Study Notes: Physical and Chemical Characterization of Biomaterials

These study notes summarize the key concepts, methods, and examples from the chapter "Physical and Chemical Characterization of Biomaterials".

---

1. MICROSTRUCTURAL CHARACTERIZATION

- Properties depend on crystallography, morphology, and composition.

- Tools: Optical Microscopy, Electron Microscopy (TEM, SEM).

- Optical Microscopy: Limited by resolution (~200 nm). Useful for grain structure (e.g., Titanium alloys).

- TEM: High resolution (<1 nm). Modes: Bright-field, Dark-field, Lattice images. Applications: Nanoparticle morphology, NiTi shape memory alloys.

- SEM: Surface imaging using secondary/backscattered electrons. Resolution ~0.3 nm. Elemental mapping with EDS.

2. SCANNING PROBE MICROSCOPY (SPM)

- STM: Atomic resolution imaging, requires conductive samples. Can manipulate atoms.

- AFM: Imaging of non-conductors and biological samples. Modes: Contact, Non-contact, Tapping. Measures morphology and local properties (elasticity, adhesion).

- NSOM: Optical resolution beyond diffraction limit (<50 nm). Useful for topography and optical properties.

3. X-RAY DIFFRACTION (XRD) & SCATTERING

- XRD: Phase identification, crystallite size (Scherrer's formula), lattice strain, unit cell dimensions.
- Example: Hydroxyapatite (HA), TCP, TTCP phases for bone applications.
- SAXS: Small-angle scattering for nanoparticle shape, size, and porosity (1-100 nm range).

4. FT-IR SPECTROSCOPY

- Based on molecular vibrations (stretching/bending). Measures absorption bands.
- Methods: Transmission (KBr pellet), ATR (non-destructive, surface-sensitive).
- Example: HA nanoparticles - phosphate and hydroxyl vibration peaks.

5. DYNAMIC LIGHT SCATTERING (DLS)

- Measures nanoparticle size in liquid via Brownian motion and scattering intensity fluctuations.
- Hydrodynamic diameter calculated by Stokes-Einstein equation.
- Non-invasive, fast, suitable for in vitro measurements.

6. CONTACT ANGLE MEASUREMENTS

- Measures surface wettability, energy, and protein adhesion potential.
- Low contact angle: Hydrophilic, good wettability.
- High contact angle: Hydrophobic, poor wettability.
- Methods: Static, Dynamic (advancing/receding angles).

7. MERCURY INTRUSION POROSIMETRY (MIP)

- Measures porosity and pore size distribution (macro to mesopores).
- Based on Washburn equation: Pressure inversely proportional to pore diameter.
- Example: Porous hydroxyapatite ceramics (~300 um macropores, ~1.3 um micropores).

8. GAS ADSORPTION METHODS (BET Analysis)

- Measures surface area and porosity using physisorption (N2, Ar).

- BET isotherm used for monolayer adsorption analysis.

- Example: HA nanorods, pore size ~3.5 nm.

KEY TAKEAWAYS

- No single technique is sufficient; combined approaches provide complete characterization.

- Structure, porosity, and surface properties strongly influence biomaterial-tissue interactions.

- Techniques range from imaging (microscopy) to spectroscopy (FTIR) to bulk property analysis (XRD, MIP, BET).