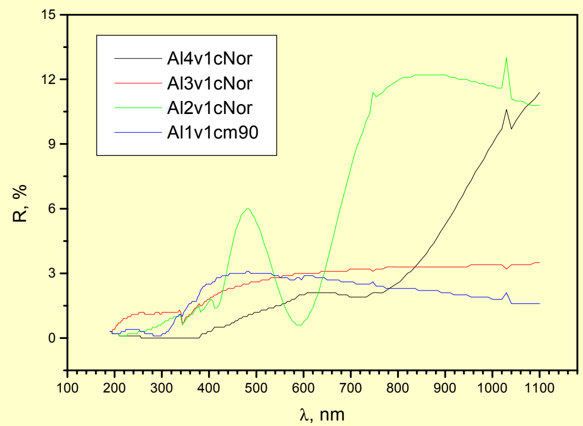
TlBr was deposed on a clean Al surface:
(surface temperature control)

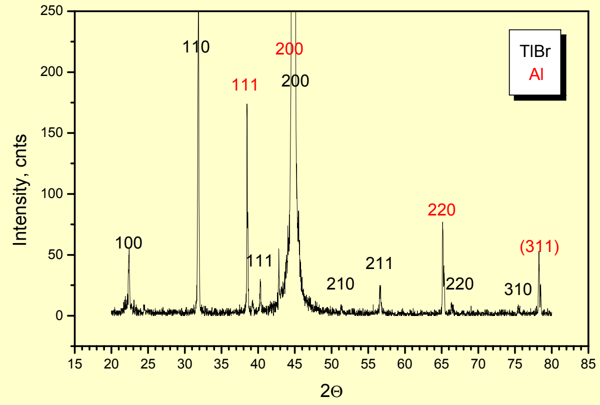
- t < 100°C => fine films, R% spectra
  => stable for ~year, XRD

- t > ~150°C => Tl-drops on Al
  => amorph. phase + Tl peaks

Al(solid) + 3TlBr(gas)
=> 3Tl(drop) + AlBr3(gas)

Output: no heating, low current





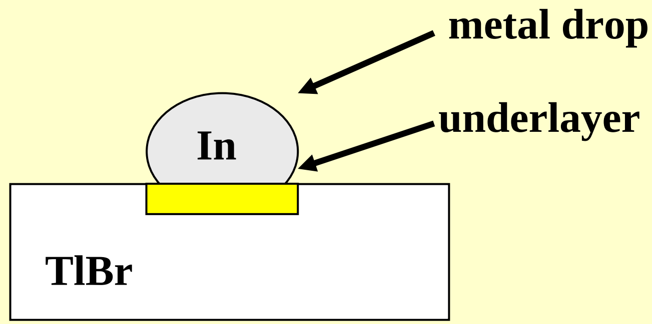
Results: Tl/, In/,Sn/TlBr interfaces

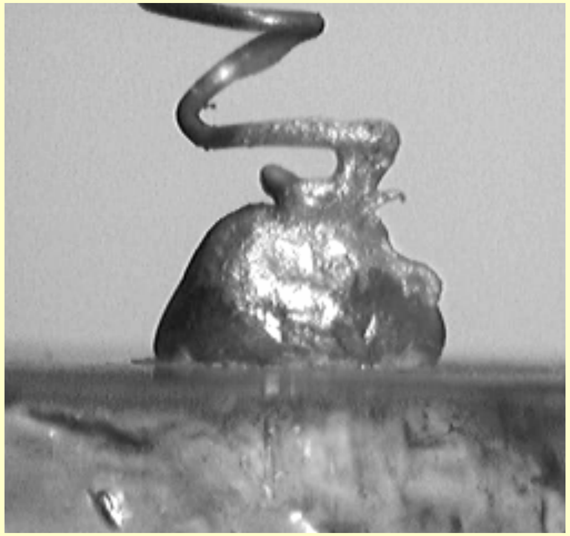
Tl, In and Sn were shortly melted at ~310 ^{o}C:
(N_2 atmosphere)

- Sn: no reaction,
  no underlayer
- In: **Yellow** underlayer compound
  ”pressed drop” on surface
- Tl: **Brown** underlayer compound
  easily **peeled off** from TlBr

\+ New process + annealing 20h

=> active reaction

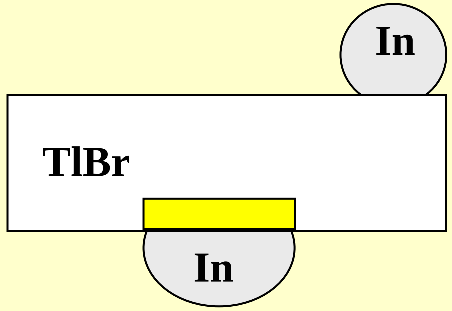




Output: Tl - aggressive with TlBr

Results: In/,Sn/TlBr interfaces

In and Sn were shortly melted at ~250 ^{o}C:
(opposite side)



- **Sn, In**:
  no reaction,
  no underlayer (In-case)

- **Sn:** *I-V* characteristics of Sn-TlBr-Sn were asymmetrical for both electrodes

=> higher temperature for the intermediate compound

Output: Sn electrode was reliable at our conditions.

Results: In/TlBr interface

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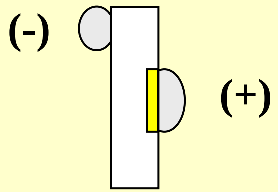
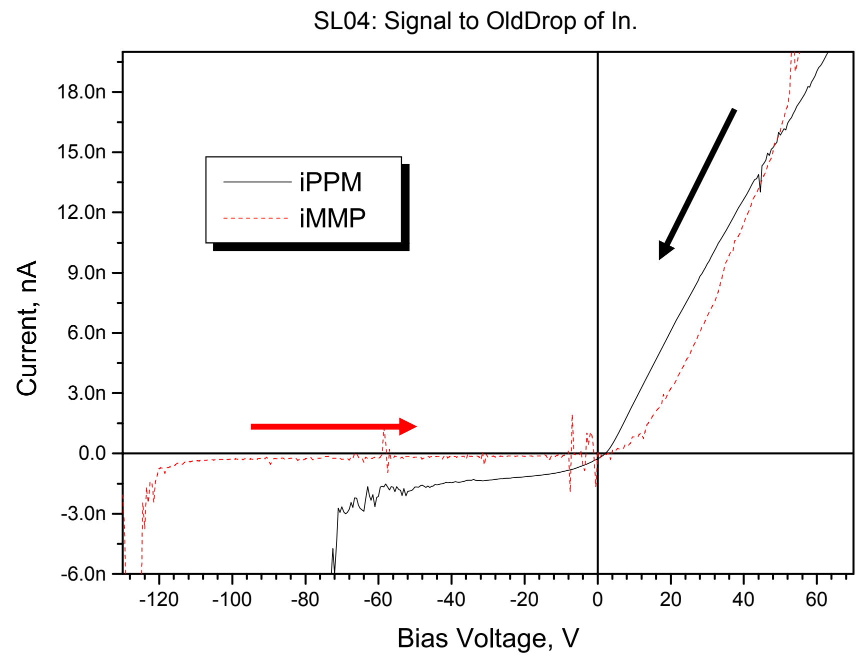
- **In:** *I-V* curves of In-TlBr-Layer-In => rectifier effect was observed

- High current connections:



Breakdown during further I-V & CV at ~200 V/cm

Compare: working field 500 V/cm,
Owens *et al.*, Nucl. Instr. and Meth. A 531, 18 (2004)



Output: low crystal quality, inner boundaries still limit the use of TlBr detector

Conclusions

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- Ti, Cr, Fe and Ni elements were inert to TlBr and Ti and Cr could be used as reliable electrodes.
- Al contact can be used for tests at low current without heating.
- Tl is reacting aggressively with TlBr.
- Sn electrode was reliable at our conditions.
- In was shown to form intermediate layer compound.
- In/TlBr interface possesses rectifier properties; however, the crystal quality currently limits the use of this interface.

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Acknowledgements

- **Crystal growth**: I.S. Lisitsky and M. Kuznetsov (GIREDMET, Russia)

- Finnish Technology Agency **TEKES**

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END

- Thank You!