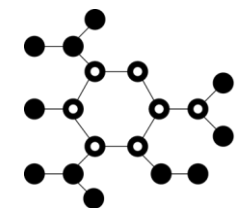**AVT-371 Research Workshop on**

"**Materials and technologies for electro-optical camouflage**"

2D materials for camouflage applications

Dr. Johan Jersblad, Ann-Sofie Olovsson, Björn Boström,
Saab Barracuda AB, SWEDEN

Dr. Erik Khranovskyy, Dr. Mykhailo Zhybak
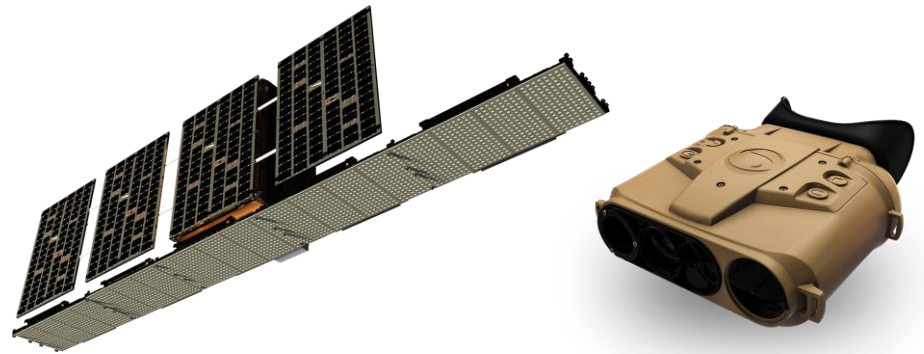GRAFREN AB, SWEDEN

24th of May 2023

2D materials and camouflage

- **Graphene**

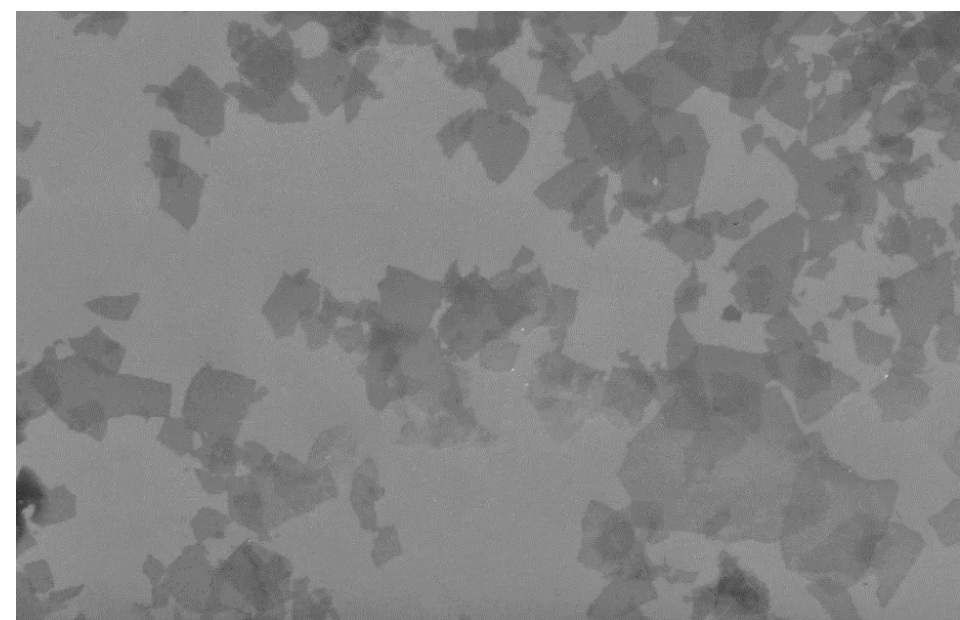 ➢ Thermal conductivity

  ➢ Electrical conductivity

- **Hexagonal Boron Nitride**

  ➢ High UV reflection

  ➢ Low SWIR reflection

G-CAM

- **Graphene camouflage with extreme material properties**
- **Partners Saab Barracuda AB, Grafren AB, Engtex AB**

Med stöd från

VINNOVA
Sveriges innovationsmyndighet

Energimyndigheten

FORMAS

Strategiska innovations-program

Graphene camouflage

- **A graphene based camouflage net is**
  - lighter
  - stronger
  - environmentally friendly
  - user friendly
  - has increased signature performance

Graphene radar camouflage

- **How much graphene do we need?**

- **How does the textile construction influence conductivity?**

- **Does the textile polymer matter?**

- **The coating process and conductivity**

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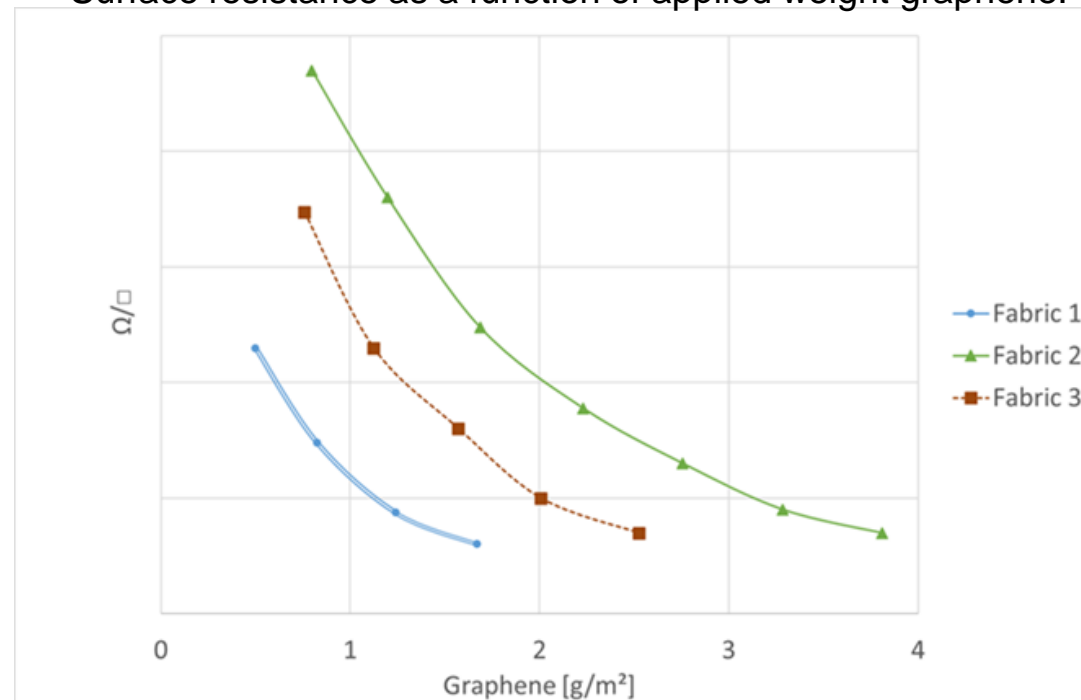# How much graphene do we need?

- **Coating of multiple textiles**
  - ➢ Variables
    - ▪ Textile construction
    - ▪ Textile polymers
    - ▪ Yarn apperance
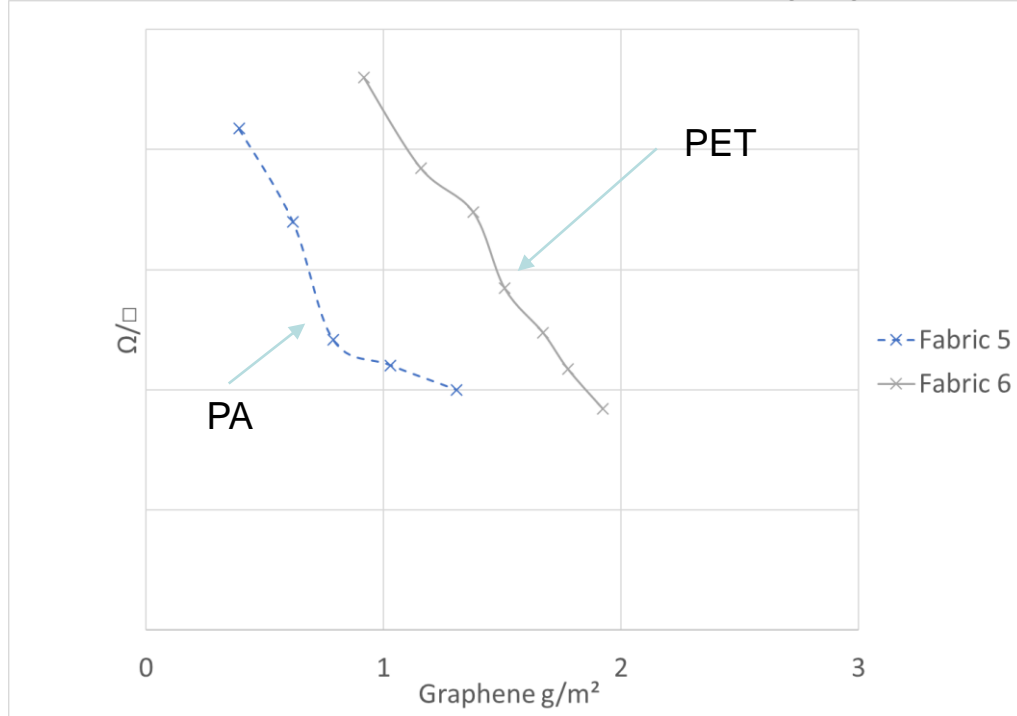
  - ➢ Strong dependence of choice of textile

Surface resistance as a function of applied weight graphene.

Textile polymer and conductivity

- **Identical textiles with different polymers**

  ➢ Substantial difference in conductivity

  ➢ PET – hydrophobic

  ➢ PA - hydrophilic

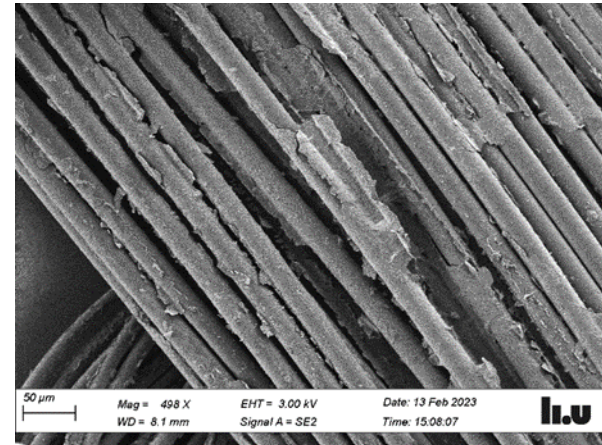Surface resistance as a function of applied weight graphene.

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Textile construction and conductivity

Surface resistance as a function of applied weight graphene.

SEM of low surface area yarns

HSA yarns

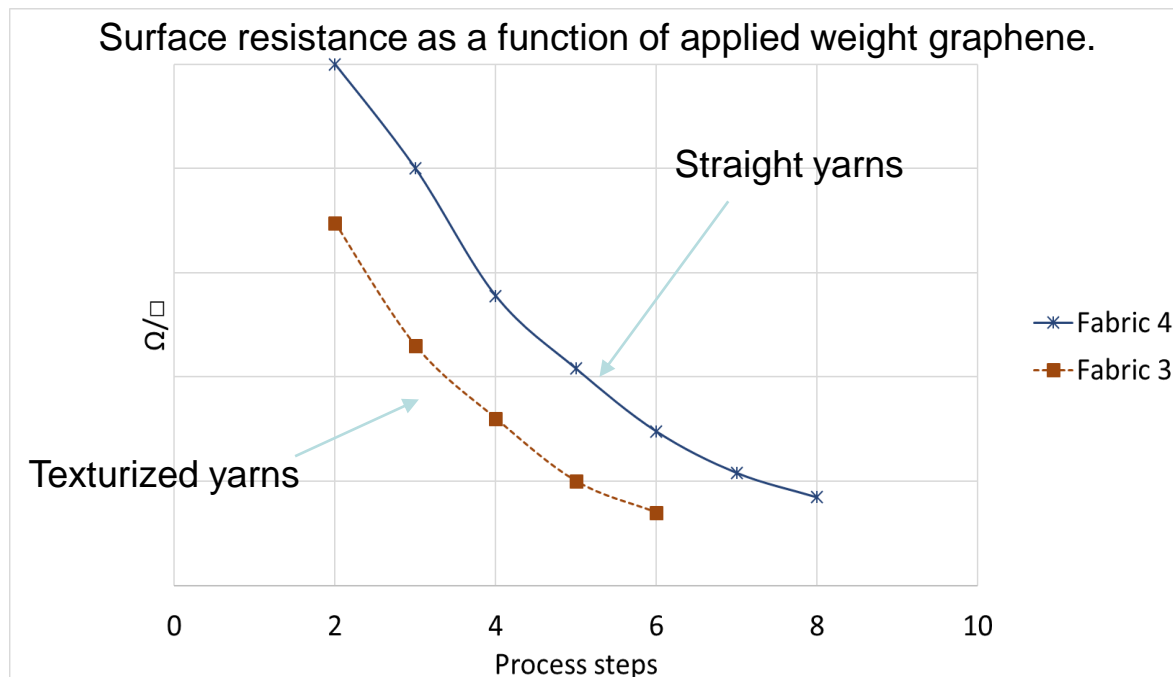LSA yarns

SEM of high surface area yarns
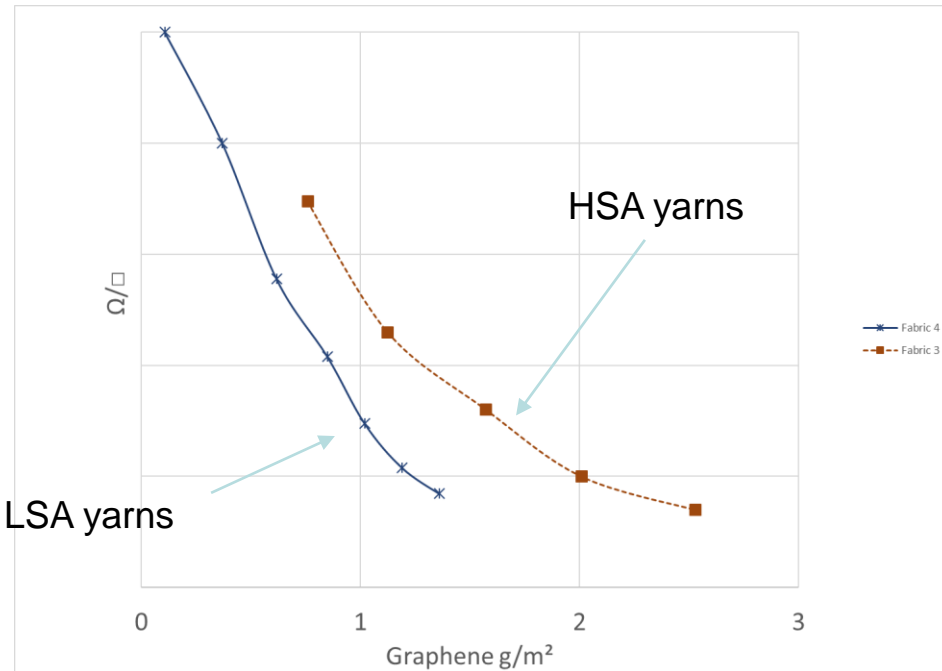
LSA – low surface area
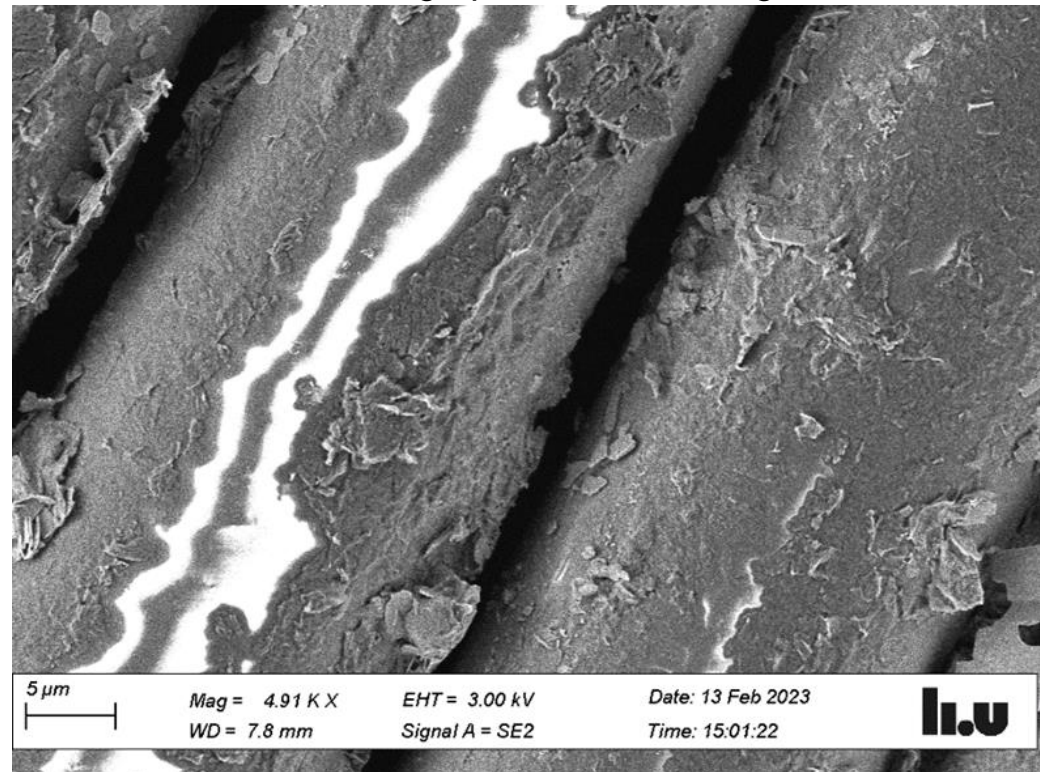HSA – high surface area
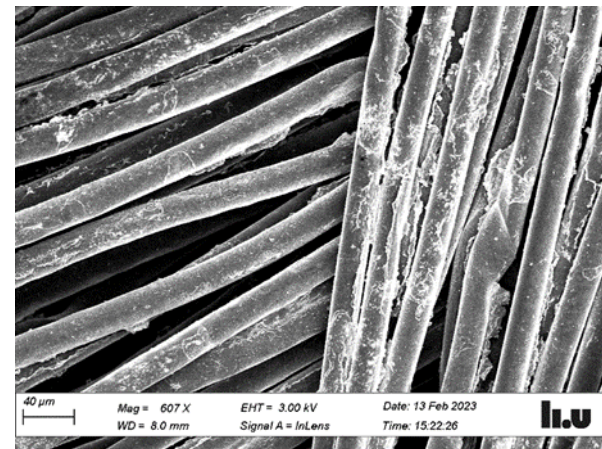
Coating process and textile

- **Number of process steps to reach desired conductivity**
  - ➤ High for textiles with low surface area
  - ➤ Low for textiles with high surface area

Surface resistance as a function of applied weight graphene.

Optimal textile

- ## The optimal textile for graphene coating

  - ➢ Highly absorbing
  - ➢ Low surface area
  - ➢ Hydrophilic

SEM of a graphene coated single fiber

| 5 µm | Mag = 4.91 K X | EHT = 3.00 kV | Date: 13 Feb 2023 | li.u |
| WD = 7.8 mm | Signal A = SE2 | Time: 15:01:22 | |

Next step

- **First graphene enhanced camouflage at AVT-371**
- **Full scale manufacturing**
- **Verification and validation**
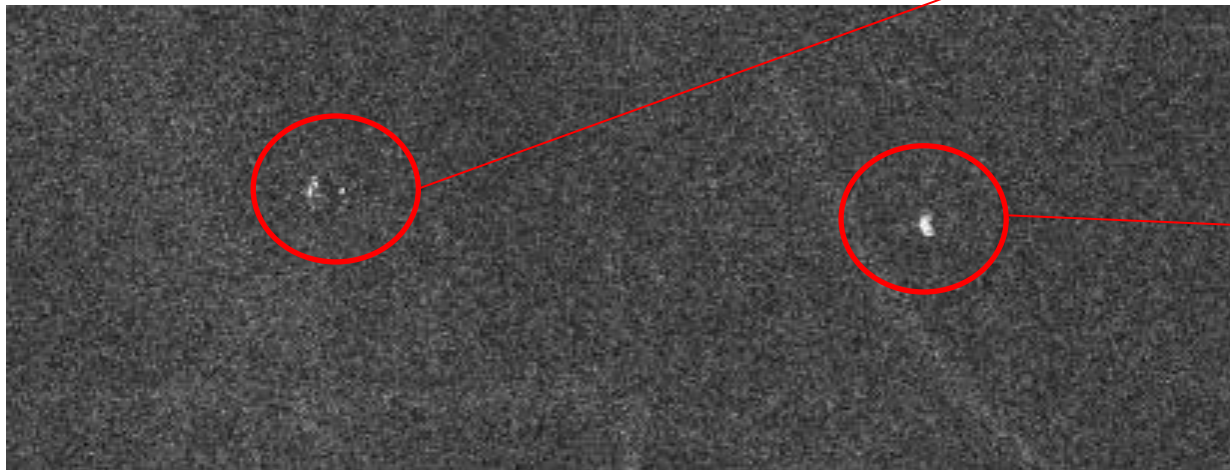
SAR image of camouflaged and uncamouflaged objects
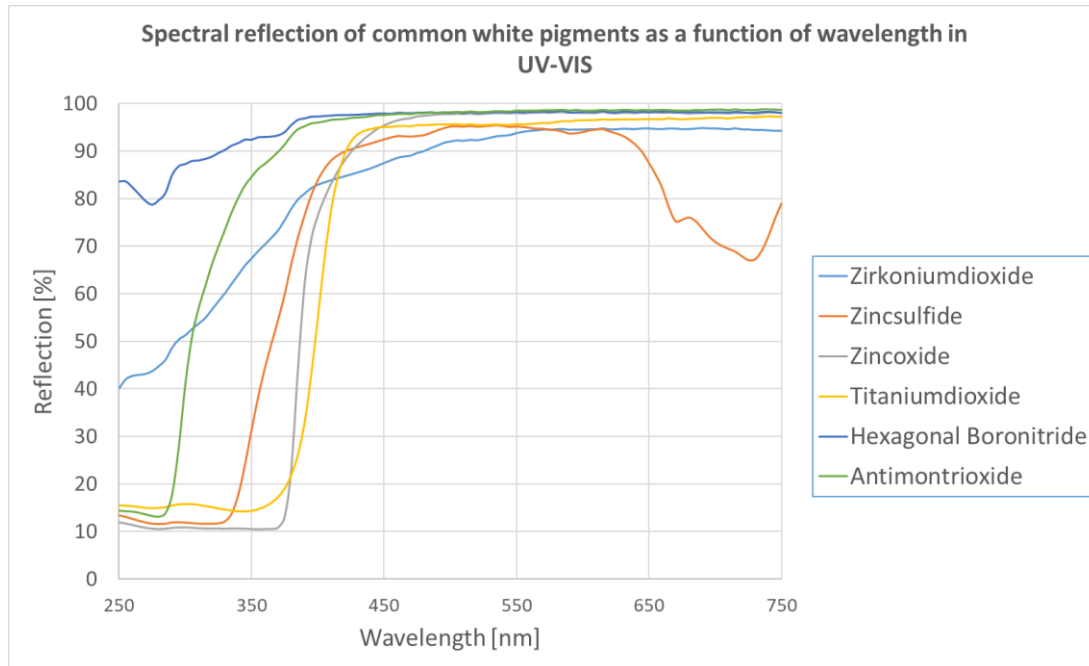
Advantages with Hexagonal Boron Nitride

- **A HBN based winter camouflage net is**
  - Light weight
  - High UV
  - Low SWIR
  - Robust
  - Environmentally friendly

Spectral reflectivity UV-VIS

UV

Spectral reflection of common white pigments as a function of wavelength in UV-VIS

VISUAL

SWIR performance of winter camouflage
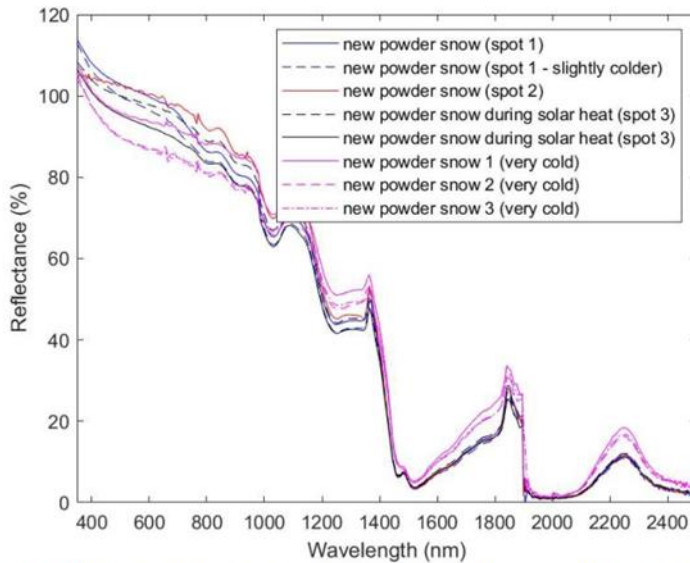
Spectral reflection of snow

Figure 2. Spectral reflectance of various types of dry, powder snow: Experimental data plotted against wavelength. Snow mass thicknesses measured were 20 cm or more.

(Spectral reflectance measurements of snow and snow covered objects: experimental studies compared with mathematical models, *Selj, Mikkelsen,* Proceedings of SPIE, the International Society for Optical Engineering 2021 ;Volum 11865**)**
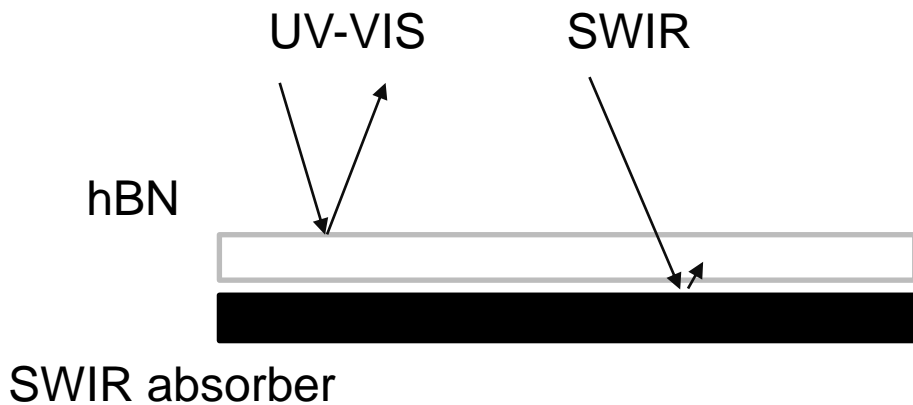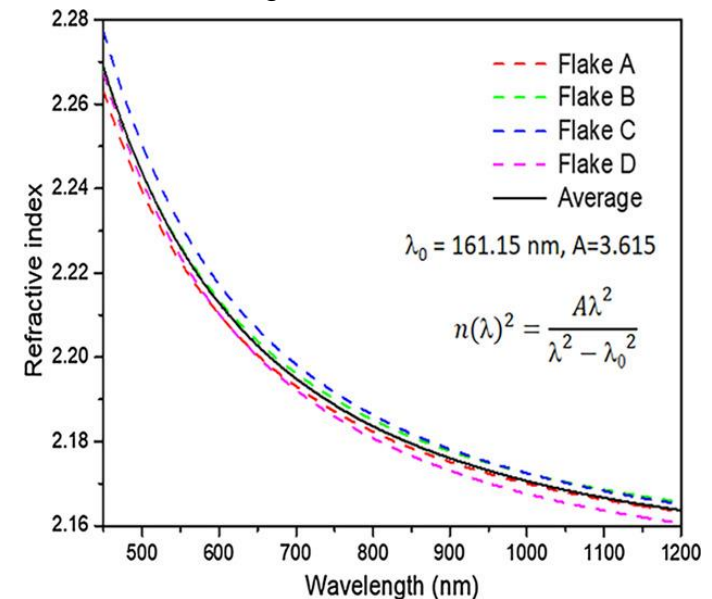
SWIR

VISUAL

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hBN and SWIR reflection

- **hBN may be the solution for improved SWIR performance in Winter camouflage**

  ➢ Refractive index decrease as a function of wavelength

  ➢ Semi-Transparent >750 nm

UV-VIS   SWIR

hBN

SWIR absorber

Refractive index as a function of wavelength for HBN

λ₀ = 161.15 nm, A=3.615

$$n(\lambda)^2 = \frac{A\lambda^2}{\lambda^2 - \lambda_0^2}$$

Flake A
Flake B
Flake C
Flake D
Average

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Future

- **2D materials are expected to have a disruptive impact on camouflage in terms of**
  - ➢ Signature performance
  - ➢ User friendliness
  - ➢ Environmental impact