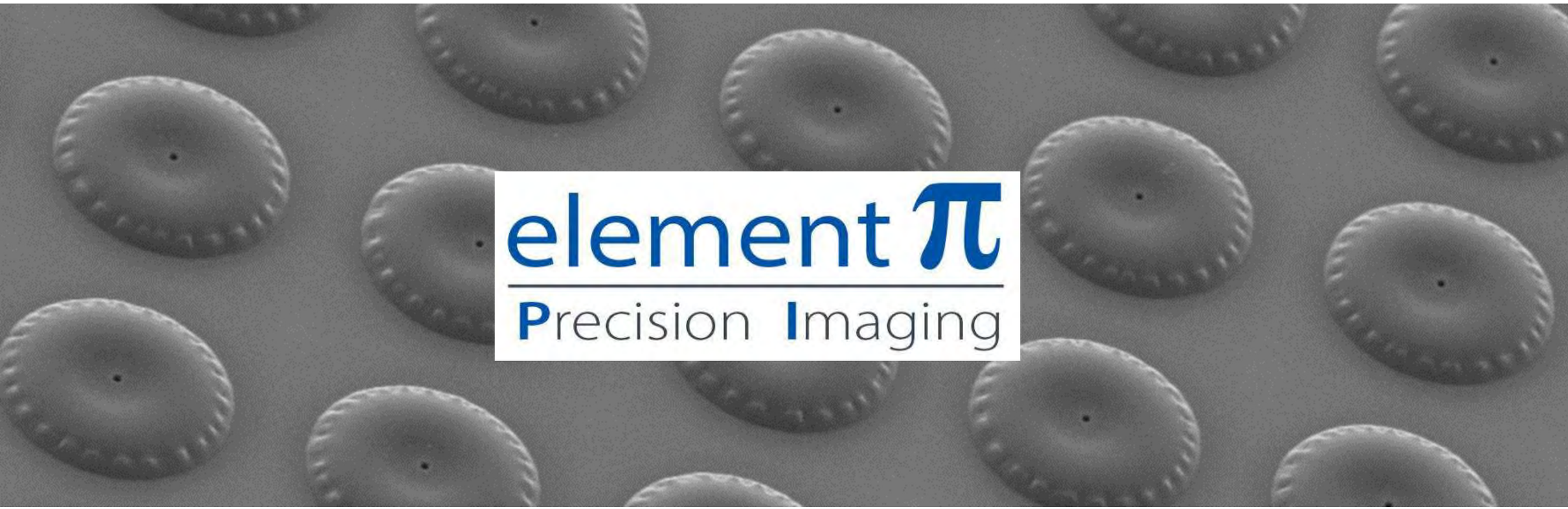
VARIABLE LOW VACUUM OPTION

10-1-2020



Standard Low Vacuum

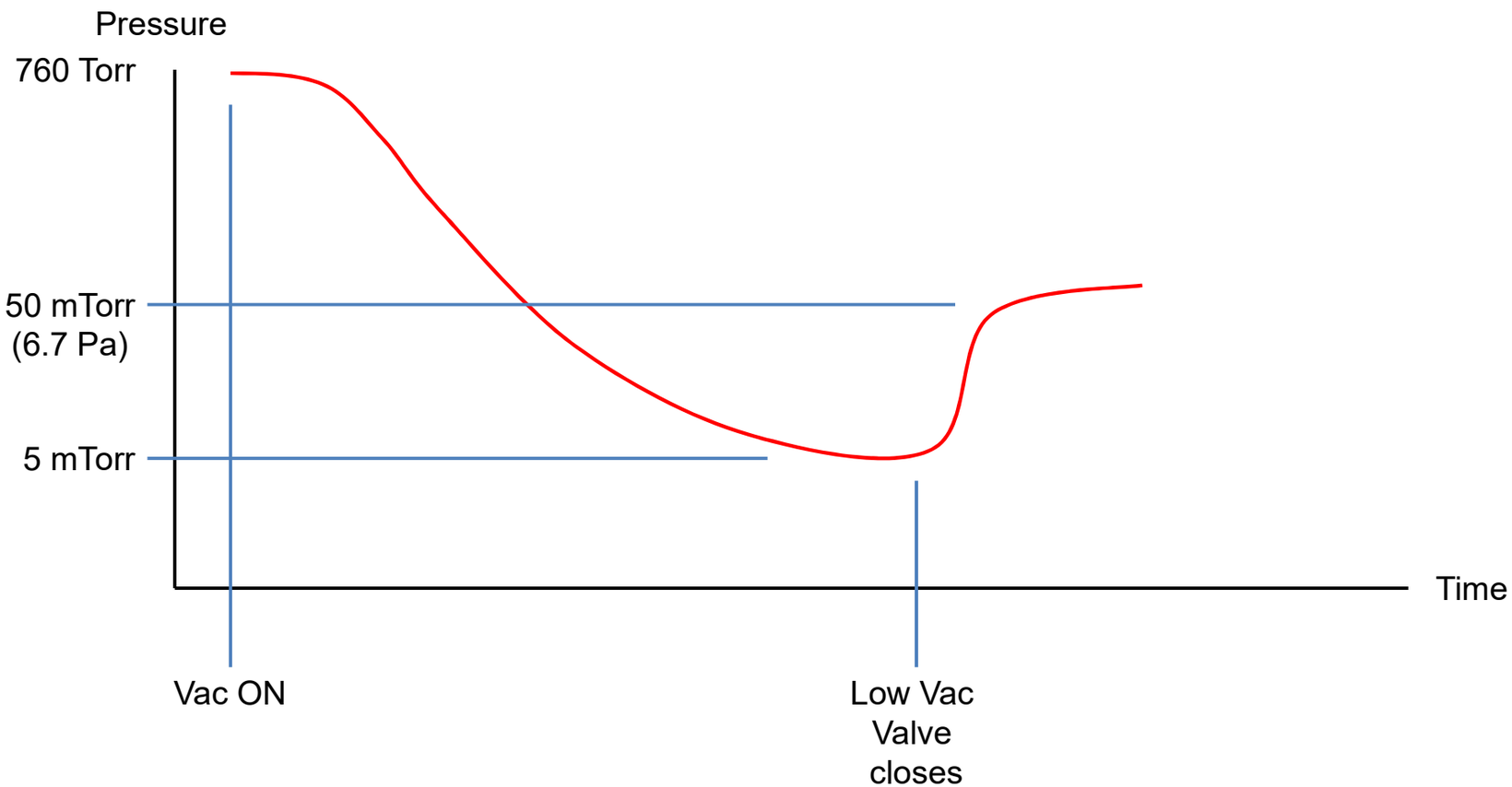
- **All Tabletop SEM system on the market today including ours essentially use a FIXED low vacuum pressure for charge reduction of non-conductive samples when sputter coating is not possible or desirable.**
  - > Our experience shows that different samples require a slightly different low vacuum pressure to achieve the best imaging.
  - > When the chamber pressure is higher than necessary to remove charging effects, the resulting images will be very flat with low contrast and less detail.

- **To achieve a low vacuum in the chamber, all Tabletop SEM systems on the market EXCEPT the EM-30 series use an on/off solenoid valve or other type of air leak design to introduce air into the SEM chamber that attracts the negatively charged electrons that build up on samples.**
  - > That air (and the charging electrons) are then swept away by the vacuum system. Apertures in the SEM column help maintain eGun vacuum as the chamber is connected with a bypass to the vacuum system.

Standard COXEM EM-30N Low Vacuum Methodology

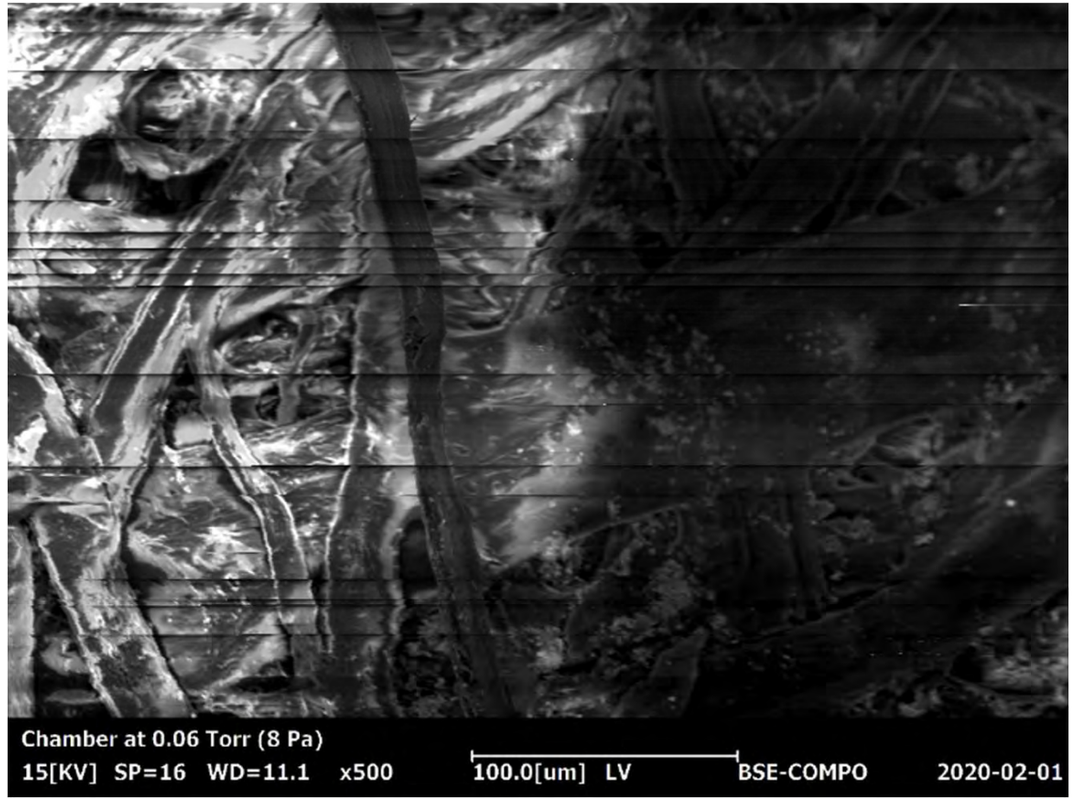
- **After selecting Low Vac mode, the vacuum in the chamber reaches about 8-10 mTorr in a few minutes while the Gun Vacuum reaches its setpoint of $3.5x10^{-5}$ Torr**
  - > NOTE: in High Vac mode, the EM-30N chamber reaches around 5 mTorr (0.67 Pa) in 3 minutes and stays there, potentially going lower given time
- **After a set time in the vacuum process, a valve in the bypass pipe to the chamber partially closes to restrict flow to the TMP**
- **The Chamber pressure then rises to around 5-8 Pa (40 to 60 mTorr)**
  - > This is a higher vacuum than competitor “air leak” designs that typically have 40-60 Pa pressure and often result n low contrast “flat” images.
  - > There is NO LEAK AIR introduced, thus the Chamber pressure takes several minutes to stabilize.
  - > This lower pressure (higher vacuum) gives better images but for highly insulating samples, there is often still charging that occurs.

Standard EM-30N Low Vac Process



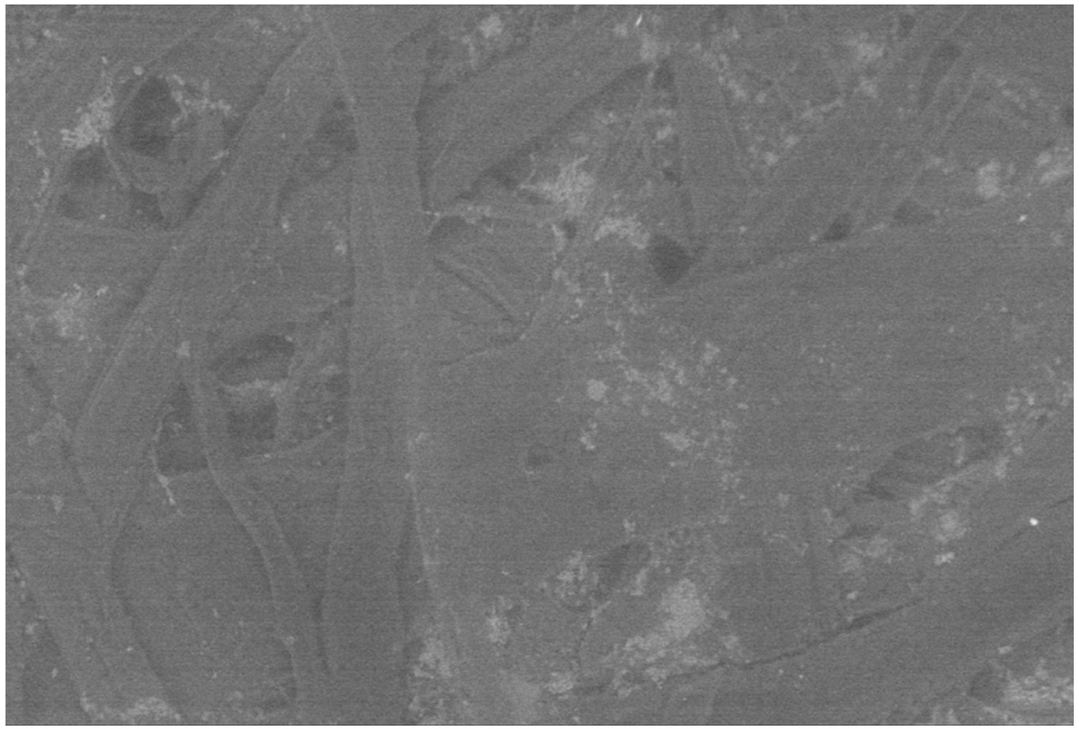
EXAMPLE - Paper

High Vacuum – Chamber at 0.5 Pa
(charging prevents imaging)



"Standard" Low Vac – Chamber at 8 Pa
(charging reduced but other image artifacts appear)

EXAMPLE - Paper

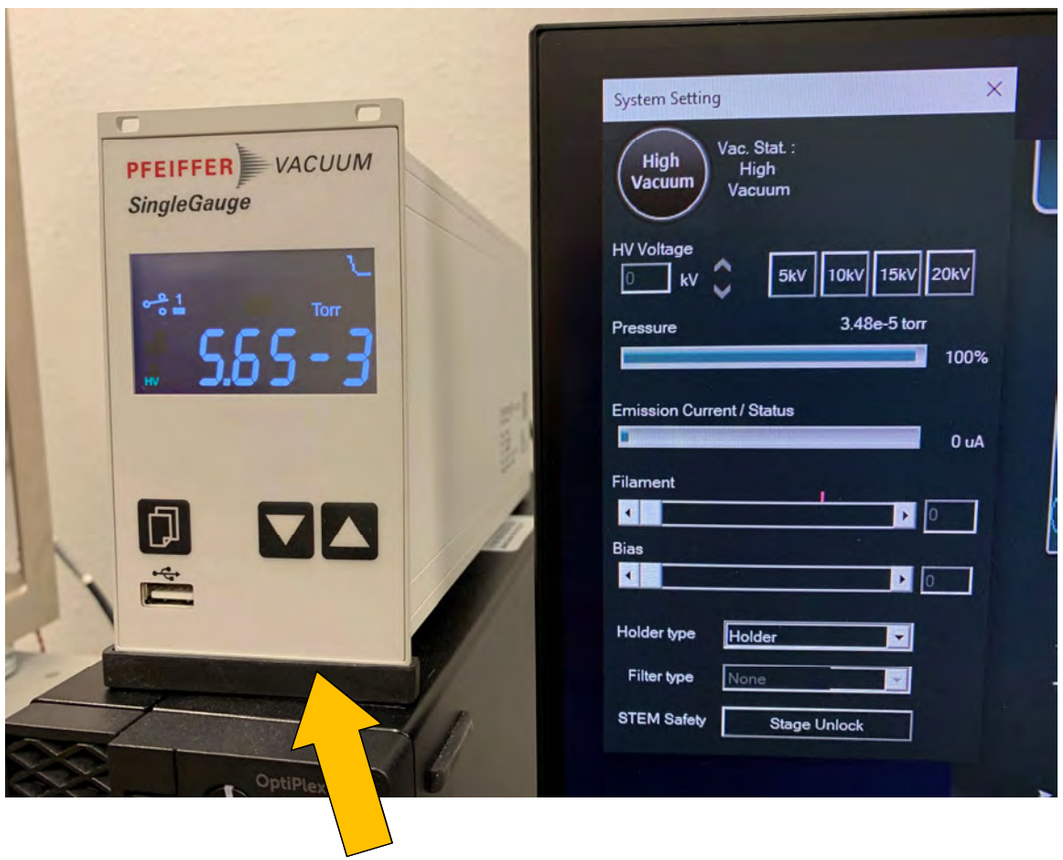


Typical Images for an SEM using the single pressure “Air Leak” method to achieve Low Vac result in very flat (low contrast) images
– Chamber at 40 Pa

VARIABLE Pressure Low Vacuum Solution for EM-30N

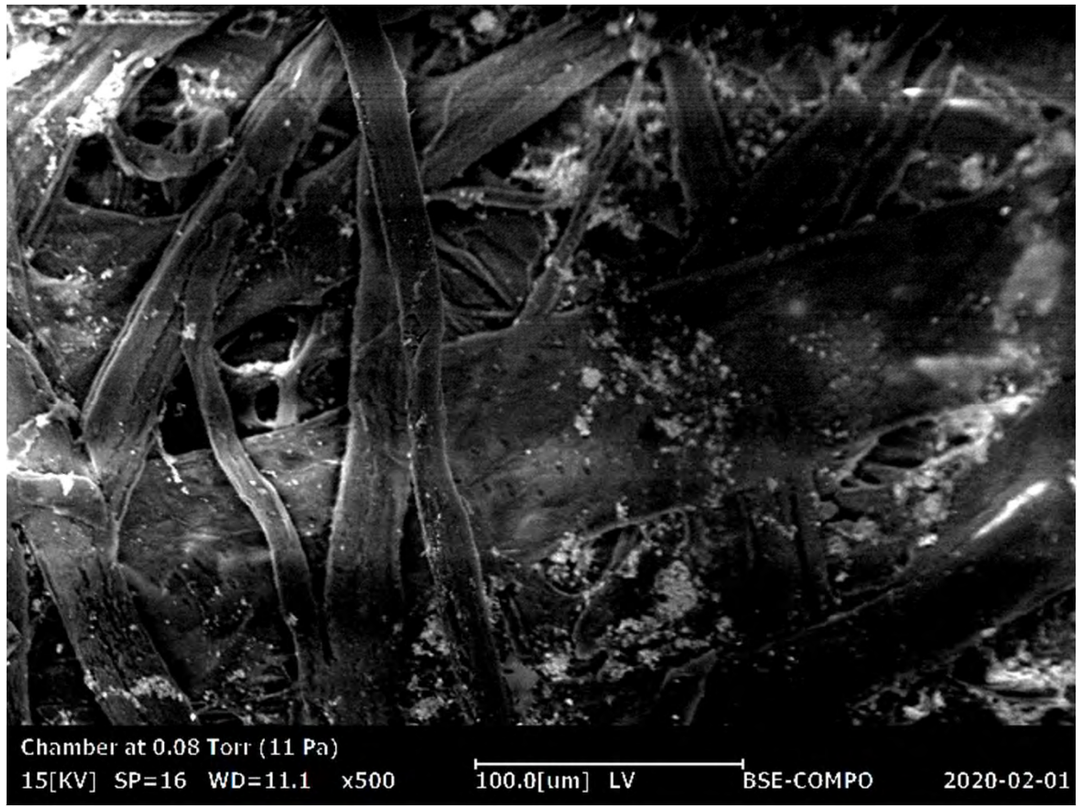
- **A special high precision “Dosing Valve” is added to the SEM chamber as shown**
  - > The Dosing Valve consists of a simple quarter turn On/Off and high precision needle valve
  - > Chamber pressure can be controlled in 0.01 mTorr increments by allowing a leak air flow
  - > The valve has a digital setting of 1 to 999 for reproducible set points

VARIABLE Pressure Low Vacuum Solution for EM-30N

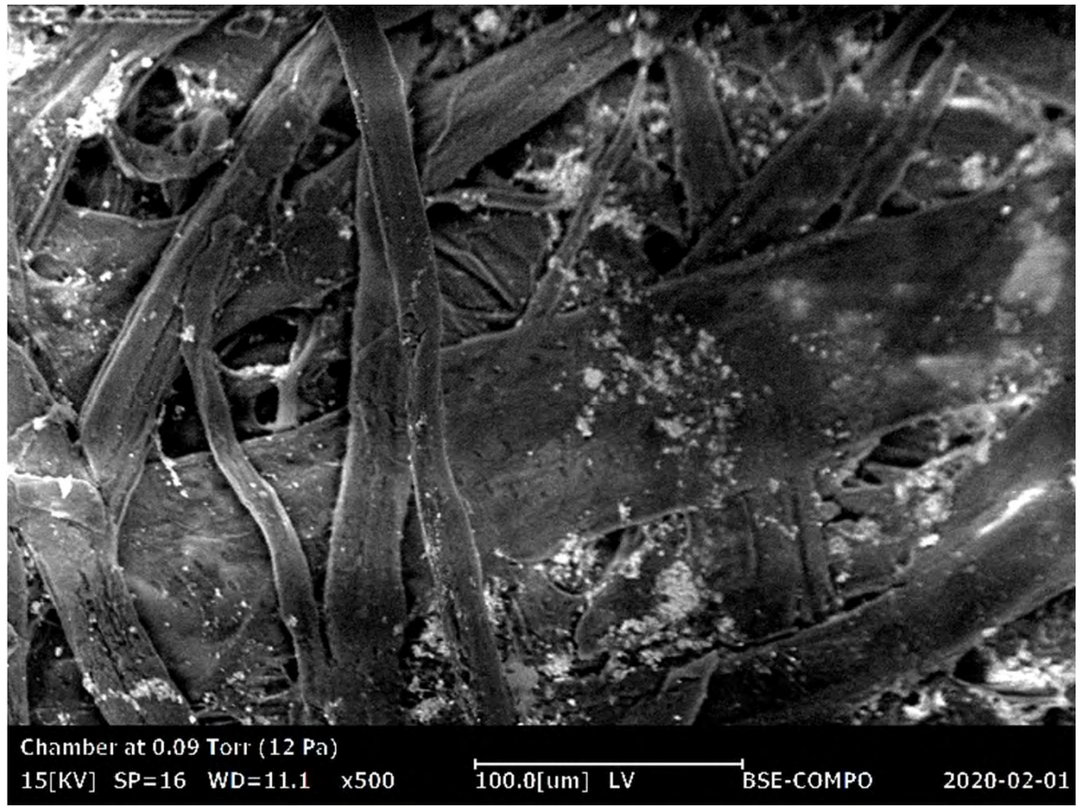


- **A Penning gauge with a dedicated external display is added to the rear chamber port**
  - > This provides an accurate reading of the chamber pressure during the dosing valve adjustment

EXAMPLE – Paper at increasing chamber pressure

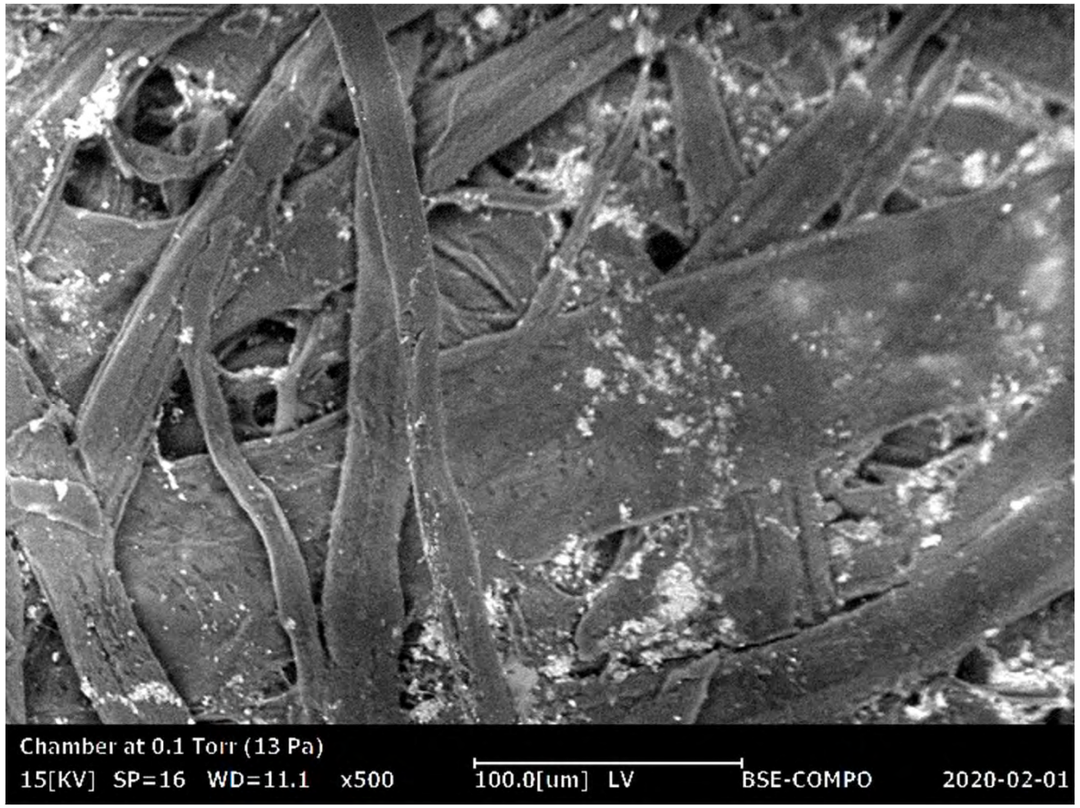


Low Vac – Chamber at **11 Pa**

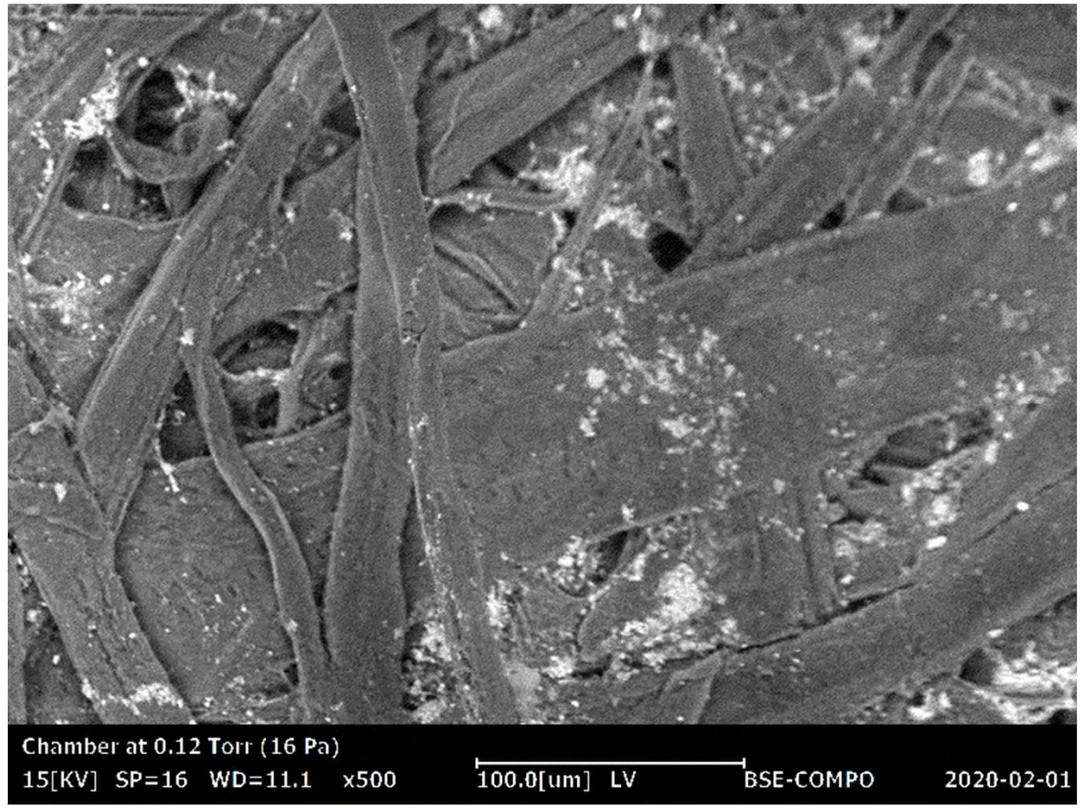


Low Vac – Chamber at **12 Pa**

EXAMPLE – Paper at increasing chamber pressure

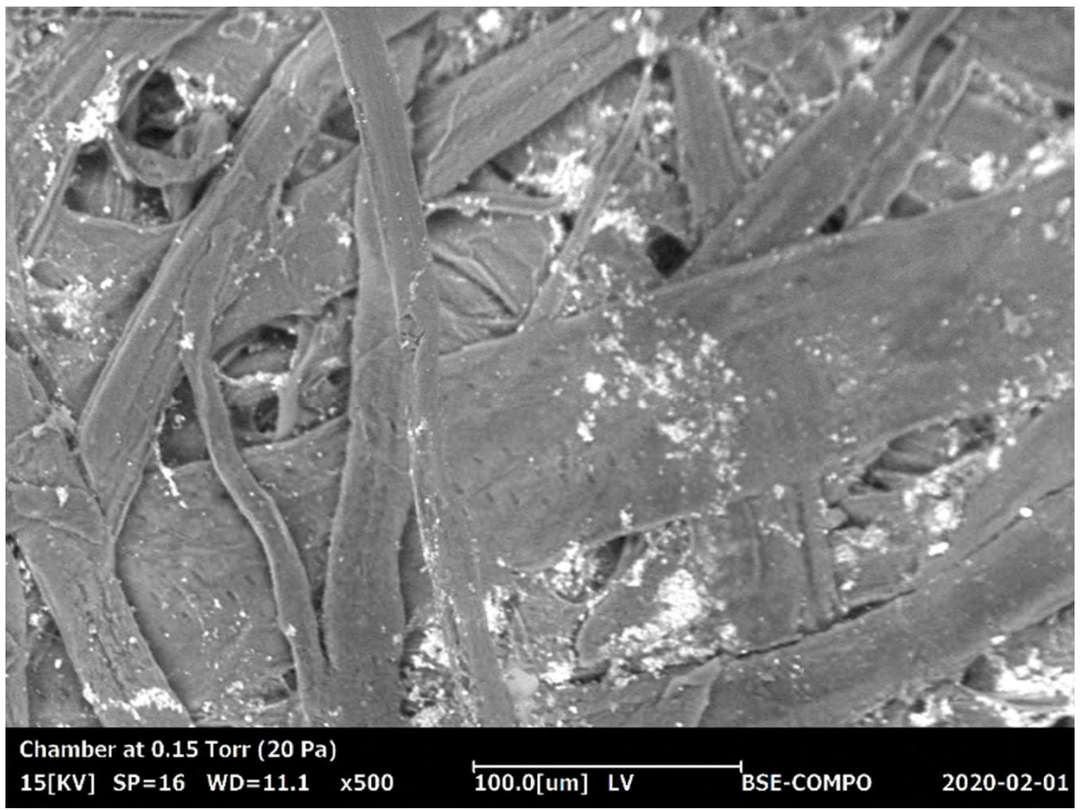


Low Vac – Chamber at **13 Pa**

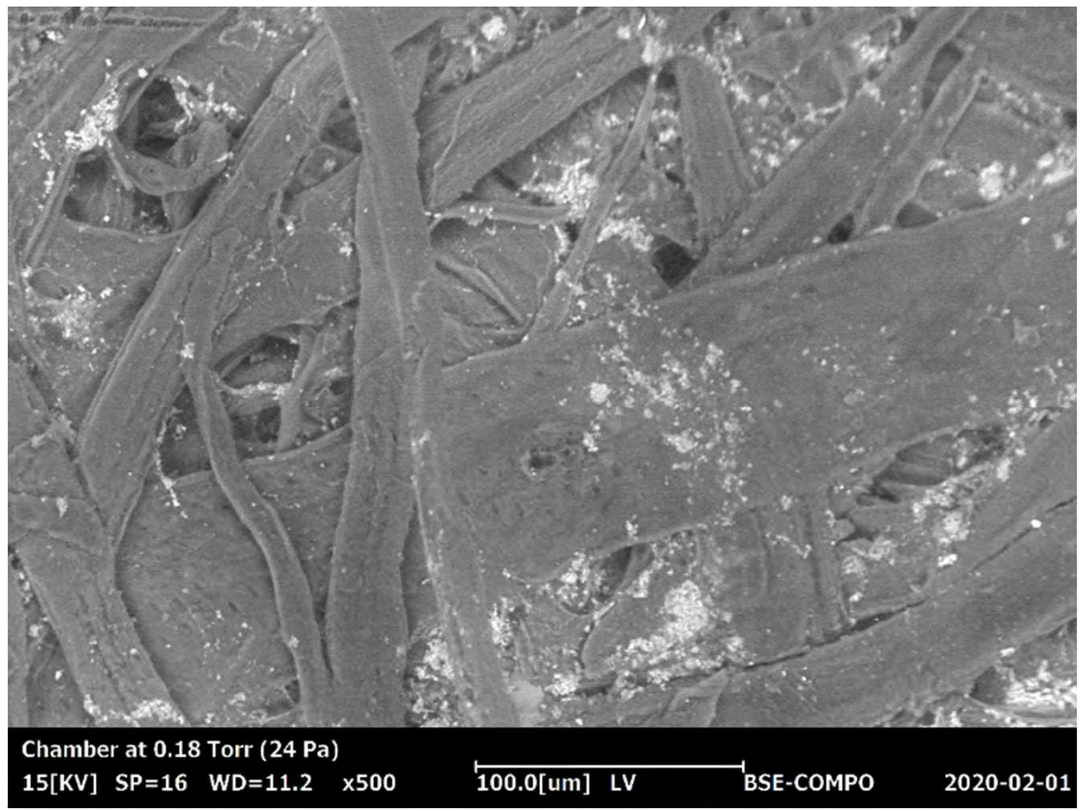


Low Vac – Chamber at **16 Pa**
(charging almost eliminated)

EXAMPLE – Paper at increasing chamber pressure



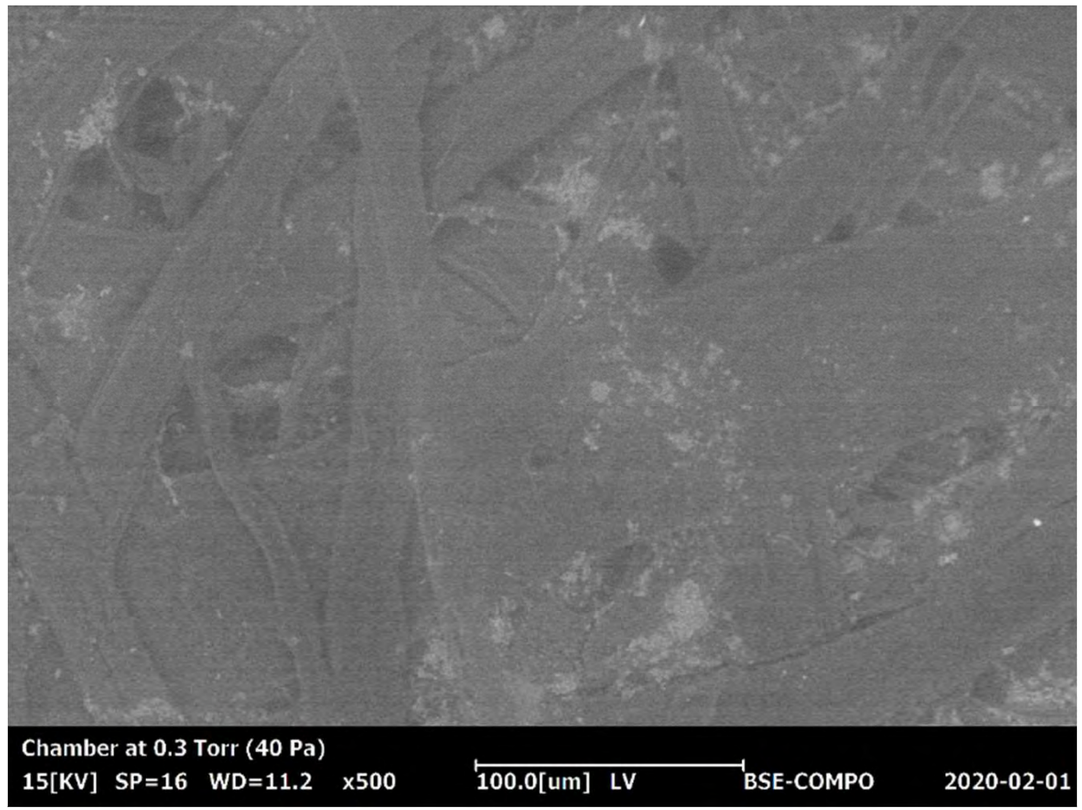
Low Vac – Chamber at 20 Pa
(charging eliminated)



Low Vac – Chamber at 24 Pa
(charging eliminated – flatter contrast)

EXAMPLE – Paper at increasing chamber pressure

Low Vac – Chamber at 33 Pa
(even flatter contrast)



Low Vac – Chamber at 40 Pa
(contrast too flat – pressure too high)

Conclusion

- **For this EXAMPLE, a chamber pressure of 20 Pa was ideal.**
- **The ideal pressure will be different for other conditons:**
  - Sample Type
  - Sample conductivity variation
  - Beam kV
  - Beam Spot Size

Having the ability to fine tune the chamber pressure to conditions that best reduce or eliminate electron charging on non-conductive samples provides a much more robust and flexible solution for the EM-30N SEM

Thank You!

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