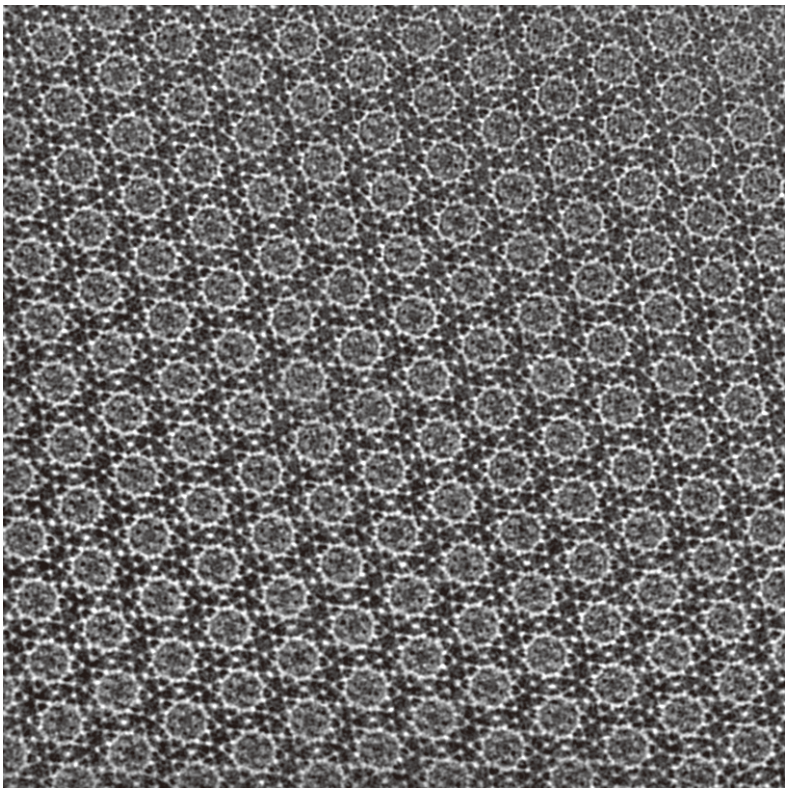
Solutions for Innovation | JEOL

OBF System

Live Low Dose, Light Element Imaging



JEOL Ltd.

OBF System

Live Low Dose, Light Element Imaging

In the new imaging method '**OBF STEM (Optimum Bright Field STEM)**', raw images acquired by a segmented STEM detector are used as the source for a phase image reconstruction, with dedicated Fourier filters to maximize the signal to noise ratio of retrieved image.
This promising method realizes higher contrast for both heavy and light elements even while operating under extremely low electron dose conditions. Beam sensitive materials difficult to observe with standard ADF and ABF STEM methods can be easily analyzed with higher contrast at a wide range of magnifications.

K. Ooe, T. Seki, *et al., Ultramicroscopy* **220**, 113133 (2021)

Ultra High Dose-Efficient STEM Imaging

The beam sensitive materials including Metal Organic Frameworks (MOFs) and Zeolites require a reduced electron dose (typically, probe current < 1.0 pA) while maintaining clear atomic contrasts for the framework of light elements. The OBF STEM has an advantage for such low dose experiments, realizing ultra high dose-efficient STEM imaging in an atomic resolution. The OBF STEM image of MOF MIL-101 (**figure 1**) and MFI Zeolite (**figure 2**) can be acquired in a single shot with higher spatial resolution 1.8 Å and 1.0 Å, respectively. The enhanced contrast and resolution can be also confirmed in each stack averaged image (insets).

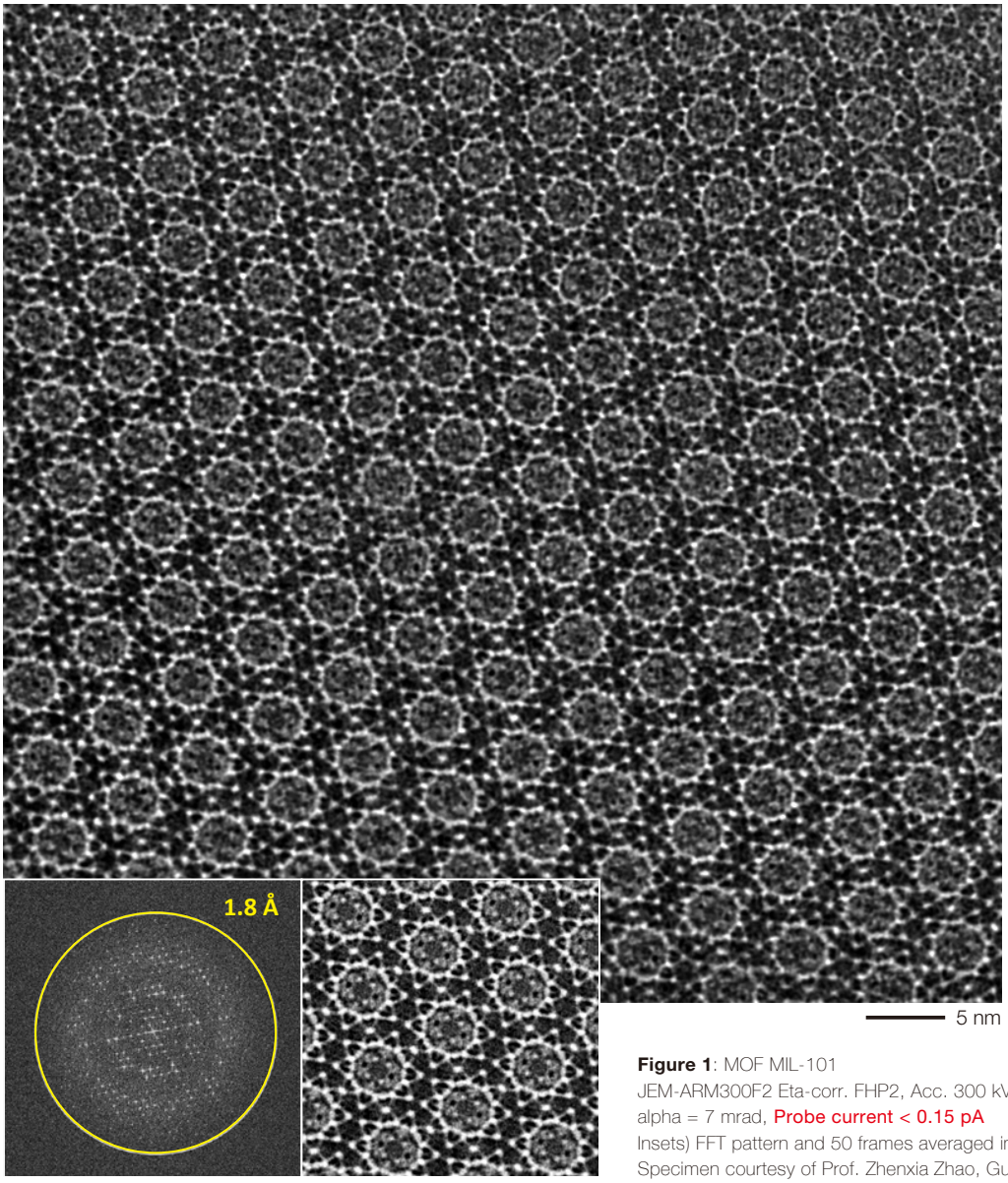


Figure 1: MOF MIL-101
JEM-ARM300F2 Eta-corr. FHP2, Acc. 300 kV,
alpha = 7 mrad, Probe current < 0.15 pA
Insets) FFT pattern and 50 frames averaged image
Specimen courtesy of Prof. Zhenxia Zhao, Guangxi University

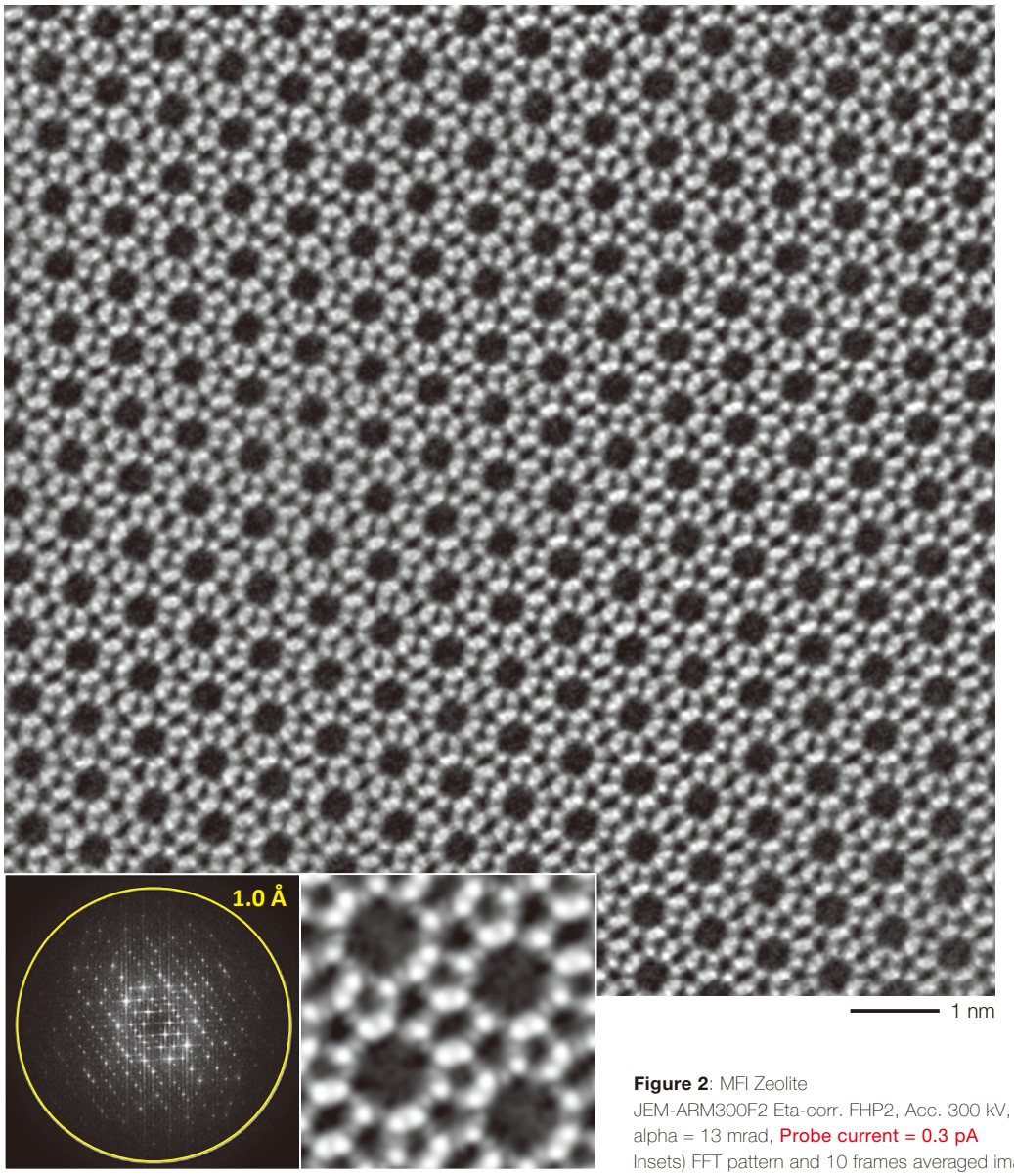


Figure 2: MFI Zeolite
JEM-ARM300F2 Eta-corr. FHP2, Acc. 300 kV,
alpha = 13 mrad, Probe current = 0.3 pA
Insets) FFT pattern and 10 frames averaged image

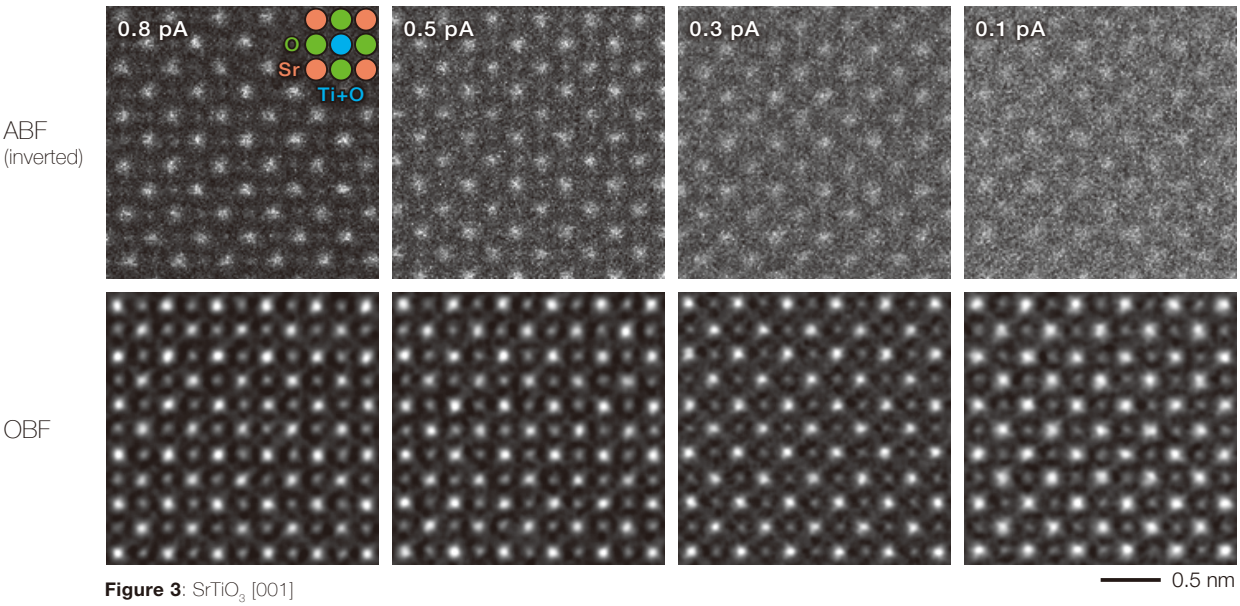


Figure 3: $SrTiO_3$ [001]
JEM-ARM300F2 Eta-corr. FHP2, Acc.300 kV, alpha = 24 mrad, Probe current = 0.8, 0.5, 0.3, and 0.1 pA

High Contrast Imaging for Light Elements

In addition to being highly dose efficient, OBF STEM is also advantageous for light element imaging.
Even in a lower acceleration voltage, both higher contrast and spatial resolution can be achieved for light elements.

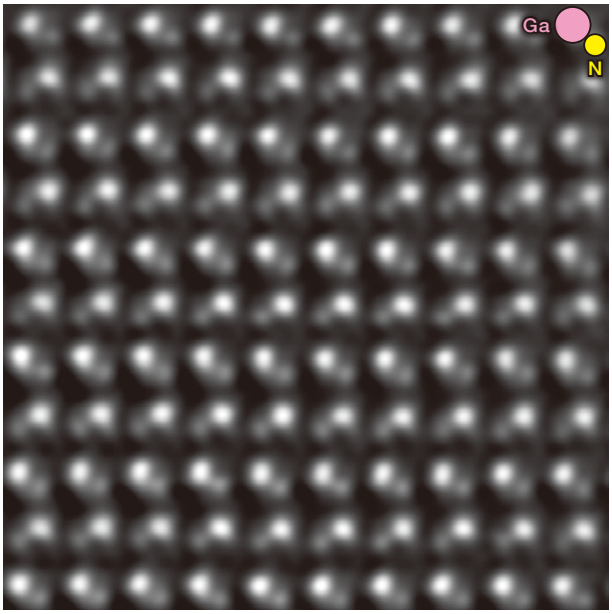


Figure 4: GaN [110]
JEM-ARM200F ASCOR UHR, Acc.60 kV, alpha = 35 mrad

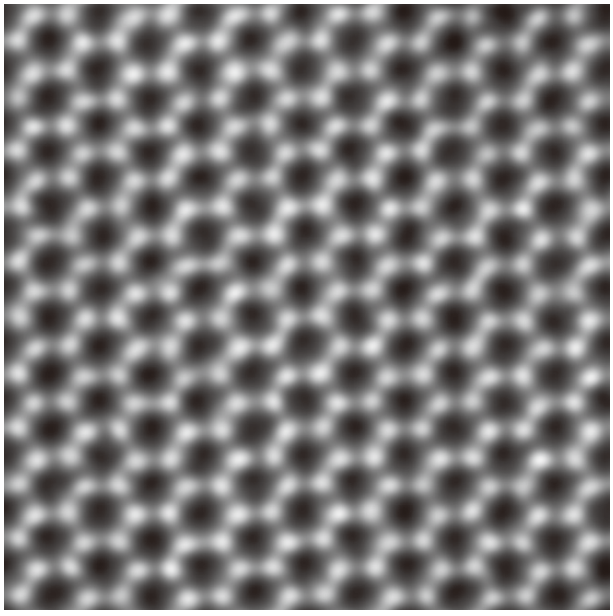


Figure 5: Graphene
JEM-ARM200F ASCOR UHR, Acc.60 kV, alpha = 35 mrad

The resolution for light elements becomes much better with a higher acceleration voltage.
Each atomic column is now clearly separated with a deep sub-angstrom resolution inside complex structures (**figure 5**) or along higher-index crystallographic axes (**figure 6**).
The quality of OBF STEM is excellent in low dose conditions, and further enhanced under the standard probe conditions of a Cs-corrected electron microscope.

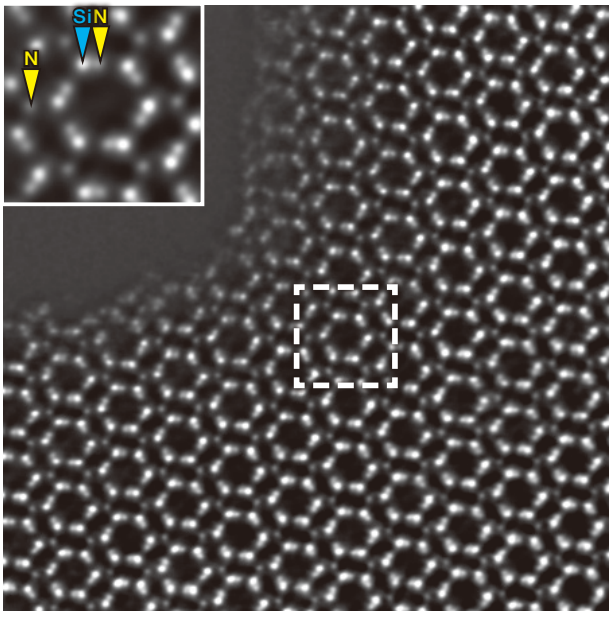


Figure 6: β -Si_3N_4 [0001]
JEM-ARM200F ASCOR UHR, Acc.200 kV, alpha = 24 mrad,
Inset) 10 frames averaged

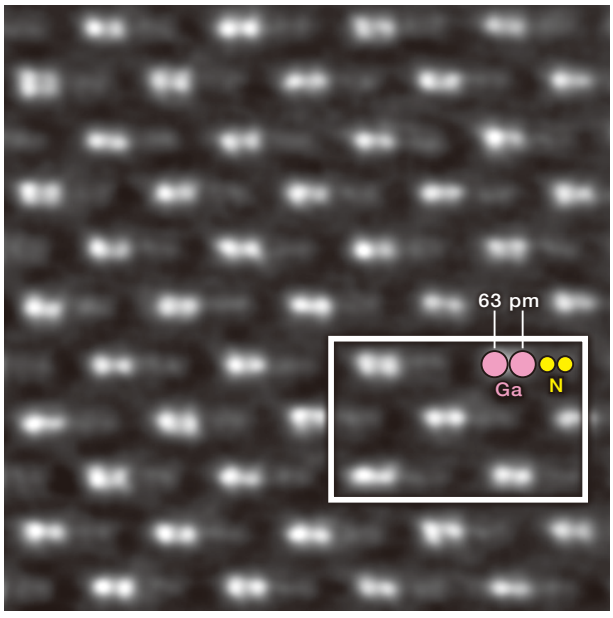


Figure 7: GaN [211]
JEM-ARM300F2 Eta-corr. FHP2, Acc.300 kV, alpha = 32 mrad,
Inset) 20 frames averaged

When the OBF method is combined with smaller illumination angles, as in the case of non Cs-corrected instruments or when operating with the objective lens turned off (STEM Lorentz mode), the micro- and mesoscopic structures can be analyzed in a large field of view.
In the fields of biological, polymer, or semiconductor materials, it is often necessary to observe fine features inside a complex structure. OBF STEM is very effective toward this goal due to its enhanced contrast for both lower and higher frequency information.

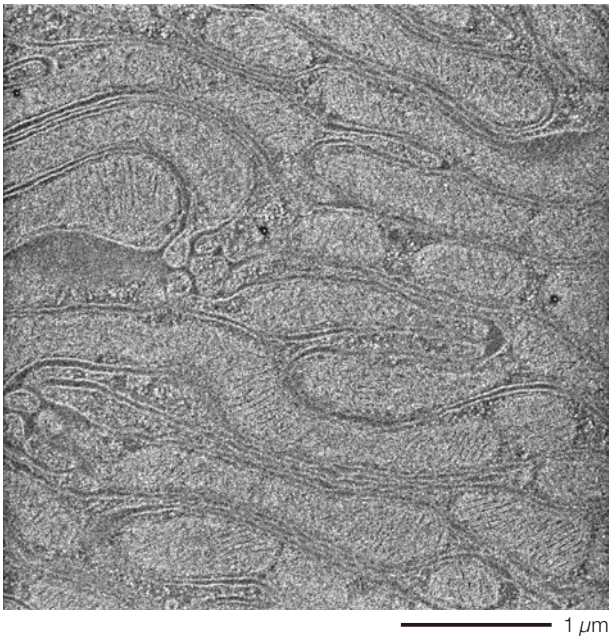


Figure 8: Mitochondria in mouse kidney, unstained
JEM-ARM300F2, Acc.300 kV, alpha = 0.13 mrad

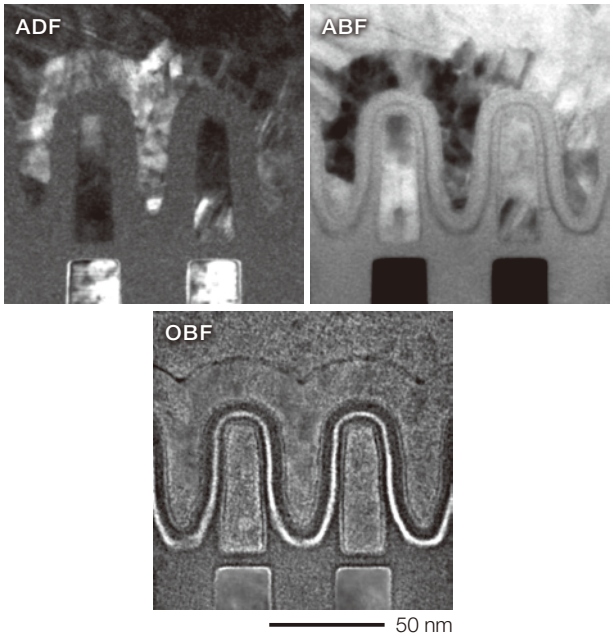
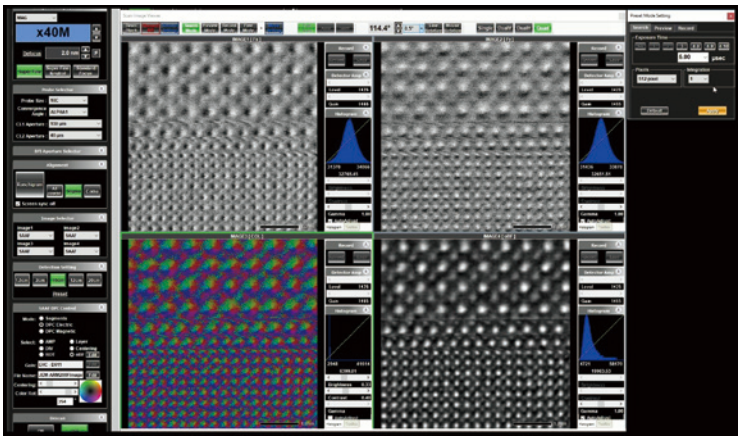


Figure 9: Semiconductor device
JEM-ARM200F, Acc.200 kV, alpha = 2 mrad

Live OBF Imaging

In an actual experiment, live OBF imaging is fundamental for beam sensitive materials as all operations should be performed in a dose limited condition. The live function is included in the OBF system, implemented within the TEM control software, with simple GUI control and real time display updates alongside conventional STEM images.



∗Specifications are subject to change without notice.

Certain products in this brochure are controlled under the "Foreign Exchange and Foreign Trade Law" of Japan in compliance with international security export control. JEOL Ltd. must provide the Japanese Government with "End-user's Statement of Assurance" and "End-use Certificate" in order to obtain the export license needed for export from Japan. If the product to be exported is in this category, the end user will be asked to fill in these certificate forms.

JEOL Ltd.

3-1-2 Musashino Akishima Tokyo 196-8558 Japan Sales Division Tel. +81-3-6262-3560 Fax. +81-3-6262-3577

www.jeol.com ISO 9001 • ISO 14001 Certified

• **AUSTRALIA & NEW ZEALAND** /JEOL (AUSTRALASIA) Pty.Ltd. Suite 1, L2 18 Aquatic Drive - Frenchs Forest NSW 2086 Australia • **BELGIUM** /JEOL (EUROPE) B.V. Planet II, Gebouw B Leuvensesteenweg 542, B-1930 Zaventem Belgium • **BRAZIL** /JEOL Brasil Instrumentos Cientificos Ltda. Av. Jabaquara, 2958 5° andar conjunto 52 ; 04046-500 Sao Paulo, SP Brazil • **CANADA** /JEOL CANADA, INC. 3275 1ere Rue, Local #8 St-Hubert, QC J3Y-8Y6, Canada • **CHINA** /JEOL (BEIJING) CO., LTD. Zhongkeziyuan Building South Tower 2F, Zhongguancun Nansanjie Street No. 6, Haidian District, Beijing, P.R.China • **EGYPT** /JEOL SERVICE BUREAU 3rd Fl. Nile Center Bldg., Nawal Street, Dokki, (Cairo), Egypt • **FRANCE** /JEOL (EUROPE) SAS Espace Claude Monet, 1 Allee de Giverny 78290, Croissy-sur-Seine, France • **GERMANY** /JEOL (GERMANY) GmbH Gute Aenger 30 85356 Freising, Germany • **GREAT BRITAIN & IRELAND** /JEOL (U.K.) LTD. Silver Court, Watchmead, Welwyn Garden City, Hertfordshire AL7 1LT, U.K. • **INDIA** /JEOL INDIA PVT, LTD, Unit No.305, 3rd Floor, ABW Elegance Tower, Jasola District Centre, New Delhi 110 025, India /JEOL INDIA PVT, LTD, Hyderabad Office 422, Regus Solitaire Business centre. 1-10-39 to 44, level 4, Gumidelli Towers, Old Airport Road, Begumpet, Hyderabad - 500016, India • **ITALY** /JEOL (ITALIA) S.p.A. Palazzo Pacinotti - Milano 3 City, Via Ludovico il Moro, 6/A 20079 Basiglio(MI) Italy • **KOREA** /JEOL KOREA LTD. Dongwoo Bldg. 7F, 1443, Yangjae Daero, Gangdong-Gu, Seoul, 05355, Korea • **MALAYSIA** /JEOL (MALAYSIA) SDN.BHD. 508, Block A, Level 5, Kelana Business Center, 97, Jalan SS 7/2, Kelana Jaya, 47301 Petaling Jaya, Selangor, Malaysia • **MEXICO** /JEOL DE MEXICO S.A. DE C.V. Arkansas 11 Piso 2 Colonia Napoles Delegacion Benito Juarez, C.P. 03810 Mexico D.F., Mexico • **QATAR** /Mannai Trading Company W.L.L. ALI Emadi Complex, Salwa Road P.O.Box 76, Doha, Qatar • **RUSSIA** /JEOL (RUS) LLC Office 351,.floor 3, 23, Novoslobodskaya St, Moscow 127055, Russia • **SCANDINAVIA** /SWEDEN JEOL (Nordic) AB Hammarbacken 6A, Box 716, 191 27 Sollentuna Sweden • **SINGAPORE** /JEOL ASIA PTE.LTD. 2 Corporation Road #01-12 Corporation Place Singapore 618494 • **TAIWAN** /JIE DONG CO., LTD. 7F, 112, Chung Hsiao East Road, Section 1, Taipei, Taiwan 10023 (R.O.C.) • **THE NETHERLANDS** /JEOL (EUROPE) B.V. Lireweg 4, NL-2153 PH Nieuw-Vennep, The Netherlands • **USA** /JEOL USA, INC. 11 Dearborn Road, Peabody, MA 01960, U.S.A.

No. 1011C248E Printed in Japan, Kp