# Master’s Thesis Engineering Technology

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# *Design and development of printed stretchable antennas for 3D integration*


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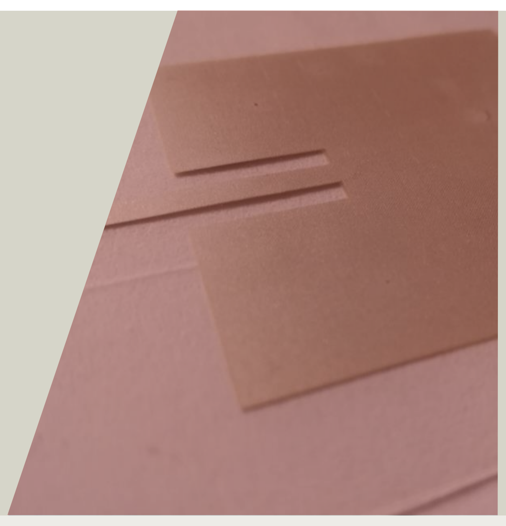
## Context

- **Printable** and **stretchable** electronics show a lot of potential over traditional wired electronics.
- They are **formable** over existing surfaces using thermo and **vacuum forming techniques**.
- Printable and stretchable electronics leads to **lightweight** applications.
- They give the possibility to add **aesthetic value** by their compactness.
- These could eventually be used in **In-mold production** processes.



## Obstacles

- Stretchable antennas are required for stretchable applications.
- Antenna parameters like **resonance frequency, reflection coefficient and efficiency** change under the influence of elongation.
- For Fremach it is unclear how the development of printed stretchable antennas should be aproached.

### 1. Antenna selection

There are **different antenna types for different applications**.
The **antenna type** depends on:

- The **application** itself (ex: near or far field communication)
- The **frequency range** to communicate at
- The available **feed** (ex: a dipole needs a balun)

Different designs this projects focuses on:

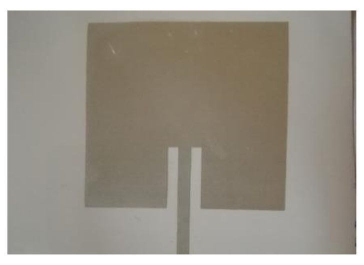


Fig 1: Inset Fed Patch antenna
For WIFI or Bluetooth


Fig 2: RFID
For wireless identification

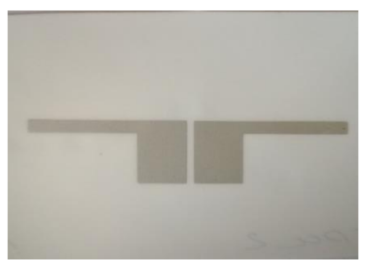


Fig 3: Dipole antenna
For radio communication

### 2. Ink selection

**Nano particles:** Nano tubes or granules which form a conductive network.
(Fig. 4) **High conductivity** (± 0,7 Ω/cm)
**Low stretchability** (0-5 %)

**Micro flakes:** Small sheets which shear over each other when stretched.
(Fig. 5) **Good conductivity** (± 3 Ω/cm)
**Good stretchability** (25%)

**PEDOT:PSS:** Conductive organic strings, resulting in a ± **transparent** ink.
(Fig.6) **Low conductivity** (±50 k Ω/cm)
**High stretchability** (40% and up)

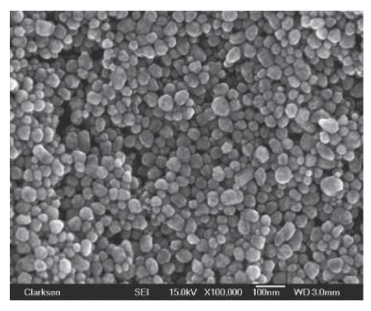


Fig 4: Silver nanoparticles [1, p. 2494]

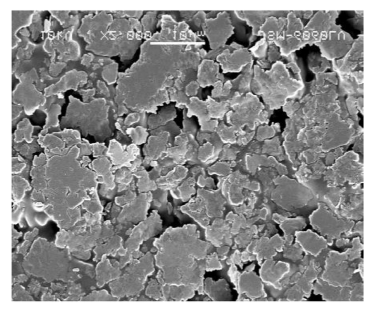


Fig 5: Silver micro flakes [2, p. 628]

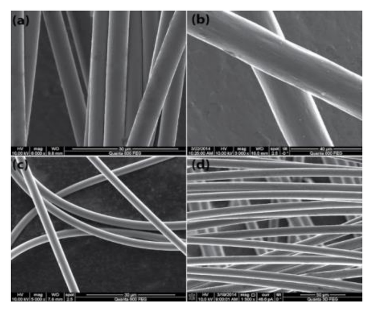


Fig 6: PEDOT:PSS strings [3, p.2528 ]

### 3. Substrate selection

The **substrate material** influences the behaviour of the antenna.

- Experiments should be carried out to determine the material with the lowest **resistance** for the ink on the substrate (Fig.7).
- The substrate material must be **stretchable**.
- The material must resist the **curing temperature** of the ink (±120°C).
- Determine the **optimal thickness** of the substrate with simulations, aiming for the lowest reflected power (Fig.8).

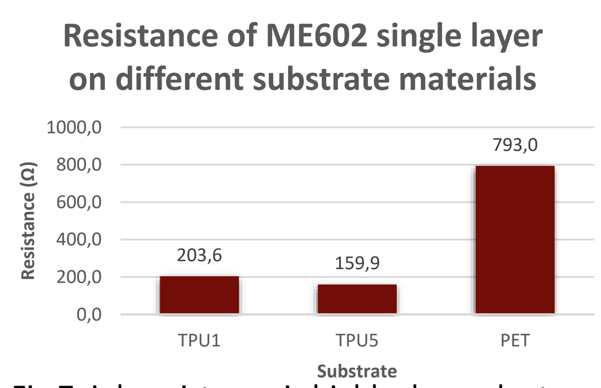



Fig 7: ink resistance is highly dependent on the substrate material

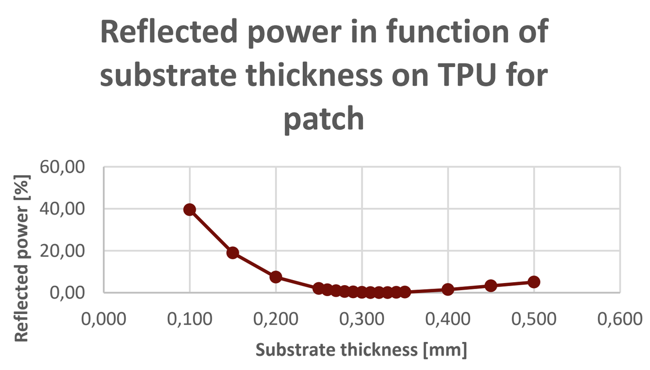



Fig 8: Reflected power of the patch antenna is the lowest with a 320µm thick substrate

### 4. Stretched ink characteristics

**When elongated, the inks resistivity increases** because of small cracks and decreasing connection points in the network of conductive particles. The maximum elongation that can be achieved for the antenna can be determined by measuring the sheet resistance in function of the elongation (Fig. 10). This must be tested with the chosen substrate material from the previous step.

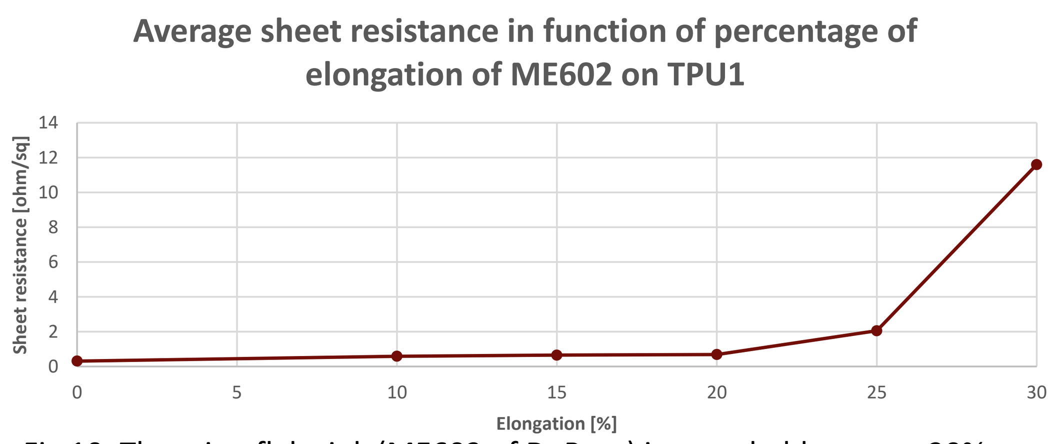



Fig 10: The microflake ink (ME602 of DuPont) is stretchable up to ±20%

### 5. Antenna simulations in Sonnet

Using Sonnet Lite, the **behavior** of the antenna can be **studied at varying levels of elongation**. The **inset fed patch** antenna appears to remain functional **up to 20 % horizontal or 10 % vertical elongation**. The **RFID** appears to be **determined solely by its resistance** (Fig.11).

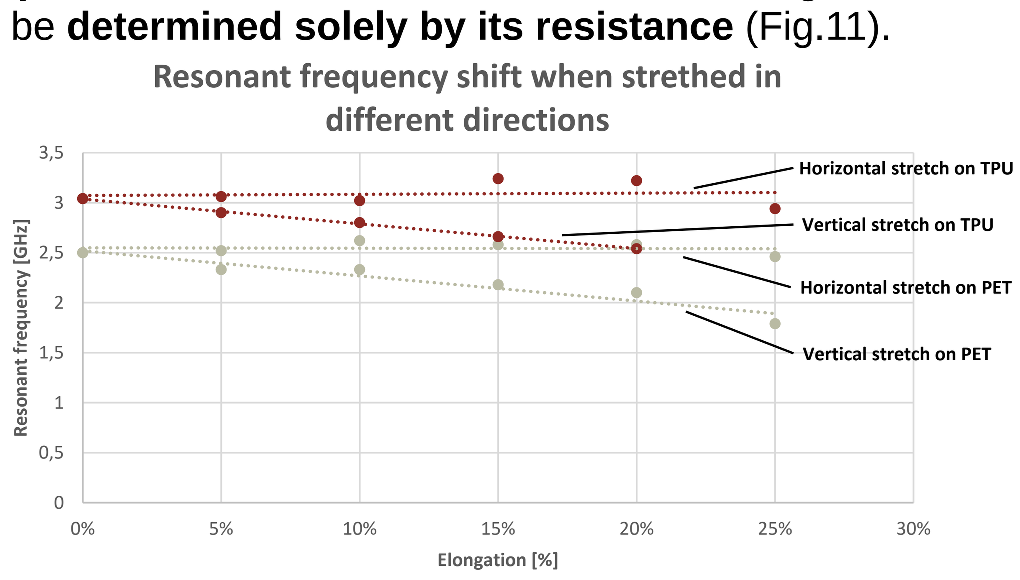



Fig 11: The resonant frequency of the patch antenna shifts differently depending on the stretch direction

### 6. Antenna characterisation

Finally, **check that the antenna parameters comply with the simulated values**.
The necessary measuring devices are:

- A **network analyser**: for reflection coefficient, resonant frequency and bandwidth.
- An **anechoic chamber**: for the efficiency, gain and radiation pattern.

When the result is not as desired, this step-by-step plan should be followed again as an iterative method.
(These measurements were not possible in this master’s thesis)


Supervisors / Cosupervisors: Prof. Dr. Ir. Wim Deferme
Indranil Basak



[1] D. Andreescu, C. Eastman, K. Balantrapu en D. V. Goia, „A simple route for manufacturing highly dispersed,” Center for Advanced Materials Processing, Clarkson University, New York, 2007.
[2] M. Zvleglic, N. Hauptman, M. Macek en M. Klansjek Gunde, „Screen-printed electrically conductive functionalities in paper substrates,” Slovenia, Ljubljana, 2011.
[3] J. Zhou, E. Qiang Li, R. Li en X. Xu, „Semi-metallic, Strong and Stretchable Wet-spun Conjugated Polymer,” Journal of Materials Chemistry C, nr. 11, pp. 2528-2538, 2015.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