Technical Data Sheet

Antimony Tin Oxide (ATO)

1. Product Identification

- Product name: Antimony Tin Oxide (ATO), Antimony-doped Tin Oxide
- Chemical name: Antimony tin oxide
- CAS number: 128221-48-7
- Chemical formula: SnO_2:Sb_2O_3 or Sb_2SnO_5 (doped compound)
- Physical form: Blue powder, approximately spherical nanoparticles

2. Key Technical Properties

Grade	SnO_2(%)	Sb_2O_3(%)
ATO-T85	85	15
ATO-T90	90	10
ATO-T92	92	8
ATO-T95	95	5

Property	Value	Notes
D50 (Particle Size)	3.0 μm	
True Density	6.95 g/cm³	at 20 °C
BET Surface Area	47–85 m²/g	Non-porous
Solubility / Dispersibility	**Water:** Insoluble **Acetone:** Dispersible **Ethanol:** Dispersible	*Requires surfactants (typ. 9.5:0.5 Ethanol:Water)
Thermal Stability	Up to ~800 °C	Stable without phase transition of SnO_2 host

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3. Functional Role and Mechanism

- Intended technical functions:
  - Electrical conductor / conduction pathway for antistatic coatings
  - Optically transparent conductive component (formulations targeting >80% visible transmittance)
  - Antistatic additive for polymers and coatings
  - Infrared/thermal absorber via free-carrier absorption
  - Investigated in research literature as a charge transport or interfacial material in perovskite solar cells.
  - Catalytic support (nanoparticle surface as catalyst carrier)
- Mechanistic description:
  - Sb^{5+} substitutes for Sn^{4+} at lattice sites, creating shallow donor states below the conduction band minimum; the extra electron from Sb^{5+} populates the conduction band and establishes n-type conductivity.
  - Crystal structure: Sb-doped SnO_2 with tetragonal rutile structure (space group $P4_2/mnm$).
  - The wide band gap (on the order of 3.2–3.8 eV) allows high visible-light transmission while maintaining an electrically conductive network.

4. Application Windows

Compatible systems

- Polyamide (PA) matrices
- Acrylic resins (PMMA and acrylic copolymers)
- Polyesters such as PET
- Ethanol/water dispersions (commonly around 9:1 ethanol:water by volume)
- Glass substrates
- Silicon wafers (typically used with adhesion promoters)
- Ceramic glazes and high-temperature coatings
- Polystyrene and other thermoplastics (within their glass transition temperature limits)

Processing guidance

- Dispersion:
  - Agglomeration control is critical; surfactants and sonication are commonly used.
  - Organic solvents (ethanol, acetone) generally provide better dispersibility than pure water.
- Thermal treatment (powder synthesis / post-treatment):
  - Calcination above about 600 °C is typically required to form the desired Sb^{5+}-doped SnO_2 phase.
  - Below about 500 °C, Sb oxidation may be incomplete.

- out 700 °C, grain growth can reduce surface area and deteriorate electrical performance.

- Thin film post-processing:
  - Post-deposition annealing in the range of roughly 300–500 °C (where the substrate allows) is often used to remove organic dispersants and improve inter-particle conductivity.

Typical use levels

- Antistatic coatings: approximately 2–15 wt% ATO loading
- Transparent conductive coatings: approximately 5–20 wt% ATO, to balance conductivity and transparency
- Percolation threshold: often around 2–3 wt% loading for formation of a continuous conductive network (system dependent)

Established application areas

- Antistatic coatings, especially in polyamide and acrylic systems
- Additive in PET-related systems (e.g., catalyst/plastics)
- Laser marking additives
- Component in certain flame-retardant formulations

5. Critical Parameters and Failure Modes

Critical control parameters

- Sb doping level:
  - Often targeted in the range of ~2–4 atomic % for a balance between carrier concentration and mobility.
  - Above about 5 at% Sb, charge compensation and mobility degradation can occur.
- Calcination temperature:
  - Approx. 600–700 °C: favorable for Sb^{5+} formation and controlled grain size.
  - Below approx. 500 °C: incomplete Sb oxidation and insufficient n-type character.
  - Above approx. 700 °C: excessive grain growth and possible deterioration of electrical properties.
- Particle size:
  - Particles below about 20 nm can maximize surface area and dispersibility.
  - Larger particles (>50 nm) reduce surface area but may show lower tendency to agglomerate.
- Sb^{3+}/Sb^{5+} ratio:
  - Higher Sb^{5+} fraction generally improves conductivity; the ratio can be tuned by oxygen partial pressure and temperature during calcination.
- Moisture / humidity:
  - Nanoparticles readily adsorb water; surface hydration and hydroxylation can trap charge carriers and increase resistivity.

- istry:
  - pH and surfactant selection strongly influence colloidal stability, film uniformity, and response to post-annealing.
- Film thickness:
  - Thickness above roughly 150 nm is often needed for robust antistatic performance.
  - Thickness below roughly 200 nm is often desirable for visual clarity in transparent coatings.

Known failure modes

- Agglomeration or coalescence at high loadings:
  - Breaks the percolated conductive network and can reduce conductivity by more than two orders of magnitude.
- Charge compensation at high Sb doping:
  - Doping above about 4–6 at% can promote Sb^{3+} and compensating defect complexes, causing mobility collapse despite high carrier concentration.
- Residual organic dispersants:
  - Residual organics between particles increase inter-particle resistance by 1–2 orders of magnitude; post-annealing above roughly 300 °C is often needed to recover conductivity.
- Moisture-induced degradation:
  - Surface hydroxylation and charge trapping on hydrated surfaces lead to time-dependent increases in resistivity, especially in high-humidity environments.
- Substrate adhesion failures:
  - Incompatible or untreated substrates (e.g., PET without surface treatment) may show delamination under thermal cycling, resulting in loss of electrical contact.
- Excessive grain growth:
  - Thermal exposure above about 700 °C can cause grain coarsening and defect compensation, resulting in reduced conductivity.

Application limitations / exclusion zones

- Long-term operation in electronics above about 800 °C
- High-moisture aqueous environments without protective overcoats
- Applications requiring p-type conductivity (ATO is inherently n-type)
- RF shielding use above about 100 GHz
- Moisture-sensitive electronics where the ATO loading is below percolation (e.g., <2 wt% in many systems)

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6. Handling, Storage and Stability

Handling

- Use in a well-ventilated area or fume hood.
- Avoid dust formation; wet methods are preferred where feasible.
- Wear suitable gloves (e.g., nitrile or neoprene), safety glasses with side shields, and appropriate respiratory protection depending on exposure level.
- Avoid direct skin contact and inhalation; wash thoroughly after handling.

Storage

- Store at room temperature (approx. 15–25 °C) in a dry place.
- Keep containers tightly closed (glass or plastic) to limit moisture uptake and contamination.
- Keep away from strong oxidizing agents, alkali metals and their alloys, strong acids, and reactive metal powders.
- Under recommended conditions the material is considered stable over an extended shelf life.

Stability

- Thermally stable up to about 800 °C with no significant phase transition or decomposition of the SnO_2 host.
- Chemically inert under most benign conditions and insoluble in water.
- Not self-reactive; reactivity is primarily limited to strongly reactive chemicals as indicated in the SDS.

7. Regulatory Notes and Safety Disclaimer

- REACH: Not registered; not listed on the Candidate List for SVHC, not in Annex XIV or Annex XVII; not on CoRAP.
- Ozone depletion / POP: Not classified as an ozone-depleting substance or a persistent organic pollutant under the major international conventions.
- Transport classification:
  - Not regulated as dangerous goods.
- Important note:
  - This type of document is a Technical Data Sheet, not a Safety Data Sheet.
  - For definitive information on hazards, exposure limits, emergency measures, and transport regulation, always refer to the product-specific SDS and applicable local regulations.

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