APPLICATION NOTE

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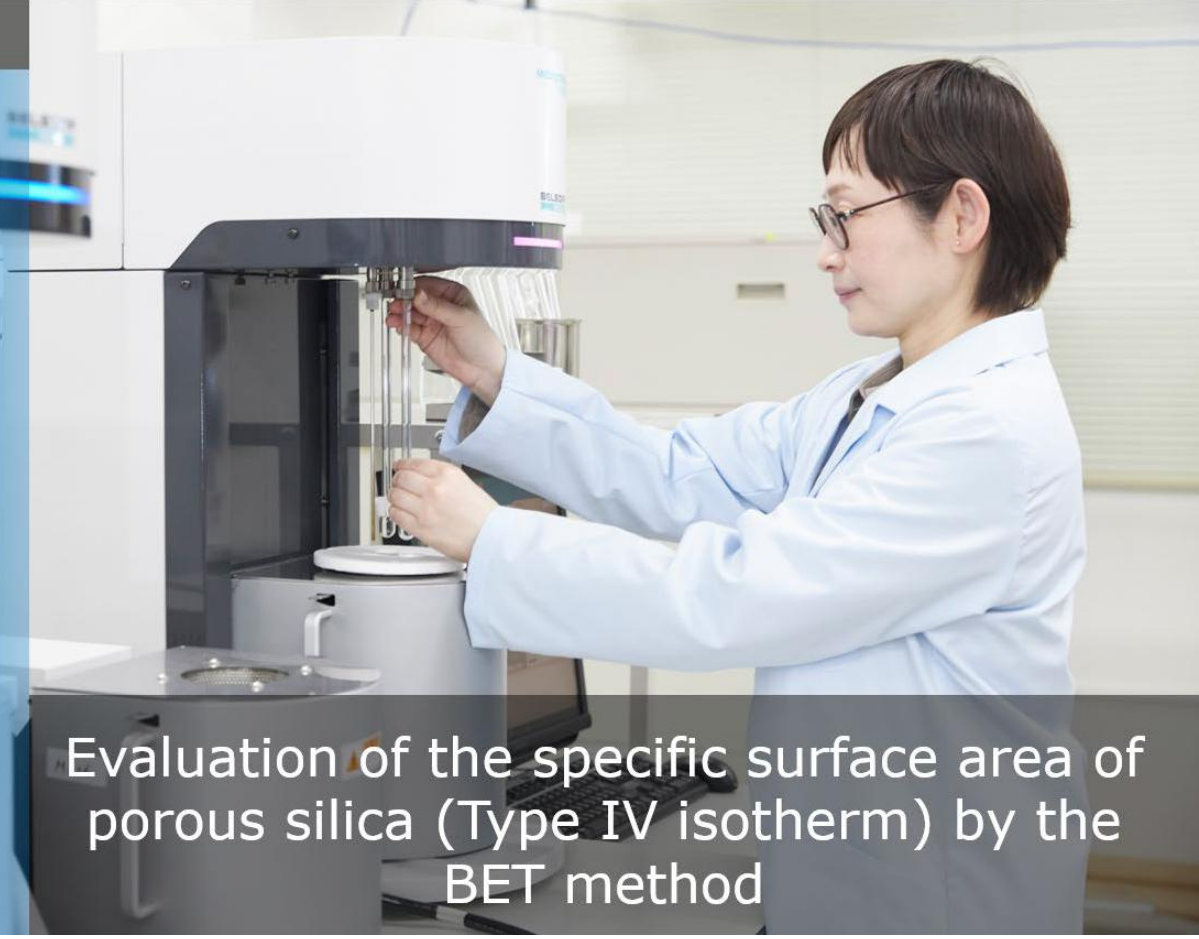
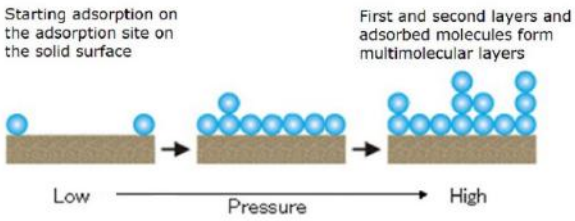


Evaluation of the specific surface area of porous silica (Type IV isotherm) by the BET method

BELSORP instruments

The Brunauer-Emmett-Teller method (shortly BET method, ISO 9277) is the most common method for the evaluation of specific surface areas. The specific surface area of macroporous, mesoporous and non-porous solids is determined by measuring the amount of physisorbed gas. The specific surface area of the material is calculated using the adsorbed volume of the monolayer and the space required by the adsorptive molecule. The BET method is applicable to sorption isotherms Type II and Type IV and the evaluation is carried out in the relative pressure range p/p0 from 0.05 to 0.30 (IUPAC-recommendation).1 Type I isotherms can be evaluated with the Rouquerol-plot.2 The BET theory is based on three assumptions:



Assumptions of BET Theory:

① Surface energy is uniform

② There is no interaction between adsorbed molecules

③ Adsorption energy above the second layer is equal to the condensation energy

The nitrogen sorption isotherm of Develosil 100 at 77 K (Fig. 1) can be classified as Type IV. From this isotherm the BET plot can be calculated, which is shown in Fig. 2. The BET surface area is determined using the measurement values in the relative pressure area from 0.05 to 0.30 as recommended by IUPAC. The BET specific surface area of Develosil 100 is 296 m2/g.3 It is noteworthy that the C-constant must be positive and the correlation coefficient R^2 should be higher than 0.99.

[1] M. Thommes, K. Keneko, A. V. Neimark, J. P. Oliver, F. Rodriguez-Reinoso, J. Rouquerol and K. S. W. Sing, Pure Appl. Chem. 2015, 87, 1051–1069

[2] for TypeI isotherms the evaluation is also carried out below the relative pressure of 0.05; see Appnote 3

[3] Evaluation of the pore surface area and pore volume of Develosil 100 is presented in Material No. 7 (mesopore evaluation by BJH method) and No. 9 (evaluation by t-plot method)

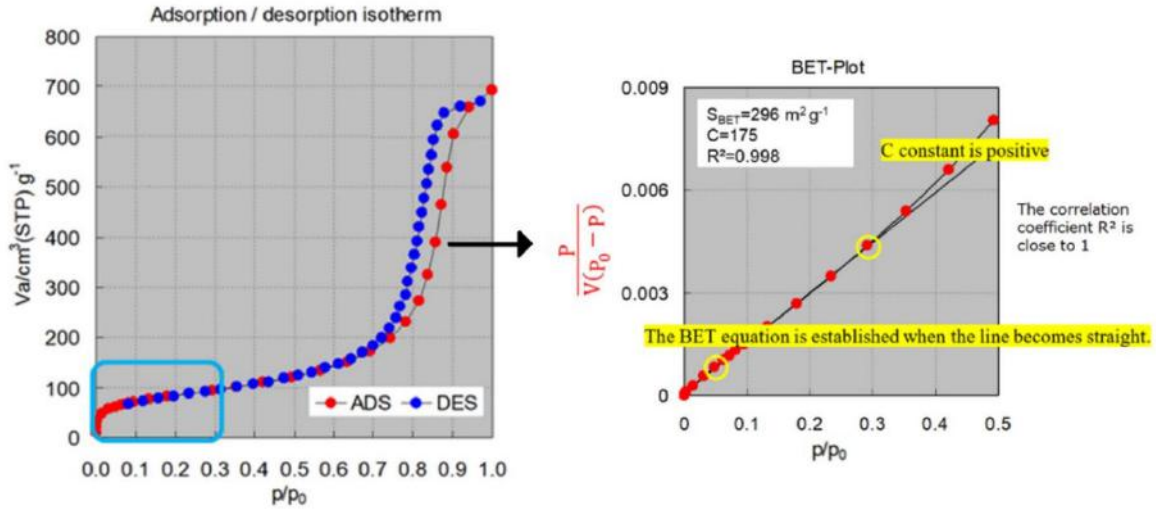


Fig. 1 Nitrogen sorption isotherm of Develosil 100 at 77 K activated under vacuum at room temperature for 15 h (left) and BET plot of Develosil 100 (right)

The BET-plot is a transformation of the adsorption isotherm:

$$\frac{p}{V_{ads}(p_0-p)} = \frac{C-1}{V_m C}\left(\frac{p}{p_0}\right) + \frac{1}{V_m C} \; *$$

(y = s * x + i)

with slope $s = \frac{C-1}{V_m C}$ and intercept $i = \frac{1}{V_m C}$

p: equilibrium pressure
p_0: saturation vapor pressure
V_{ads}: adsorbed amount at equilibrium pressure p
V_m: adsorbed monolayer volume
C: BET constant

C = exp((E1-EL)/RT) with E1 heat of adsorption of the first layer and EL heat of liquification respectively evaporation.

From slope and intercept of the linear part of the BET plot, the monolayer volume Vm and BET constant C can be calculated:

$$V_m = \frac{1}{s+i}$$

$$C = 1 + \frac{s}{i}$$

From the monolayer volume the BET specific surface area is obtained by:

$$S_{BET} = \frac{V_m \times N_A \times A_{CS}}{Vmol \times m} \; [m^2/g]$$

R = 8.314 J/mol K
$T(N_2)$ = 77 K
V_{mol} = 22.414 x 10^{-3} m³/mol
N_A = 6.022 x 10^{23} mol
A_{CS} (N_2) = 16.2 x10^{-20} m²
m = mass of adsorbent in g

[4] y-axis can also be expressed as 1/Vads[(p0/p)-1]